California Air Pollution Control Officers Association

Handbook for Analyzing Greenhouse Gas Emission Reductions, Assessing Climate Vulnerabilities, and Advancing Health and Equity

Designed for Local Governments, Communities, and Project Developers

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Acknowledgements: 2021 Update

This Handbook benefited from the hard work and creative insights of many people. The California Air Pollution Control Officers Association (CAPCOA) appreciates the efforts of all who contributed their time and energy to the project. In particular, CAPCOA thanks the following organizations and agencies.

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Dedication

This Handbook is intended to provide tools and methods to people who are doing the hard work on the ground. The hard work of reducing our impact on climate change, making communities more resilient to the effects of climate change, and promoting health and equity among communities that bear disproportionate environmental burdens. The hard work to include everyone in what Dr. Martin Luther King Jr. referred to as "an inescapable network of mutuality" in his 1967 *Christmas Sermon on Peace*.

What we do today will either remedy or perpetuate past environmental injustices. What we do today will shape our climate tomorrow. Our communities are being changed by climate and will change more.

When we understand the tons of carbon emitted, the feet of sea level rise, and the degrees of temperature change, we will know better the consequences of our actions. When we listen, respect, engage, involve, and empower all people affected by our actions, we will know better the diverse concerns, needs, and hopes of all our communities.

With this understanding, we can and must take action to reduce our contributions to climate change, to make our communities more resilient, and to implement solutions that are informed by and responsive to the people most affected by new plans, projects, and programs. We need to do this with and for the people left out too often in the past to mold a better future for this generation and the generations to come. We need to do this for a state, a country, and a planet that is changing rapidly due our actions and inactions.

This Handbook is dedicated to all Californians—whose health, wellbeing, and safety are at the heart of all our efforts. We build and design communities for people, yet often the human perspective is lost amidst discussions around emissions, thresholds of significance, vehicle miles traveled, and site plans. We aim to re-center people in this conversation—especially the people whose voices have been marginalized and excluded from participating in the planning that shapes all our lives. At its core, the Handbook is designed and developed by people, for people, and for the sake of creating livable, prosperous, resilient communities in which all can thrive, now and into the future.

An Important Consideration

CAPCOA prepared this Handbook to provide a common platform of information and tools for evaluating greenhouse gas reduction measures, climate vulnerabilities and promoting equity to support sustainable, resilient, and equitable land use planning and project design. It was prepared in collaboration with academia, agencies, community organizations and leaders, local governments, nongovernmental organizations, and technical experts. The quantification methods, tools, and recommendations provided in this Handbook were developed based on the latest science and literature available at the time of publication. A table of updates with publication dates can be found in Appendix F.

Our understanding of climate science and accepted practice for how equity and environmental justice can and should be addressed in land use planning continues to evolve. Regulations, policies, and government programs to reduce greenhouse gas emissions are likewise dynamic. Future legislation, litigation, public opinion, and scientific research may influence how climate change, emissions reduction, and health and equity are reviewed and addressed in our community.

In light of these considerations, this Handbook should be viewed as a *planning resource*. It provides strategies, tools, and analytical methods to facilitate integrated and resilient decision making, despite potential future planning uncertainty. The Handbook should not be used to dictate public policy or provide legal advice.

Table of Contents

Acronyms and Abbreviations

°F	degrees Fahrenheit
A/C	air conditioning
AADT	annual average daily traffic
AB	Assembly Bill
ACS	American Community Survey
ACT	Advanced Clean Truck
AF	acre-feet
AFUE	annual fuel utilization efficiency
AMMP tool	CARB's Benefits Calculator Tool for the Alternative Manure Management Program
APEN	Asian Pacific Environmental Network
APG	California Adaptation Planning Guide
AQI	air quality index
ARCCA	Alliance of Regional Collaboratives for Climate Adaptation
Bayview CBTP	Bayview Community Based Transportation Plan
BCZ	building climate zones (as defined by the CEC)
BEV	battery electric vehicle
BIPOC	Black, Indigenous, and People of Color
BMR	below market rate
BRACE	Building Resilience Against Climate Effects
BRT	bus rapid transit
Btu	British Thermal Unit
C.F.R.	Code of Federal Regulations
CA Code	California Plumbing Code
CAA	Clean Air Act
CAFE	Corporate Average Fuel Economy
CalBRACE	California Building Resilience Against Climate Effects
CalEEMod	California Emissions Estimator Model
CalEPA	California Environmental Protection Agency
CALFIRE	California Department of Forestry and Fire Protection

CALGreen	2019 California Green Building Standards
Caltrans	California Department of Transportation
CAPCOA	California Air Pollution Control Officers Association
CAPP	Community Air Protection Program
CARB	California Air Resources Board
CAS	Climate Adaptation Strategy
CBO	community-based organization
CBSA	core-based statistical area
CBSC	California Building Standards Commission
CBTP	community-based travel planning
CCA	Community Choice Aggregation
CCR	California Code of Regulations
CDC	U.S. Centers for Disease Control and Prevention
CDPH	California Department of Public Health
CE	combustion efficiency
CEC	California Energy Commission
CEQ	Council on Environmental Quality
CEQA	California Environmental Quality Act
CEUS	California Commercial End-Use Survey
CH_4	methane
CHP Tool	Combined Heat and Power Energy and Emission Calculator
CHP	combined heat and power
CLT	community land trust
CNG	compressed natural gas
CNRA	California Natural Resources Agency
CO	carbon monoxide
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
COMET	COMET-Planner Tool
Commercial Forecast	Uncalibrated Commercial Sector Forecast
CoSMoS	Coastal Storm Modeling System
CPUC	California Public Utilities Commission

CSTDM	California Statewide Travel Demand Model
CTR	commute trip reduction
DBE	disadvantaged business enterprise
DGS	Department of General Services
DOC	dissolved organic carbon
DR	demand response
Du	dwelling units
DVBE	disabled veteran-owned business enterprise
DWR	California Department of Water Resources
EA	environmental assessment
EBT	Electronic Benefit Transfer
ECAP	Equitable Climate Action Plan
EDFZ	Electricity Demand Forecast Zone
EDG	Community Resilience Economic Decision Guide and Online Tool
EER	energy efficiency ratio
EGC	Enterprise Green Communities
EIR	environmental impact report
EIS	environmental impact statement
ESP	energy service provider
ETWU per the MWELO	estimated total water use
eVMT	electric mode vehicle miles traveled
Explorer	Cool Surface Savings Explorer
FCEV	fuel cell electric vehicle
FCZ	Forecast Climate Zone (as defined by the CEC)
FEMA	Federal Emergency Management Agency
FHWA	Federal Highway Administration
FVS	Forest Vegetation Simulator
g	grams
gal	gallon
GHCN-Daily	Global Historical Climatology Network–Daily
GHG	greenhouse gas

GMP	gross metropolitan product
GSP	groundwater sustainability plan
GWP	global warming potential
ha	hectare
HDPE	high-density polyethylene
HERS	Home Energy Rating System
HFCs	hydrofluorocarbons
HPI	The California Healthy Places Index
HUD	U.S. Department of Housing and Urban Development
HVAC	heating ventilation and air conditioning
IBHS	Insurance Institute for Business & Home Safety
ICARP	Integrated Climate Adaptation and Resiliency Program
ICT	Innovative Clean Transit
LDA	light-duty automobiles
LDT1	light-duty truck class 1
LDT2	light-duty truck class 2
ILSR	Institute for Local Self-Reliance
IOUs	investor-owned utilities
IPCC	Intergovernmental Panel on Climate Change
ITE	Institute of Transportation Engineers
ITHIM	Integrated Transport and Health Impact Model
KSF	1,000 gross square feet
kWh	kilowatt-hours
lb	pound
LBNL	Lawrence Berkeley National Laboratory
LCFS	Low Carbon Fuel Standard
LED	light-emitting diode
LFG	landfill gas
LGBTBE	LGBTQIA+-owned business enterprise
LHC	Little Hoover Commission
LOS	level of service
MAWA per the MWELO	maximum allowable water use

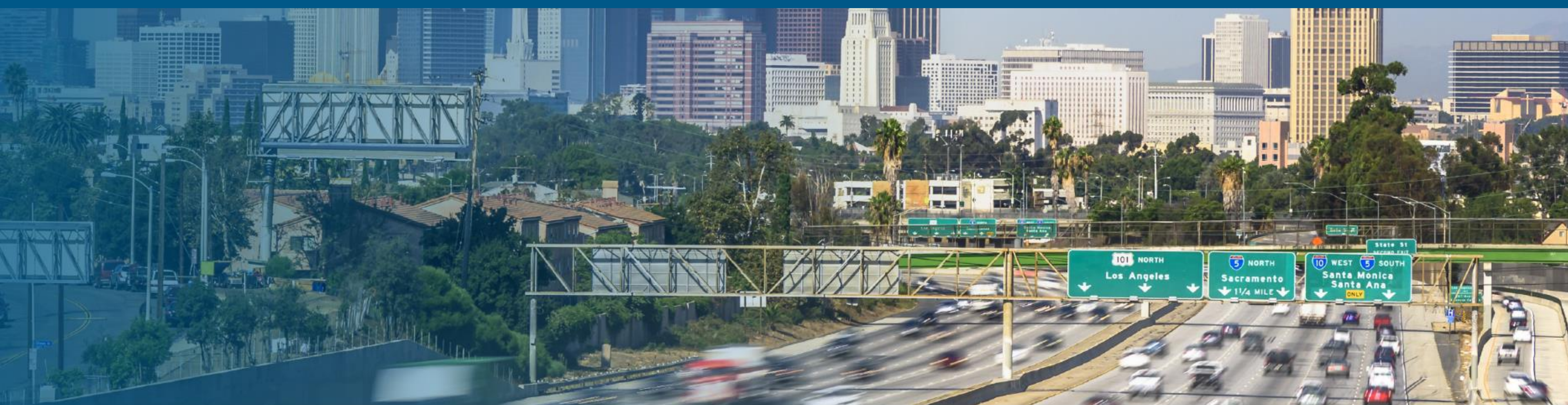
MBE	minority-owned business enterprise
MCHX	microchannel heat exchanger
MHSA	Mental Health Services Act
MJ	megajoule
MMBtu	1 million British thermal units
mpg	miles per gallon
MPO	metropolitan planning organization
MSA	metropolitan statistical area
MSW	municipal solid waste
MT	metric ton
MTC	Metropolitan Transportation Commission
MTV	maximum transfer value
MWELO	Model Water Efficient Landscape Ordinance
MWh	megawatt-hour
N_2O	nitrous oxide
NAACP	National Association for the Advancement of Colored People
NAAQS	national ambient air quality standards
NDC	Nationally Determined Contribution
NEPA	National Environmental Policy Act
NGO	non-governmental organization
NH_3	ammonia
NHTS	National Household Travel Survey
NHTSA	National Highway Traffic and Safety Administration
NO_2	nitrogen dioxide
NOAA	National Oceanic and Atmospheric Administration
NOx	nitrogen oxides
NREL	National Renewable Energy Laboratory
NWL	natural and working lands
NYLSRJP	New York Law School Racial Justice Project
ODS	ozone-depleting substances
OEHHA	Office of Environmental Health Hazard Assessment
OPC	Ocean Protection Council

OPR	California Office of Planning and Research
PBID	property business improvement district
PBOT	Portland Bureau of Transportation
PFCs	perfluorinated carbons
PHEV	plug-in hybrid electric vehicle
PM2.5, PM10	particulate matter
PV	photovoltaic
PVC	polyvinyl chloride
RAD	Responsible Appliance Disposal
RASS	Residential Appliance Saturation Study
REC	renewable energy credit
REIA	Racial Equity Impact Assessment and Implementation Guide
Reporting Rule	Greenhouse Gas Reporting Rule
ROG	reactive organic gases
RPS	Renewable Portfolio Standard
RSM	Regional Sediment Management
RTP	regional transportation plan
SACOG	Sacramento Area Council of Governments
SAF	solar availability factor
SAFE	Safer Affordable Fuel-Efficient
SAJE	Strategic Actions for a Just Economy
SANDAG	San Diego Association of Governments
SB	Senate Bill
SCAQMD	South Coast Air Quality Management District
scf	standard cubic foot
sf	square feet
SF_6	sulfur hexafluoride
SFMTA	San Francisco Municipal Transportation Agency
SFPD	San Francisco Planning Department
SHP	separate heat and power
SHRA	Sacramento Housing and Redevelopment Agency
SIP	State Implementation Plan

SLCPs	Short-Lived Climate Pollutants
SMUD	Sacramento Municipal Utility District
SOx	sulfur dioxide
SR2S	Safe Routes to Schools
State Water Board	State Water Resources Control Board
TAC	technical advisory committee
TCR	The Climate Registry
TDV	Time Dependent Valuation
TE	thermal efficiency
TOD	transit-oriented development
TRB	Transportation Research Board
TRUs	Transport Refrigeration Units
U.S. DOE	U.S. Department of Energy
U.S. EPA	U.S. Environmental Protection Agency
U.S.C.	United States Code
UC Davis	University of California, Davis
UHI	urban heat island
UNIDAD	United Neighbors in Defense Against Displacement
USDN	Urban Sustainability Directors Network
USFS	United States Forest Service
USGS	United States Geological Survey
VMT	vehicle miles traveled
VOC	volatile organic compounds
VTA	Valley Transportation Authority
WARM	Waste Reduction Model
WBE	women-owned business enterprise
WMO	World Meteorological Organization
WUCOLS	Water Use Classification of Landscape Species
WUI	wildland-urban interface
ZEBs	zero-emission buses
ZNE	zero net energy

Introduction

CHAPTER 1



Background

Climate change is already having profound impacts on people and planning in California. Local governments, institutions, project developers, and communities across the state must prepare for growing climate impacts while working to reduce their greenhouse gas (GHG) emissions. These are real challenges, but they also represent new opportunities. We can design and build healthier neighborhoods, develop solutions for clean air, and create more equitable, resilient communities and economies. This Handbook offers data and methods to help effectively achieve these objectives.

Local governments and communities are increasingly experiencing the effects of climate change and, in response, are developing measures and plans to mitigate and adapt to those effects. Climate change is principally driven by human actions, particularly burning fossil fuels like coal, oil, and natural gas that emit GHGs. GHGs trap heat in the atmosphere, which slowly increases global average temperatures, causing additional cascading effects such as extreme heat and heat waves, melting polar ice, disappearing snowpack, rising sea levels, changing precipitation patterns, ocean acidification, and more extreme or more frequent weather events.

To slow the pace of climate change and prevent its worst effects from materializing, local, state, and national governments must design measures that mitigate (i.e., lessen the severity or even eliminate) the root cause of the issue: GHG emissions from human activities. To do so, they need tools and resources to accurately assess and quantify GHG emissions, and to design effective methods to reduce emissions.

In response to this need, the California Air Pollution Control Officers Association (CAPCOA) prepared this report, *Handbook for Analyzing Greenhouse Gas Emission Reductions, Assessing Climate Vulnerabilities, and Advancing Health and Equity: Designed for Local Governments, Communities, and Project Developers* (hereafter referred to as the "Handbook"). The Handbook provides methods to quantify GHG emission reductions from a specified list of measures, primarily focused on project-level actions. The Handbook also includes a method to assess potential benefits of different climate vulnerability reduction measures, as well as measures that can be implemented to improve health and equity, again at the project level.

CAPCOA included a wide range of measures in the Handbook that are frequently used to reduce GHG emissions, bolster communities against expected climate impacts, and enhance community health and equity. To focus on the most effective measures, they were screened using the following factors:

- Feasibility of quantifying emissions reductions or benefits.
- Availability of robust and meaningful data, including peer reviewed studies.
- Ability of measures (alone or in combination with other measures) to appreciably reduce GHG emissions, reduce climate vulnerabilities, and improve health and equity.

This does not mean that other measures should not be considered or may not be effective or quantifiable; on the contrary, there are many ways to reduce emissions of GHGs, reduce climate vulnerabilities, and improve health and equity. CAPCOA seeks to provide a high-quality quantification tool to local governments, communities, and stakeholders with the broadest applicability possible. CAPCOA encourages users to be bold and creative as they approach the challenges of climate change and equity and does not intend for the Handbook to limit the scope of measures considered.

In addition to CAPCOA, other organizations that helped to prepare this Handbook include the Sacramento Metropolitan Air Quality Management District, with contract support from ICF, Fehr & Peers, and STI, who performed the technical analysis.

Process and Approach for Handbook Development

The Handbook builds on CAPCOA's previous efforts to provide accurate and reliable quantification measures. In 2010, CAPCOA published *Quantifying Greenhouse Gas Mitigation Measures: A Resource for Local Government to Assess Emissions Reductions from Greenhouse Gas Mitigation Measures* (hereafter referred to as the "2010 Handbook"). Since that time, climate science has evolved and GHG reduction practices have advanced in sophistication. New priorities have also arisen, such as strengthening climate resilience and infusing health and equity into integrated planning efforts. Therefore, CAPCOA decided it was time to develop an updated and expanded resource to provide the latest data and methods to quantify GHG emissions reductions, climate change vulnerability reductions, and equity improvements in a single resource: The Handbook.

WHAT'S NEW IN THIS HANDBOOK?

This Handbook is an updated and expanded resource from the 2010 Handbook. It provides the following.

- Updated data and new measures to quantify GHG emission reductions.
- Method to identify and score future potential climate hazards.
- Measures to quantify reduced vulnerability to climate change.
- Measures to improve health and equity.

The Handbook development process involved five key tasks.

1. Identifying and evaluating new and emerging GHG reduction measures and removing outdated measures from the 2010 Handbook.
2. Evaluating and selecting climate risk reduction and health and equity measures.
3. Developing methods to quantify GHG emissions reduction measures and identify associated co-benefits.
4. Developing methods to assess climate change vulnerability and a framework to quantify reductions in climate vulnerabilities.
5. Developing health and equity measures.

The development process was a collaborative and methodical effort that involved careful review and input from experts in agencies, academia, public organizations, non-governmental organizations (NGOs), and other stakeholder groups. A technical advisory committee (TAC) was formed to provide ongoing guidance, peer review, and quality control assurance at each step of the process. The Handbook was drafted and finalized through an iterative process that incorporated comments and suggestions from the Sacramento Metropolitan Air Quality Management District, the TAC, and the public.

The Handbook was primarily funded by a California Department of Transportation (Caltrans) Senate Bill (SB) 1 Adaptation Planning Grant. Additional funding was provided by the Sacramento Metropolitan Air Quality Management District, the California Department of Public Health, and the Bay Area Air Quality Management District.

In 2024, the CAPCOA Board added 11 new quantified measures (see Appendix F). The additions were facilitated by the U.S. EPA's Climate Pollution Reduction Grants program.

Intent and Audience

The purpose of the Handbook is to provide local governments with accurate, reliable, and standardized emission reduction quantification methods for land use, climate action, and long-term planning. It also aims to support and enhance the consideration of climate vulnerabilities, health, and equity during the planning process. The Handbook is intended to support the efforts of local governments to address GHG emissions and vulnerabilities to climate change in their planning efforts and environmental review of new projects, and to achieve more equitable outcomes when addressing these impacts. The Handbook will also be useful for project proponents and other parties interested in enhancing resiliency, sustainability, and equitable development.

The guidance provided in the Handbook specifically addresses appropriate procedures to apply quantification methods to achieve accurate and reliable results. The Handbook includes background information on programs and concepts associated with the quantification of GHG emissions and climate change vulnerability. The Handbook does not provide policy guidance on any of these issues, nor does it dictate how a jurisdiction should address questions of policy. Policy considerations are left to individual agencies and their governing boards. The Handbook is intended to create a standardized approach to quantifying GHG reduction and climate change resilience measures so the effectiveness of these measures can be considered and compared on a common basis.

Using the Handbook

The Handbook is organized as follows.

- *Chapter 1: Introduction* – provides an overview of the Handbook and its contents.
- *Chapter 2: Integrated and Resilient Planning* – discusses the changing climate, its impacts on society and public health, federal and state planning efforts to address the problem, and how equity and resilience can be improved.

- *Chapter 3: Measures to Reduce GHG Emissions* – provides details on measures and methods to quantify and reduce GHG emissions, accompanied by measure factsheets.
- *Chapter 4: Assessing Climate Exposures and Measures to Reduce Vulnerabilities* – outlines a method to assess climate change vulnerability and the potential benefits of different climate risk reduction measures at the project level.
- *Chapter 5: Measures for Advancing Health and Equity* – describes measures to improve public health and social equity.
- *Chapter 6: Resources to Support Resilient and Equitable Emission Reduction Planning* – presents additional resources that can help resilient and equitable planning efforts.
- *Appendix A: Key Terms and Definitions* – defines the key terms used in the Handbook.
- *Appendix B: Federal and State Planning Framework* – describes federal and state regulations and policies related to reducing GHG emissions, increasing climate resilience, and improving public health and social equity.
- *Appendix C: Emission Factors and Data Tables* – provides the emission factors and data used to estimate GHG emission reductions.
- *Appendix D: Climate Vulnerability Worksheets* – contains worksheets planners can use to assess climate vulnerability.
- *Appendix E: Measure Index* – crosswalks the Handbook measures to cross-cutting themes across all chapters (e.g., active transportation).
- *Appendix F: Summary of Updates to the Handbook* – summarizes the revisions and updates made to the Handbook since the 2021 comprehensive update.

Because the quantification and analysis methods in the Handbook were developed to meet the highest standards for accuracy and reliability, CAPCOA believes they will be generally accepted for most purposes, though the decision to accept any quantification method rests with the reviewing agency and Handbook user. The methods contained in the Handbook include generalized information about the measures, including considerations and best practices for successful implementation and assumptions that influence the expected measure outcome. These assumptions include emissions factors, energy usage rates, climate exposures for a specific location, and other data from various sources (most commonly from published data from public agencies). The data were carefully reviewed to ensure they represent the best information available. The use of generalized information allows the quantification methods to be applied across a range of circumstances, including variations in location, climate, and population density, among others.

For instances in which high quality, project-specific data are available, those data should be used instead of the more generalized data presented in the Handbook. The quantification and analysis methods provided in this Handbook allow for such substitutions. Handbook users should confirm any substituted data meets quality standards and will not result in an inappropriate or under- or overestimation of measure benefits. CAPCOA will not be able to provide case-by-case review of adjustments or project-specific data inputs. More information on the measures and analysis data are provided in Chapter 3, *Measures to Reduce GHG Emissions*, Chapter 4, *Assessing Climate Exposures and Measures to Reduce Vulnerabilities*, and Chapter 5, *Measures for Advancing Health and Equity*.

APPROPRIATE USES OF THE HANDBOOK

- Explore emissions reduction measures and identify methods to quantify GHG reductions for a program or plan.
- Learn about co-benefits of reducing GHG emissions.
- Conduct a preliminary assessment of climate vulnerability for a project or a plan.
- Explore ways to make a project or plan more climate resilient.
- Identify ways to include and empower underserved and marginalized communities and address their concerns.

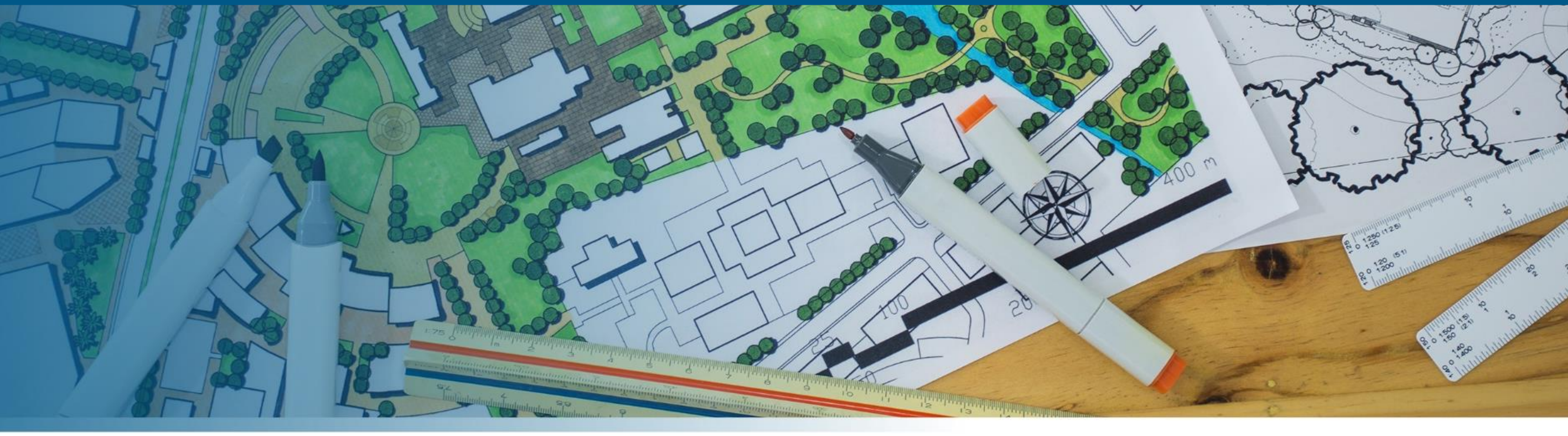
Equally important to understanding how to effectively use the Handbook is knowing its limitations and potential *misuses*. This will help safeguard against inappropriate application of the Handbook in certain contexts. The Handbook should not be used to dictate public policy or provide legal advice. While the list of measures presented in the Handbook is comprehensive, it should not be used to exclude or reject other strategies from consideration. As discussed above, there are many ways to reduce emissions, reduce climate vulnerabilities, and improve health and equity, some of which may not be captured in this Handbook or may be developed after its publication. Conversely, the Handbook measures and quantitative methods (including available defaults) should not be automatically applied to a project without thoughtful consideration of project-specific circumstances. Finally, the Handbook should not be used to complete an environmental justice analysis pursuant to Executive Order 12898 or the National Environmental Policy Act (NEPA). The Handbook may be used as a starting point for these types of analyses, but it does not constitute guidance for compliance with the executive order or NEPA requirements.

References

California Air Pollution Control Officers Association (CAPCOA). 2010. *Quantifying Greenhouse Gas Mitigation Measures: A Resource for Local Government to Assess Emission Reductions from Greenhouse Gas Mitigation Measures*. August. Prepared by CAPCOA in association with Northeast States for Coordinated Air Use Management, National Association of Clean Air Agencies, Environ, and Fehr & Peers.

Integrated and Resilient Planning

CHAPTER 2



The Changing Climate

The Earth's climate is dynamic and has shifted over time. However, changes in the global climate have accelerated over the past 50 years due to human activities. Underserved and low-income communities are disproportionately impacted by the effects of climate change, as well as other environmental burdens, including air pollution. Various federal and state regulations have been adopted to reduce greenhouse gas (GHG) emissions, improve environmental justice and social equity, and help communities plan for and adapt to anticipated changes in our climate. Beyond regulation, developers and decisionmakers can build future equity and resilience through informed and holistic project planning.

California is already seeing the effects of climate change on its natural resources, populations, and infrastructure. Major environmental indicators have shifted; since the start of the twentieth century, peak runoff in the Sacramento River now occurs nearly a month earlier, and glaciers in the Sierra Nevada have lost about 70 percent of their area. The state has experienced major climate events in recent years, including a drought from 2012–2016 that heavily affected the agricultural sector and resulted in statewide water conservation efforts, followed by an extremely wet winter in 2016–2017 that caused significant loss of life and damage to infrastructure. The frequency, size, and devastation of wildfires have also increased: 12 of the 20 largest wildfires (in terms of acres burned) in the state's recorded history occurred between December 2017 and the writing of this Handbook, including five in 2020 and four in 2021 alone (Cal Fire 2021).

As human activities and natural processes continue to increase GHG emissions across the globe, the impacts of climate change are likely to continue and worsen in the future. Specifically, the following climate hazards are projected to occur in California over the next century (Bedsworth, et al. 2018).

- Increase in annual average maximum daily temperature of up to 5.8°F by 2050 and up to 8.8°F by 2100.
- Increase in intensity of atmospheric river events, with northern California experiencing more wet extremes and southern California becoming drier.
- Increase in frequency and intensity of drought.
- Increase in the amount of precipitation falling as rain (instead of snow) and a corresponding decrease in accumulated snowpack.
- Increase in high wildfire risk conditions and projected increase in number of acres burned by wildfire.
- Increase in sea level rise along the coast, ranging from about 0.7 to 2.3 feet, by 2050.

These and other climate hazards will negatively impact public health and infrastructure. Increased temperatures, increased humidity, and a higher frequency of extreme heat events will lead to worsening air quality and increased risk of dehydration, respiratory problems (e.g., asthma), and cardiovascular problems (e.g., heart attacks) among individuals. Cumulative deterioration of public health from heat-related ailments and other climate stressors are projected to increase emergency room visits and hospitalizations (Ziegler, Morelli, and Fawibe 2017). Extreme events like heat waves, flooding, and wildfires can cause loss of life and directly damage buildings and infrastructure. Extreme weather events can shutdown critical services and inhibit individuals from reaching healthcare and other critical supports. Power infrastructure and supply chains can also be disrupted (No Harm Canada n.d.). Climate hazards can also have significant indirect impacts, such as increased water prices during drought conditions and reduced recreational opportunities along coastal communities from sea level rise.

Certain populations will be more vulnerable to climate change and its associated direct and indirect impacts. For example, children, seniors, and persons with underlying medical conditions (e.g., chronic heart disease) may be more susceptible to developing negative health outcomes from exposure to worsening air quality (CARB 2021). As discussed further below, the adverse impacts of climate change are also expected to disproportionately affect communities of color and underserved and low-income communities, which may have fewer resources to respond to changing conditions (Milanes et al. 2018).

To adapt to an uncertain future, California planners will need to anticipate climate change risks and build communities that remain resilient in the face of a changing climate. The resources and guidance presented in the Handbook provide tools to support resilient planning.

Social Environment and Public Health

Exposure to Environmental Burdens

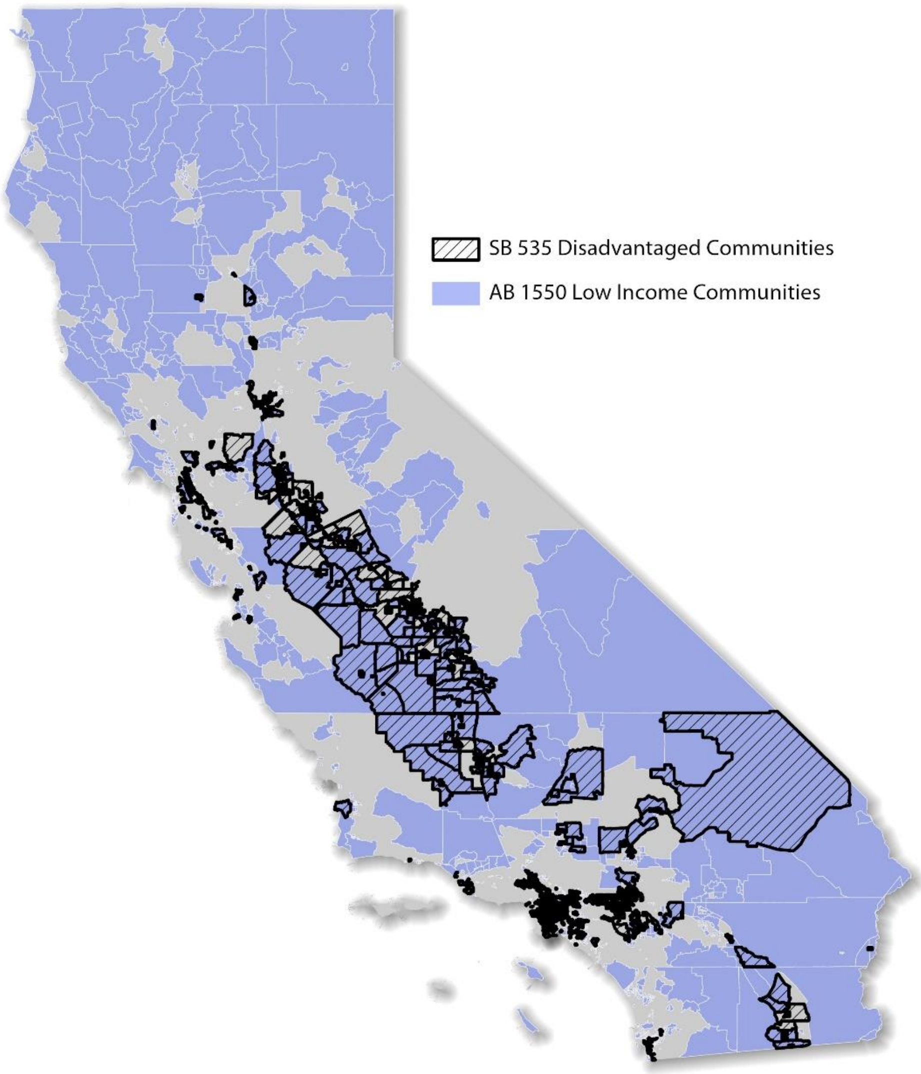
Underserved and low-income communities have historically suffered from disproportionately higher rates of pollution and other environmental hazards compared to more affluent communities. Socioeconomic determinants of public health—like educational attainment, housing costs, linguistic isolation, poverty, and unemployment rates—are shaped by public policy and planning. Past exclusionary housing and planning practices segregated and redlined certain populations. These policies made it more difficult for communities of color and low-income and immigrant populations to access critical resources necessary to support healthy, thriving, and prosperous lives.

CalEPA designates *disadvantaged communities* as the 25 percent highest scoring census tracts using results of CalEnviroScreen and lands controlled by federally-recognized Tribes. *Low-income communities* are census tracts with median household incomes at or below 80 percent of the statewide median income or at or below the state income limit threshold.

Structural and institutional racism continue to persist and shape California communities. Nearly one-quarter of children under 5 years old in California are currently living in poverty (August et al. 2021). Low-income populations often reside in neighborhoods that score among the lowest for key environmental and social indicators, such as access to clean water (Urban Environment & Social Inclusion Index 2021).The California Environmental Protection Agency (CalEPA) designates communities in California as disadvantaged or low-income for the purposes of allocating climate investments. Figure 2-1 shows these communities and highlights the considerable number of locations currently designated as disadvantaged, low-income, or both (CalEPA 2021).

The impacts of disproportionate exposure to environmental burdens are often felt at the individual, household, and community level (Gochfeld and Burger 2011; Katz 2012). For example, studies have found that low-income individuals have higher rates of hospitalization and greater risk of mortality when exposed to air pollution (Cakmak, Dales, and Judek 2006; Finkelstein et al. 2003). Communities with lower levels of education have higher rates of respiratory illnesses, such as childhood asthma, because of greater exposure to air pollution (August et al. 2021). Unemployment and poverty may also force individuals to live in areas with greater levels of environmental degradation (August et al. 2021). These disparities can magnify and exacerbate the spread and impact of disease and environmental disasters, as evidenced most recently by COVID-19: individuals of color have been hospitalized with COVID-19 at 3 to 4 times the rate of white persons and have fatality rates about 2 to 2.5 times greater, according to the Centers for Disease Control and Prevention (CDC) (2021).

Figure 2-1. CalEPA Designated Disadvantaged and Low-Income Communities in California[1]



[1] Senate Bill 535-designated disadvantaged communities are designated by CalEPA, based on the 25% highest scoring census tracts in CalEnviroScreen, 4.0; census tracts without scores but having the highest 5% of cumulative pollution burden scores in CalEnviroScreen 4.0; disadvantaged census tracts from the 2017 designation; and land under control of federally recognized Tribes.

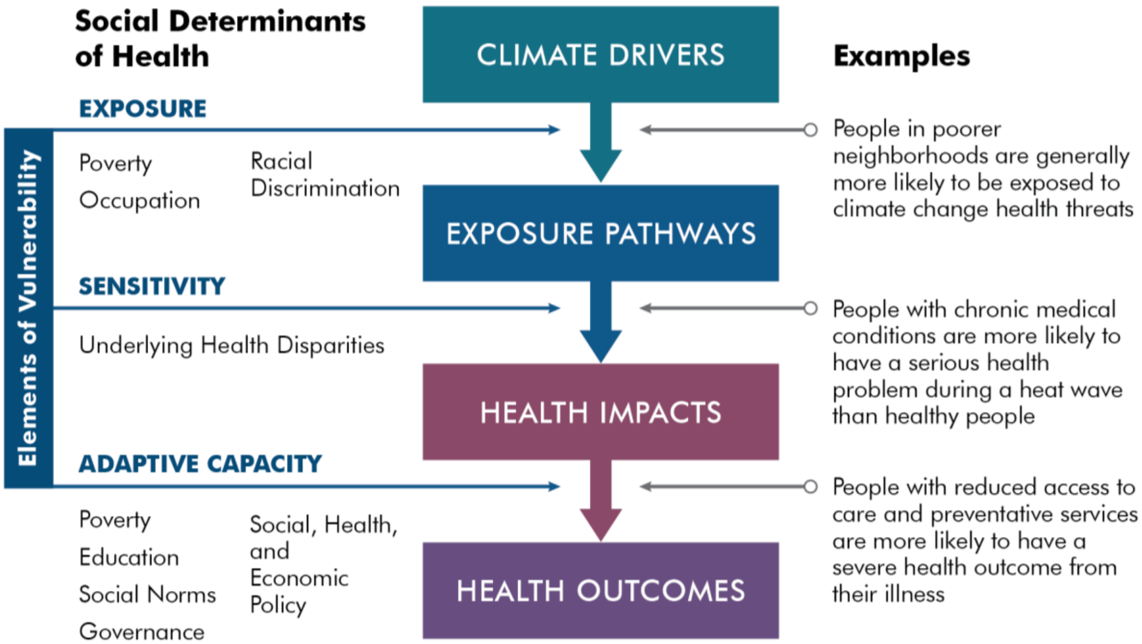
Improving conditions in communities over-burdened by pollution and other environmental hazards will require targeted and systematic changes in funding and policy priorities. The resources and guidance presented in this Handbook provide tools to support more equitable planning.

Vulnerability to Climate Change

Underserved communities are expected to be disproportionally affected by the health, economic, and physical consequences of climate change. Individuals in these communities are likely to face a double threat from climate change to their health: they have higher exposure to climate hazards and have higher sensitivity to environmental stressors (August et al. 2021). Factors that contribute to higher exposure include occupation, time spent in risk-prone locations, ability to respond to extreme events, socioeconomic status, and the condition of community infrastructure (Gamble et al. 2016). Communities of color, low-income communities, outdoor workers, those with limited English language skills, children, the elderly, and people who are unhoused are all groups with higher vulnerability to climate hazards (Ebi et al. 2018; Gamble et al. 2016). These populations already experience higher rates of chronic medical conditions that can be worsened by climate change (Gamble et al. 2016).

Figure 2-2, which has been adapted from Gamble et al. (2016), illustrates the intersection of various social determinants on health and vulnerability to climate change. Implementing policies and processes to address underlying social factors that exacerbate health outcomes from climate exposures will improve the overall resilience and wellbeing of our communities.

Figure 2-2. Intersections of Social Determinants on Health and Vulnerability



Various tools and resources are available to help decisionmakers prioritize people and places for investments based on combined climate and health vulnerability. The California Department of Public Health's (2020) *Climate Change and Health Vulnerability Indicators for California* identifies the following three categories of indicators.

- Exposure indicators: heat, air quality, drought, wildfires, and sea level rise
- Population sensitivity indicators: children and elderly, poverty, education, race and ethnicity, outdoor workers, vehicle ownership, linguistic isolation, disability, health insurance, and violent crime rate
- Adaptive capacity indicators: air conditioning ownership, tree canopy, impervious surfaces, and public transit access.

CCHVIz is an online platform that allows users to visualize the indicator data across California (CDPH n.d.). Indicators are available at the census tract level or the next smallest scale available, such as the county or regional level.

The California Healthy Places Index (HPI) developed by the Public Health Alliance of Southern California (2021) showcases community conditions that predict life expectancy and can be used to compare and explore factors influencing health by census tract across California. The HPI reflects a combination of 25 community characteristics that are weighted and validated against life expectancy. Climate change exposures, social vulnerability, and adaptive capacity indicators are included as separate "decision support" layers that can be overlaid with the HPI map and scores. The indicators are grouped into eight policy action areas (economic, education, transportation, social, neighborhood, housing, clean environment, and healthcare access). Detailed policy guides offer specific solutions for healthier communities.

Federal and State Planning Efforts

Regulations are essential to helping economies and societies prosper. They provide structure and limits for government agencies, businesses, civil society organizations, and citizens. They also help realize public benefits like increased safety, improved health, economic opportunities, and fairness. Regulations often set goals to guide future planning and development efforts and create strategies and mechanisms to achieve those goals.

This section describes important federal and state regulations, policies, and legislation related to GHG emissions reductions, climate change vulnerability and adaptation, and social equity. These various requirements directly influence and inform planning efforts across California and are important to consider when reviewing measures in later chapters. Appendix B, *Federal and State Planning Framework*, provides greater detail on these efforts and resources for further reading.

The regulatory landscape is constantly shifting as amendments, revocations, and new requirements are adopted. The text in this section was drafted in 2021 and reflects the regulatory landscape as of this date. Readers may need to conduct additional research to ensure they have the latest information. Potential resources that may be consulted to provide updated information include the State's Adaptation Clearinghouse, the Alliance of Regional Collaboratives for Climate Adaptation legislative tracking site, and the Berkeley Law California Climate Policy Dashboard.

Federal Regulations and Requirements

There is no comprehensive federal law specific to climate change, societal equity, or the reduction of GHG emissions. However, in 2021, the United States rejoined the Paris Agreement to reduce national GHG emissions and the federal government submitted the United States' *Nationally Determined Contribution (NDC)*, which aims to reduce national GHG emissions by 50 to 52 percent by 2030 from 2005 levels. The NDC, executive orders, and other goals and efforts of the Biden Administration make up a new "whole-of-government" approach to reduce GHG emissions, increase climate resilience, improve equity, and boost economic growth (White House 2021a).

Clean Air Act and Greenhouse Gases

The federal *Clean Air Act (CAA)* was enacted in 1963 and has been amended numerous times since, most recently in 1990. The CAA established federal national ambient air quality standards (NAAQS) for six criteria pollutants and specifies future dates for achieving compliance. These standards were set to improve air quality and public health outcomes. For local areas not meeting those standards, states must submit and implement a State Implementation Plan that demonstrates how the standards will be met (U.S. EPA 2021).

In 2009, the U.S. Environmental Protection Agency (U.S. EPA) released its final *Greenhouse Gas Reporting Rule (Reporting Rule)*. The Reporting Rule is a response to the 2008 Consolidated Appropriations Act, which required U.S. EPA to develop mandatory reporting of GHGs above appropriate thresholds. The rule applies to most entities that emit 25,000 metric tons of carbon dioxide equivalent or more per year. Starting in 2010, facility owners were required to annually report their GHG emissions (U.S. EPA 2016).

U.S. EPA signed the *Endangerment Finding* and *Cause or Contribute Finding for Greenhouse Gases* under Section 202(a) of the CAA in 2009. Under the Endangerment Finding, EPA found that the current and projected concentrations of the six key GHGs—carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), perfluorinated carbons (PFCs), sulfur hexafluoride (SF_6), and hydrofluorocarbons (HFCs)—in the atmosphere threaten the public health and welfare of current and future generations (U.S. EPA 2020).

In 2021, President Biden signed Executive Order 14008, which aims to tackle the climate change by making climate considerations an essential element of U.S. foreign policy and national security. It orders that the U.S. works to build resilience, at home and abroad, against the impacts of climate change that are already occurring and will continue to intensify without extensive climate mitigation efforts (Federal Register 2021).

Fuel Efficiency Standards

The *Corporate Average Fuel Economy (CAFE)* standards were first enacted in 1975 to reduce energy consumption by improving the fuel economy of vehicles. The standards set fleet-wide averages that each automaker must meet. By improving the fuel efficiency of vehicles, the standards improve national energy security, save consumers money, and reduce GHG emissions.

In 2011, the U.S. EPA and the National Highway Traffic Safety Administration (NHTSA) issued a *Final Rule for Phase 2 GHG Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-duty Engines and Vehicles*. This rule includes three regulatory categories of heavy-duty vehicles—combination tractors, heavy-duty pickup trucks and vans, and vocational vehicles—and applies to model years 2014–2018. Phase 2 of these standards were established in 2016 for model years 2019–2027 (U.S. EPA 2020b).

The passenger vehicle standards were updated in 2012 CAFE for model years 2017–2025 to incorporate stricter fuel economy requirements that required new passenger cars and light trucks to reach 54.5 miles per gallon by 2025. The program also included incentives to encourage adoption of new technologies to improve vehicle performance, such as electric vehicles (U.S DOT 2014).

In 2018, the *Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule* was proposed, which would amend prior CAFE and GHG emissions standards and create new standards for model year 2021–2026 vehicles and reduce fuel economy requirements. In September 2019, NHTSA and U.S. EPA established "The Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule Part One: One National Program," which withdrew California's ability to create its own fuel economy standards under the CAA. The rule was finalized in 2020.[2] The SAFE rule has been legally challenged by California and many other states (NHTSA 2020). On April 22, 2021, NTHSA issued a notice of proposed rulemaking to repeal the SAFE Vehicles Rule (49 Code of Federal Regulations Parts 531 and 533). The public comment period for this repeal concluded on June 11, 2021.

Environmental Planning

Signed in 1970, the *National Environmental Policy Act (NEPA)* was enacted to minimize the negative environmental impacts of new development. It requires federal agencies to incorporate environmental considerations (including related social and economic effects) into planning and decision-making processes through a systematic interdisciplinary approach (U.S. EPA 2020).

[2] CARB's EMFAC2021 accounts for future fuel economy and emissions impacts of the SAFE Vehicles Rule. While prior versions of EMFAC, including EMFAC2014 and EMFAC2017, do not account for the rule, CARB (2019a, 2020) has published off-model adjustment factors that can be used to adjust emissions output from EMFAC2014 and EMFAC2017.

Environmental Justice and Equity

Title VI of the Civil Rights Act of 1964 specifically prohibits discrimination based on race, color, or national origin by any program or activity that receives federal funds. All federal agencies help execute the provisions of Title VI. Violators of the act may lose federal funding for projects or programs.

Executive Order 12898, signed in 1994, directs all federal agencies to make achieving environmental justice part of their mission. Agencies are directed to identify and address disproportionately high and adverse human health or environmental effects of agency programs, policies, and activities on minority and low-income populations.

Pursuant to Executive Order 12898, the Council on Environmental Quality (CEQ) issued *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations* to help agencies carry out the order. The guidance includes six principles for environmental justice analyses and provides guidance for how to assess human health or environmental effects on low-income, minority, and tribal communities (CEQ 1997). Following this guidance, federal agencies have developed plans and strategies to address environmental justice through agency actions.

In 2021, President Biden signed *Executive Order 13985*, which advances racial equity by addressing issues that have historically created inequity and advances civil rights, social justice, and equal opportunity. It declares that the government will address historic failures to invest sufficiently, justly, and equally in underserved communities, and will increase investment in underserved communities by promoting equitable delivery of government benefits and opportunities (White House 2021b).

The Soul Consoling Tower was built by Ryozo Kado in 1943 to remember the lives lost at the Manzanar War Relocation Center, where over 11,000 Japanese Americans were imprisoned during World War II by Executive Order 9066.

Also signed in 2021, *Executive Order 13990* recommits the executive branch to using scientific evidence in decision-making processes to advance public health and environment outcomes. More specifically, it states the administration's intent to ensure clean air and water, limit pollution and hold polluters responsible, reduce exposure to toxic chemicals, enhance environmental justice, and create well-paying union jobs. It also requires federal agencies to review federal regulations and actions that conflict with these objectives, with input from environmental justice organizations and other stakeholders (White House 2021c).

State Regulations and Rules

California has adopted numerous statewide laws, regulations, and policies to address GHG emissions reductions, climate adaptation, and equity. California has been a trailblazer and standard setter for climate-related regulations and programs. For example, California passed the Pavley 1 rule in 2002, which set the nation's first GHG standards for automobiles, and the state's GHG cap-and-trade program was the first multi-sector cap-and-trade program for GHG emissions in North America.

GHG Reduction Goals and Strategies

Executive Order S-3-05, signed in 2005, states that California is vulnerable to the effects of climate change and to help mitigate it, establishes GHG emissions reduction targets for state agencies and requires the CalEPA to report the impacts of global warming on California and progress be made toward reducing GHG emissions through 2050 (Office of Governor 2005).

In 2006, *Assembly Bill 32, the California Global Warming Solutions Act of 2006*, established a cap on statewide GHG emissions and created a regulatory framework to reduce emissions to 1990 levels by 2020, which has been achieved. The California Air Resources Board (CARB) adopted a *GHG cap-and-trade program* in 2011 as a key mechanism to reduce GHG emissions and achieve California's GHG reduction goal. The cap-and-trade program created a market-based system that set an overall emissions limit (a "cap") for specific sectors, which is reduced annually. Revenues from the program are appropriated to state agencies to implement programs that reduce GHG emissions (C2ES n.d.). The cap-and-trade program was initially slated to sunset in 2020 but the passage of *Senate Bill (SB) 398* in 2017 extended the program through 2030.

Executive Order B-30-15, signed in 2015, established the connection between reducing GHG emissions to limit future climate change and adapting to current and future climate change impacts. It set a statewide interim GHG reduction target to reduce GHG emissions by 40 percent below 1990 levels by 2030 (Office of the Governor 2015). *SB 32* (passed in 2016) legislatively adopted this 2030 target. CARB adopted the *2017 Climate Change Scoping Plan* in November 2017 to meet the GHG reduction requirement set forth in SB 32. In December 2022, CARB adopted the *2022 Scoping Plan Update* that assesses progress toward achieving the 2030 target and outlines a path to achieving carbon neutrality by 2045.

Executive Order B-55-18 set a new state goal to achieve carbon neutrality as soon as possible (and no later than 2045) and to achieve and maintain net negative emissions thereafter. It also states that all policies and programs undertaken to achieve the goal should support climate adaptation, resource conservation, biodiversity, and improve public health in urban and rural communities, particularly low-income and underserved communities (Office of Governor 2018). The 2045 carbon neutrality goal was adopted into statute by the Legislature with the California Climate Crisis Act of 2022 (AB 1279).

Complementary to the state's larger GHG reduction goals, *SB 605* (2014) directed CARB, in coordination with other State agencies and local air districts, to develop a comprehensive *Short-Lived Climate Pollutants (SLCP) Reduction Strategy*. SLCPs include CH_4, HFC, and anthropogenic black carbon. These pollutants have relatively short atmospheric lifetimes but much greater influence on the climate, compared to CO_2. *SB 1383* directed CARB to approve and implement the SLCP Reduction Strategy to achieve specific SLCP reduction targets. CARB adopted the SLCP Reduction Strategy in March 2017 as a framework for achieving the reduction targets set by SB 1383 (BAAQMD 2020).

Clean Energy and Conservation

SB 1078 (2002) and SB 107 (2006), California's *Renewables Portfolio Standard (RPS)* obligates investor-owned utilities (IOUs), energy service providers (ESPs), and Community Choice Aggregations (CCAs) to increase the proportion of energy generated from renewable energy sources. The most recent RPS target was established by SB 100 in 2018, which set a target to source 60 percent of energy from renewables by 2030 and mandated 100 percent of electricity come from carbon-free energy sources by 2045 (California Legislative Information 2018).

The California Green Building Standards Code (Part 11, Title 24), known as *CALGreen*, was adopted in 2007 as part of the California Building Standards Code. The code includes voluntary and mandatory standards related to sustainable site development, energy efficiency, water conservation, material conservation, and reducing internal air contaminants (California Building Standards Commission 2019). *SB 350*, which was signed in 2015, requires a doubling of energy efficiency (electrical and natural gas) by 2030, including improvements to the efficiency of existing buildings. The 2022 CALGreen standards took effect on January 1, 2023.

The State has made water conservation a priority. The *California Water Action Plan* was developed by CNRA in 2016 and sets forth a collection of actions to improve reliable water supply, restore the state's ecosystems, and build a resilient and sustainable water resource system. The Water Action Plan also emphasizes diversified regional supply portfolios to increase resiliency to droughts, floods, population growth, and climate change (CNRA 2016).

Mandatory recycling requirements to reduce landfilled waste and associated GHG emissions were originally established in 2011 through *AB 341*. *AB 1826* was passed in 2014 and requires businesses that generate two cubic yards per week of solid waste (beginning on January 1, 2020) to arrange for recycling services for organic waste (e.g., food and lawncare waste).

In 2019, CARB and other state agencies jointly released the *2030 Natural and Working Lands Climate Change Implementation Plan.* The plan outlines specific conservation, restoration, and management activities that will improve resiliency, maintain a natural carbon sink, and improve environmental quality. The plan sets a 2030 goal to at least double the pace and scale of state-supported land activities by 2030 and beyond, among other goals. The plan estimates that these activities will increase emissions by 12.4-35.9 $MMTCO_2e$ by 2030 and reduce emissions by 83.1–84.2 $MMTCO_2e$ by 2045 (CARB 2019b).

Vehicle Fuel Efficiency

Pavley I (AB 1493) set the nation's first GHG standards for automobiles and required CARB to adopt vehicle standards that lower GHG emissions from new light-duty vehicles to the maximum extent feasible beginning in 2009 (CARB 2021a). In 2012, CARB strengthened the Pavley standards through the *Advanced Clean Cars* regulations, which limit GHG emissions from passenger vehicles for model years 2017–2025 (CARB 2021b).

Executive Order S-01-07 establishes a statewide goal to reduce the carbon intensity of California's transportation fuels by at least 10 percent by 2020. In 2018, CARB passed amendments to the Low Carbon Fuel Standard that set a target to reduce fuel carbon intensity by 20% by 2030, compared to a 2010 baseline (CARB 2018b).

The *Innovative Clean Transit (ICT) regulation* requires all public transit agencies to gradually transition to 100 percent zero-emission bus fleets by 2040. Large and small transit agencies must submit their ZEB rollout plans by July 1, 2020 and July 1, 2023, respectively. State funding to transit agencies is contingent upon the agencies' compliance (CARB 2021d). To further accelerate the transition of zero-emission heavy-duty vehicles, CARB adopted the *Advanced Clean Truck Regulation* in June 2020. The regulation requires the sale of zero-emission medium-and-heavy-duty vehicles as an increasing percentage of total annual California sales from 2024 to 2035. By 2035, zero-emission truck/chassis sales must be 55 percent of Class 2b–3 truck sales, 75 percent of Class 4–8 straight truck sales, and 40 percent of truck tractor sales. By 2045, every new medium-and-heavy-duty truck sold in California will be zero-emission (ICCT 2020). This effort is currently in litigation.

Climate Adaptation

Executive Order S-13-08 requires the California Natural Resources Agency (CNRA) to develop a *Climate Adaptation Strategy* (CAS) in partnership with local, regional, state, and federal entities. It also required the development of a California Sea Level Rise Assessment Report that is reviewed every two years. Among other directives, it directs state agencies planning construction projects to assess the vulnerability to sea level rise and other climate change impacts (Adaptation Clearinghouse 2008). In 2009, California adopted a statewide CAS that summarized climate change impacts and recommended adaptation strategies for seven sectors.

Executive Order B-30-15 requires the CNRA update the state's CAS every 3 years and orders state agencies to take current and future climate impacts into account in all planning and investment decisions (Office of Governor 2015). In 2018, the CNRA updated the CAS to describe ongoing climate actions and recommend cost-effective and achievable next steps to respond to climate change in 11 sectors (CNRA 2018).

SB 246 establishes an integrated climate adaptation and resiliency plan to coordinate regional and local efforts with state strategies. The program emphasizes climate equity considerations throughout all sectors and regions to help develop holistic strategies for climate adaptation (California Legislative Information 2015). As a result of SB 246, in 2020, a new version of the *California Climate Adaptation Planning Guide* was developed by the California Emergency Management Agency and CNRA to include new requirements for local adaptation planning.

SB 379 ensures that climate adaptation is integrated into local jurisdictions' general plan processes. It requires California cities and counties to integrate climate adaptation into the safety element of their general plans by conducting a vulnerability assessment to identify local climate change risks and then develop adaptation and resilience goals, policies, objectives, and implementation measures based on the assessment (OPR 2017). Furthermore, *SB 1035* requires local planning agencies to review and revise the safety element of city or county general plans as necessary to address new climate adaptation risks and resiliency strategies. Planning agencies must do this during each revision of the housing element of the general plan or a local hazard mitigation plan, and not less than once every 8 years (California Legislative Information 2018b).

The State Water Resources Control Board has taken a variety of actions to respond to climate change, including the adoption of the *Comprehensive Response to Climate Change*. It requires the State Water Board to integrate proactive measures to respond to climate change in all its actions. The resolution also outlines specific measures to reduce GHG emissions, improve ecosystem resilience, and respond to climate change impacts (State Water Board 2017).

In response to the increasing frequency and intensity of wildfires across California, the *Wildfire Preparedness and Response* bill was signed in 2018. It allocates $200 million annually from 2019-2024 to fund grants to fire departments, cities, counties, and nonprofit organizations to help reduce forest fuel loads with thinning and prescribed burns in high-risk areas. The California Department of Forestry and Fire Protection (CalFire) distributes the funding and provides technical assistance. The bill also requires utilities to create and implement wildfire mitigation plans (Adaptation Clearinghouse 2018).

The California Coastal Commission adopted the *Sea Level Rise Policy Guidance* in 2015 and an update in 2018. The guidance provides an overview of the sea level rise science and broad recommendations for how to plan for and address sea level rise impacts. The guidance is broadly applicable and is used by the Coastal Commission, local governments, project applicants, and other stakeholders. The Coastal Commission describes the guidance as “a menu of options” that local planners can select from as appropriate, rather than a checklist of requirements (CCC 2019).

Social Equity

SB 1000 requires cities and counties with disadvantaged communities to include an environmental justice element in their general plans to ensure that local governments address environmental justice when planning long-term land use and growth goals and policies. Local governments must identify any disadvantaged communities and develop measures to mitigate and reduce health risks that can be attributed to the environment (Strategic Growth Council 2021). *SB 32* (discussed above) also includes an environmental justice component that requires GHG reduction targets to be met in a way that benefits the most disadvantaged communities (California Legislative Information 2016a). The *GHG cap-and-trade program* (discussed above) requires 35 percent of program revenue to be directed toward environmentally disadvantaged and low-income communities (California Legislative Information 2016a).

AB 2722 was signed in 2016 to help create more sustainable cities, to address climate justice, and to help California meet its GHG emissions reduction goals. To achieve this, the California Strategic Growth Council created the Transformative Climate Communities program, which issues grants to develop and implement transformative climate plans. The funds are used to create and implement cross-cutting community plans that improve air and water quality, reduce emissions, and provide climate, economic, employment, and health benefits to disadvantaged communities (California Legislative Information 2016b).

AB 617 requires the State to develop a statewide annual reporting system for emissions of criteria air pollutants and toxic air contaminants for certain stationary sources. It also requires the State to prepare a monitoring plan for emissions and to prepare a statewide strategy to reduce emissions of toxic air contaminants and criteria pollutants in communities that experience a high cumulative exposure burden, in consultation with environmental justice groups and other stakeholders. (California Legislative Information, 2017). In response, CARB established the *Community Air Protection Program (CAPP)*, which focuses on reducing pollution exposure to communities that are most affected by air pollution. The CAPP provides funds for deploying clean technologies in communities and to retrofit pollution controls on industrial sources (CARB 2021c).

Planning Guidance

Photo Credit: Port of San Francisco, March 2019

The *California Environmental Quality Act (CEQA)* guidelines, first established in 1970, explain how to determine if an activity is subject to environmental review, what steps are involved in the process, and what documents are required. With respect to GHG emissions, the guidelines require agencies to describe, calculate, or estimate the amount of GHG emissions that are expected to result from a project. They also require a determination of whether a project would exacerbate physical climate change effects (OPR 2021). *SB 743* required revisions to the CEQA Guidelines (which occurred in 2018 and became effective in 2020) to establish new impact analysis criteria for the assessment of a project's transportation impacts. The intent behind SB 743 and revising the CEQA Guidelines was to integrate and better balance the needs of congestion management, infill development, active transportation, and GHG emissions reduction (Caltrans 2021).

SB 375 provides a planning process that coordinates land use planning, regional transportation plans, and funding priorities to help California meet its GHG reduction goals. SB 375 requires regional transportation plans developed by metropolitan planning organizations to incorporate a sustainable communities strategy (SCS) in their regional transportation plans (Institute for Local Government 2015). The goal of the SCS is to reduce regional vehicle miles traveled through land use planning and transportation planning.

Building Future Equity and Resilience through Better Planning

As discussed in *Social and Environment and Public Health*, underserved and low-income communities and communities of color experience disproportionate environmental and climate change impacts. It is important that resources be targeted to historically over-burdened communities when planning for an equitable and climate-resilient future. Equally, decisionmakers must consider potential unintended consequences that may arise from implementation of emission reduction or adaptation measures. Striving for equity may also mean considering non-traditional measures that create socioeconomic co-benefits.

Planners can support more equitable development by engaging directly with local communities. Community-driven processes allow community members and organizations to set adaptation priorities and influence investments, identify inequities in planning, direct resources to the most at-risk areas and groups, and promote democracy and transparency in government (Georgetown Climate Center 2017).

The GHG emission reduction and climate adaptation measure descriptions presented in Chapters 3 and 4 include equity considerations. Chapter 5, *Measures for Advancing Health and Equity*, presents a non-exhaustive list of measures, examples, and resources to promote future health and equity in project and community planning. Chapter 6, *Resources to Support Resilient and Equitable Emission Reduction Planning*, provides resources and guidance on incorporating equity into resilient planning.

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Measures to Reduce GHG Emissions

CHAPTER 3

The California Air Pollution Control Officers Association (CAPCOA) has included a wide range of measures that are frequently used to reduce greenhouse gas (GHG) emissions and provide other benefits, like improved air quality, energy and fuel savings, and water conservation. This chapter provides methods and data to quantitatively evaluate many of the measures. While there is no one-size-fits-all approach to GHG planning, the guidance presented in this chapter has been developed to broadly apply across project types, land use types, and California regions.

Categorizing Measures

When thinking about minimizing GHG emissions in a community or for a project, it is useful to organize GHG reduction measures into categories. The standard method of categorizing emissions is to group them by economic sector, such as transportation or energy. Consistent with this practice, the emission reduction measures presented in this chapter are categorized into the following nine sectors. Measures in each sector apply to a similar emissions source or process, as described below.

- Transportation: Measures that promote transit and alternative transportation, support use of alternatively fueled vehicles, or encourage land use planning practices that reduce vehicle trips and vehicle miles traveled (VMT). Measures within the transportation sector are separated into seven subsectors: Land Use, Neighborhood Design, Parking or Road Pricing/Management, Transit, Trip Reduction Programs, Clean Vehicles and Fuels, and School Programs.
- Energy: Measures that target energy efficiency improvements/reduced natural gas consumption, renewable energy generation, building electrification, or methane (CH_4) recovery at landfills and wastewater treatment plants.
- Water: Measures that reduce water demand and/or use a less energy-intensive water source.
- Lawn and Landscaping: Measures that promote zero-emission landscaping equipment over conventional fossil fuel-powered counterparts.
- Solid Waste: Measures that require alternative waste management pathways, such as recycling and composting, to increase landfill waste diversion and prevent edible food from going to the landfill so it can be consumed by those in need.
- Natural and Working Lands: Measures that enhance the sequestration capacity of natural lands or reduce the intensity of emissions from working lands and promote zero-emission agriculture equipment over fossil fuel-powered counterparts.
- Construction: Measures that promote efficient construction management practices or alternatively fueled construction equipment.
- Refrigerants: Measures to reduce or replace high global warming potential (GWP) refrigerants with lower impact compounds.
- Miscellaneous: General measures that will reduce GHG emissions through the implementation of novel or off-site projects defined by the user and promote zero-emission off-road equipment over fossil fuel-powered counterparts.

EMISSIONS SECTORS

Categorizing emissions by sector is standard practice for GHG inventories and reduction plans, but users should note that there is often variation in the scope and nomenclature of sectors. For example, the sectors in this Handbook do not align exactly with the California Air Resources Board or U.S. Environmental Protection Agency inventories because of differences in scale and intended use. Users should take care when comparing sectors in this Handbook to other inventories or plans.

The nine emission sectors are illustrated in Figure 3-1. The figure shows all quantified GHG reduction measures included in this chapter. Users may click on an individual measure to navigate directly to the quantification method for that measure. Figure 3-1 does not include non-quantified measures. These measures are presented later in this chapter in *Supporting or Non-Quantified GHG Reduction Measures*.

Figure 3-1. Navigation Trees for Quantitative GHG Reduction Measures

Transportation

LAND USE

- T-1. Increase Residential Density
- T-2. Increase Job Density
- T-3. Provide Transit-Oriented Development
- T-4. Integrate Affordable and Below Market Rate Housing
- T-17. Improve Street Connectivity
- T-55. Infill Development

TRIP REDUCTION PROGRAMS

- T-5. Implement Commute Trip Reduction Program (Voluntary)
- T-6. Implement Commute Trip Reduction Program (Mandatory Implementation and Monitoring)
- T-7. Implement Commute Trip Reduction Marketing
- T-8. Provide Ridesharing Program
- T-9. Implement Subsidized or Discounted Transit Program
- T-10. Provide End-of-Trip Bicycle Facilities
- T-11. Provide Employer-Sponsored Vanpool
- T-12. Price Workplace Parking
- T-13. Implement Employee Parking Cash-Out
- T-23. Provide Community-Based Travel Planning

PARKING OR ROAD PRICING/MANAGEMENT

- T-14. Provide Electric Vehicle Charging Infrastructure
- T-15. Limit Residential Parking Supply
- T-16. Unbundle Residential Parking Costs from Property Cost
- T-24. Implement Market Price Public Parking (On-Street)

NEIGHBORHOOD DESIGN

- T-18. Provide Pedestrian Network Improvement
- T-19-A. Construct or Improve Bike Facility
- T-19-B. Construct or Improve Bike Boulevard
- T-20. Expand Bikeway Network
- T-21-A. Implement Conventional Carshare Program
- T-21-B. Implement Electric Carshare Program
- T-22-A. Implement Pedal (Non-Electric) Bikeshare Program
- T-22-B. Implement Electric Bikeshare Program
- T-22-C. Implement Scootershare Program
- T-22-D. Transition Conventional to Electric Bikeshare

TRANSIT

- T-25. Extend Transit Network Coverage or Hours
- T-26. Increase Transit Service Frequency
- T-27. Implement Transit-Supportive Roadway Treatments
- T-28. Provide Bus Rapid Transit
- T-29. Reduce Transit Fares
- T-46. Provide Transit Shelters

CLEAN VEHICLES AND FUELS

- T-30. Use Cleaner-Fuel Vehicles

SCHOOL PROGRAMS

- T-40 Establish a School Bus Program
- T-56. Active Modes of Transportation for Youth

Energy

ENERGY EFFICIENCY IMPROVEMENTS

- E-1. Buildings Exceed 2019 Title 24 Building Envelope Energy Efficiency Standards
- E-2. Require Energy Efficient Appliances
- E-3-A. Require Energy Efficient Residential Boilers
- E-3-B. Require Energy Efficient Commercial Packaged Boilers
- E-4. Install Cool Roofs and/or Cool Walls in Residential Development
- E-5. Install Green Roofs in Place of Dark Roofs
- E-6. Encourage Residential Participation in Existing Demand Response Program(s)
- E-7. Require Higher Efficacy Public Street and Area Lighting
- E-8. Replace Incandescent Traffic Lights with LED Traffic Lights
- E-9. Utilize a Combined Heat and Power System
- E-21. Install Cool Pavement

RENEWABLE ENERGY GENERATION

- E-10-A. Establish Onsite Renewable Energy Systems—Generic
- E-10-B. Establish Onsite Renewable Energy Systems—Solar Power
- E-10-C. Establish Onsite Renewable Energy Systems—Wind Power
- E-11. Procure Electricity from Lower Carbon Intensity Power Supply
- E-26. Biomass Energy

BUILDING DECARBONIZATION

- E-12. Install Alternative Type of Water Heater in Place of Gas Storage Tank Heater in Residences
- E-13. Install Electric Ranges in Place of Gas Ranges
- E-14. Limit Wood Burning Devices and Natural Gas/Propane Fireplaces in Residential Development
- E-15. Require All-Electric Development
- E-16. Require Zero Net Energy Buildings
- E-17. Require Renewable-Surplus Buildings

METHANE RECOVERY

- E-18. Establish Methane Recovery in Landfills
- E-19. Establish Methane Recovery in Wastewater Treatment Plants

Water

- W-1. Use Reclaimed Non-Potable Water
- W-2. Use Grey Water
- W-3. Use Locally Sourced Water Supply
- W-4. Require Low-Flow Water Fixtures
- W-5. Design Water-Efficient Landscapes
- W-6. Reduce Turf in Landscapes and Lawns
- W-7. Adopt a Water Conservation Strategy

Lawn and Landscaping

- LL-1. Replace Gas Powered Landscape Equipment with Zero-Emission Landscape Equipment

Solid Waste

- S-1. Institute or Extend Recycling Services
- S-2. Implement Organics Diversion Program
- S-3. Require Edible Food Recovery Program Partnerships with Food Generators

Natural and Working Lands

- N-1. Create New Vegetated Open Space
- N-2. Expand Urban Tree Planting
- N-3. Implement Management Practices to Improve the Health and Function of Natural and Working Lands
- N-4. Require Best Management Practices for Manure Management
- N-7. Wildfire Resilience and Management
- N-8. Agricultural Equipment Efficiency

Construction

- C-1-A. Use Electric or Hybrid Powered Equipment
- C-1-B. Use Cleaner-Fuel Equipment
- C-2. Limit Heavy-Duty Diesel Vehicle Idling
- C-3. Use Local Construction Contractors

Refrigerants

- R-1. Use Alternative Refrigerants Instead of High-GWP Refrigerants
- R-2. Install Secondary Loop and/or Cascade Supermarket Systems in Place of Direct Expansion Systems
- R-3. Install Transcritical CO_2 Supermarket Systems in Place of High-GWP Systems
- R-4. Install Microchannel Heat Exchangers in A/C Equipment in Place of Conventional Heat Exchanger
- R-5. Reduce Service Leak Emissions
- R-6. Reduce Operational Leak Emissions
- R-7. Reduce Disposal Emissions

Miscellaneous

- M-1. Establish a Carbon Sequestration Project
- M-2. Establish Offsite Mitigation
- M-3. Implement an Innovative Strategy for GHG Mitigation
- M-6. Off-Road Equipment Efficiency

Selecting Measures

The GHG reduction measures presented in this chapter are diverse. Users are encouraged to carefully review the measure factsheets to determine which measures are most applicable to their project and capable of achieving their GHG reduction goals. There are several reasons a user might implement measures to reduce GHG emissions. Some measures may be implemented voluntarily, simply because users are seeking to reduce their GHG footprint. Other users may be obligated under law or statute to mitigate current or future impacts of specific actions or activities. This can include project-level impacts, such as those evaluated under the California Environmental Quality Act (CEQA), or plan-level impacts, such as those resulting from the implementation of a general plan or climate action plan.

When considering which measures are applicable from the Handbook, the underlying reasons and context for reducing GHG emissions should be incorporated into the decision-making process. For example, if a user is seeking to achieve substantial GHG reductions to comply with a CEQA requirement, measures that have the greatest potential to reduce emissions may be most applicable. Or, if a city is aiming to implement a climate action plan by engaging the community, measures that inspire community members and are easily accessible and affordable may be the most applicable.

Other factors for determining measure applicability include the project type, scale, and locational context. Some measures are broad and applicable to many types of projects (e.g., Measure E-2, *Require Energy Efficient Appliances*), while others have a narrower scope of application (e.g., Measure E-19, *Establish Methane Recovery in Wastewater Treatment Plants*). Additionally, certain measures are suitable for urban environments, while others are best implemented in rural contexts. The measure factsheets presented in *GHG Reduction Measure Factsheets and Quantification Methods* later in this chapter summarize these and other important considerations for measure selection to support informed decision making.

Consideration of Measure Co-Benefits

Co-benefits, or additional benefits that often are associated with emissions reduction measures, are valuable elements of climate action planning. Citing co-benefits has become increasingly prevalent in justifying funding, planning, and implementing of emission reduction measures. Like the quantification of GHG reductions, only those benefits with literature and methodologies to support their accurate and reliable quantification are presented in this chapter. Where quantification is not achievable, co-benefits are noted qualitatively for each measure.

The co-benefit categories considered in this Handbook include the following and are visually depicted in the measure factsheets by the corresponding icons.

Improved air quality. Criteria pollutant reductions.

Energy and fuel savings. Electricity, natural gas, refrigerant, propane, gasoline, or diesel reductions.

VMT reductions. Reductions in vehicle miles traveled.

Water conservation. Water use reductions.

Enhanced pedestrian or traffic safety. Reduced collisions; pedestrian/bicyclist safety.

Improved public health. Toxic air contaminant reductions (including exposure); increased physical activity; improved public safety.

Improved ecosystem health. Improved biological diversity and soil and water quality.

Enhanced energy security. Systemwide load reduction; local energy generation, levelling out peaks.

Enhanced food security. Stability of food systems; improved household access to food.

Social equity. Address existing social inequities (e.g., housing/anti-displacement, community engagement, availability of disposable income).

This Handbook assigns co-benefits to measures that are likely to result from measure implementation; however, it should be noted that the achievement of co-benefits is not guaranteed because many co-benefits are dependent on how the measure is implemented. Determining what co-benefits apply to an individual measure in a specific circumstance is not an exact science, and there is no single methodology that can be uniformly applied for this purpose. When considering co-benefits that may be achieved, it is best to comprehensively think through the implications of implementing that measure. For example, Measure E-12, *Install Alternative Type of Water Heater in Place of Gas Storage Tank Heater in Residences,* reduces GHG emissions because it eliminates the onsite combustion of natural gas. Because combusting natural gas also results in emissions of other air pollutants that can cause adverse health effects, this measure would also improve air quality and achieve public health benefits. These co-benefits would be achieved by the measure in all project applications. Depending on where and how the measure is implemented, it may also address disparities in social equity and protect a homeowner or renter from rapid changes in fossil fuel prices, especially if solar energy is produced locally or on site. Users are encouraged to use the co-benefit icons identified for each measure as a starting point for this type of thought exercise and expand or revise for their specific project or application.

Note that while all measures achieve at least one co-benefit, some measures may also yield a disbenefit. For example, measures that electrify a fossil-fuel source will lead to improved air quality and fuel savings but increased electricity consumption. Potential disbenefits are discussed, where appropriate, for individual measures.

Quantifying GHG Reductions

The emissions quantification methods in this chapter are designed to provide GHG estimates using readily available data and user-specified information. In general, emission reductions are quantified (1) as a percentage of emissions from a given source or activity, or (2) as absolute emissions reductions from a given source or activity implementation of the measure. Where appropriate, some measures refer readers to external tools to quantify GHG reductions.

Quantification methods that provide a percent reduction rely on the underlying assumption that GHG emissions are proportional to the emissions source. For example, emissions reductions achieved by transportation measures are estimated using the expected percent reduction in vehicle trips or VMT, with an associated adjustment to account for the relationship between VMT reduction and vehicle emissions, as described further in the *Transportation* section. For these measures, users will need to multiply the reduction percentage by the amount of emissions that would be generated by that source without implementation of the measure to calculate the absolute reductions.[2] This Handbook does not include methods for inventorying emissions from specific sources or under various scenarios, such as baseline or existing conditions. There are several tools and models available for inventorying project-level GHG emissions, including CAPCOA's California Emissions Estimator Model (CalEEMod).

Quantification methods that calculate absolute reductions estimate the amount of emissions that would be released as a result of the source or activity with implementation

[2] The reduction percentage is denoted as a positive value when specified in text or in tables as a "reduction," and is denoted as a negative value when calculated in equations.

of the measure (e.g., the reduction in water sector GHG emissions achieved from using reclaimed water). GHGs evaluated in this Handbook include carbon dioxide (CO_2), CH_4, nitrous oxide, and commonly used refrigerants. All GHG reductions are expressed in metric tons (MT) of carbon dioxide equivalents (CO_2e), where individual GHGs that would be reduced by a measure are converted to CO_2e by multiplying emissions by their GWP. GWP represent a ratio of the heat trapping characteristic of a gas compared to CO_2, which has a GWP of 1. This Handbook primarily uses GWPs from the Intergovernmental Panel on Climate Change's (IPCC)(2007) Fourth Assessment Report, consistent with statewide GHG emissions reporting protocol.[3] Users are encouraged to consult the latest IPCC assessment report and CARB statewide inventory guidance available at the time of their analysis to determine if alternative GWPs should be used. For commonly used refrigerants, GWPs were obtained from the IPCC's Fourth Assessment Report and databases from CARB and the World Meteorological Organization.

Measures presented in this chapter address those reductions over which a user can exercise direct control, as well as indirect emissions associated with electrical generation and the use of natural gas.

Quantification Accuracy and Reliability

IPCC (2006) defines *good practices* for GHG emissions quantification as those that "contain neither over- nor underestimates so far as can be judged, and in which uncertainties are reduced as far as practicable." Part of the challenge in developing methods that meet this standard of good practice is assuring the accuracy of the methods. This Handbook defines *accuracy* as the closeness of the agreement between the result of a measurement or calculation and the true value, or a generally accepted reference value. When a method is accurate, it will, for a particular case, produce a quantification of emissions that is as close to the actual emissions as can practicably be done with information that is reasonably available.

Quantification methods that meet the standard of good practice must also be *reliable*, which is different from being accurate. A reliable method will yield accurate results across a range of different cases, not only in one case. In some cases, the accuracy of quantification may be sacrificed to achieve reliability. This is because a method that can be applied across a range of scenarios must be generalized to some extent. For example, methods for transportation sector measures do not, for the most part, differentiate between peak and off-peak vehicle trips, even though off-peak trips will have a lower emission impact because of the effects of congestion on travel time and engine performance. To fully address all the factors that affect the emissions associated with vehicle trips for a specific project, a far more detailed analysis would be needed, and it would not be readily applied to other situations. The methods contained in this Handbook

[3] The Handbook uses the IPCC's (2007) Fourth Assessment Report because CARB currently (as of 2021) calculates CO_2e values for the statewide GHG inventory using GWPs from this report. GWPs are regularly reassessed by the IPCC, which published updated GWPs in their Fifth Assessment Report (IPCC 2014).

have been developed to provide the best balance between accuracy and reliability, because accessibility and ease of use is an important consideration.

The quantification methods included in this Handbook will only be accurate to the degree that a project adheres to the assumptions, limitations, and other criteria specified for a given measure. Most of the quantification methods provide default assumptions for user consideration. The default values are based on the most up-to-date regional-, state-, or national-level data and may not be appropriate for all projects. Accordingly, it is recommended that defaults only be used if they adequately reflect analysis conditions, and no local or project-specific information is available. When a range of effectiveness may be quantified for a specific measure depending on defaults, this Handbook often presents those defaults that would yield the lower end of reductions to avoid overstating potential measure benefits. Where defaults are not available for a specific assumption, data must be provided by the user for the calculations to be valid. The quality of the data provided by the user will substantially affect the quality of the results achieved. Data supplied by the user could be a rough estimate, based on a small, onetime sample, or derived through a full project-specific study. Using a rough estimate for any of the data inputs will yield results that are less accurate than if higher quality data inputs are provided.

Users are encouraged to consider the intended use of the quantification, to make sure that the results achieved will be sufficiently rigorous to support the conclusions drawn from them. When quantification is performed for CEQA or other regulatory compliance, it is recommended that project-specific data be as robust as possible. Approximations and unsubstantiated numbers are discouraged. Moreover, it is strongly recommended that the source(s) and/or basis of all project-specific data supplied by the user be clearly identified in the analysis and the limitations of the data be discussed.

Measure Scales

GHG reduction measures can be applied at different scales or geographic levels. Some measures may only be applicable at the project-level, whereas others may be more appropriate within a broader planning context, such as for a general plan or climate action plan. Geographic levels considered in this Handbook include the Project/Site and Plan/Community. Project/Site refers to measures that reduce emissions at the scale of a parcel, employer, or development project. Plan/Community refers to measures that reduce emissions at the scale of a neighborhood (e.g., specific plan, general plan, climate action plan), corridor, or entire municipality (e.g., city- or county-level).

The transportation measures can be quantified at either the Project/Site scale or the Plan/Community scale, but never both. While some of the transportation measures could be implemented at both scales in practice, the quantification methods presented in this Handbook are limited to only the scale for which there is literature to defensibly support emissions quantification. For example, a bike-sharing program could be implemented at the Project/Site scale for employees to use at a business park, and it could be implemented at the Plan/Community scale by a municipality in their downtown district. However, there is limited defensible research on the GHG reductions associated with small scale, site-specific bike-share programs. Therefore, only the Plan/Community scale version of this measure is quantified in this Handbook. The *Transportation* section notes each instance in which a transportation measure could be implemented at a scale for which this document does not provide a quantification method.

Some non-transportation measures can be quantified at both the Project/Site scale and the Plan/Community scale. For example, a multi-family development at the Project/Site scale may construct homes without wood-burning devices, while a specific plan for new single-family housing at the Plan/Community scale could require that all future homes prohibit wood-burning devices. The quantification method for this measure would be the same, regardless of the scale of application.

Combining Measure Reductions

When quantifying measures, it is important to be mindful of potential interactions among different measures. Often, combining measures can lead to better emission reductions than implementing a single measure by itself. For example, for Measure LL-1, *Replace Gas Powered Landscape Equipment with Zero-Emission Landscape Equipment*, to succeed, electrical outlets on the exterior of buildings should be accessible so that the electric landscaping equipment can be charged. Measure LL-3, *Electric Yard Equipment Compatibility,* should, therefore, be considered as a supporting action to equipment electrification. Where appropriate, these synergistic relationships are noted within the individual measure quantification methods. However, the compounding effect of combining these select measures is not quantified in this Handbook.

Unfortunately, the effects of combining some measures are not always beneficial, linear, complementary, or accurate. There are two primary reasons for this. The first reason is that there may be diminishing returns when certain measures are implemented together to reduce a particular source of emissions. For example, there may be six measures to increase ridership on a public transit line, any one of which might increase transit ridership by 20 percent. But implementing all these measures will not necessarily increase ridership by 120 percent. In fact, for each successive measure applied, it is likely that a lesser effect will be observed. The second reason is that there may be competition between measures. For example, a campaign to increase ridership on a commuter rail line may be implemented while a new public transit bus line is established with overlapping service areas. Although the ridership campaign might be expected to cause 5 percent of drivers to switch to rail, some of those potential new riders might use the new bus service instead, making the ridership campaign less effective. At the same time, the new bus line might also be expected to reduce vehicle trips by 5 percent, but the actual reduction may be lower if some of the ridership comes from rail passengers. Together, the ridership campaign for the rail line and the new bus line may only reduce vehicle trips by 7 percent, and not the 10 percent predicted from summing the estimates of their independent effectiveness.

Where appropriate, guidance for combining measure reductions is provided within the introductions to each sector. Likewise, the quantification methods for each measure identify any applicable calculation maximums.

Combining Sector Reductions

The following procedures must be followed when combining measures among the nine sectors where the GHG reduction achieved by individual measures is calculated as a percentage of emissions from a given source or activity. Specifically, the relative magnitude of emissions between sectors must be considered. Users should first determine the percent contribution made by each individual sector to the overall project GHG emissions. This percent contribution by a sector should then be multiplied by the reduction percentages from measures in that sector to determine the scaled GHG emission reductions. This should be done for each sector to be combined. The scaled GHG emissions for each sector can then be added together to give a total GHG reduction for the combined measures in all sectors.

For example, consider a project with total GHG emissions that come from the following sectors: transportation (50 percent), building energy use (40 percent), water (6 percent), and solid waste (4 percent). This project implements transportation measures that result in a 10 percent reduction in VMT. The project also implements measures that result in a combined 30 percent reduction in water usage. The overall reduction in GHG emissions is calculated in the below example.

$$\%\ \text{Reduction}_{\text{Transport}} = 50\%\ \text{total emissions} \times 10\%\ \text{sector reduction} = 5\%\ \text{total reduction}$$

$$\%\ \text{Reduction}_{\text{Water}} = 6\%\ \text{total emissions} \times 30\%\ \text{sector reduction} = 1.8\%\ \text{total reduction}$$

$$\%\ \text{Reduction}_{\text{Total}} = 5\% + 1.8\% = 6.8\%\ \text{total reduction}$$

As discussed above, GHG reductions for some measures in this Handbook are expressed in terms of the absolute MT CO_2e that would be reduced. Reductions from these measures should be combined following the same approach as shown above. However, rather than multiplying percentages, users can simply subtract the expected reductions from the sector emissions.

Users may need to combine sector reductions that are a product of measures where reductions are given as both percentages and absolute values. This can be achieved by modifying the above equations to include actual project emissions. The following equations extend the above project example to include a 10 MT CO_2e reduction achieved by waste sector measures. Uncontrolled project emissions are assumed to be 2,000 MT CO_2e.

$$\begin{aligned}\text{Absolute Reduction}_{\text{Transport}} &= 2{,}000\ \text{MT}\ CO_2e \times 50\%\ \text{total emissions} \times 10\%\ \text{sector reduction} \\ &= 100\ \text{MT}\ CO_2e\ \text{reduction}\end{aligned}$$

$$\begin{aligned}\text{Absolute Reduction}_{\text{Water}} &= 2{,}000\ \text{MT}\ CO_2e \times 6\%\ \text{total emissions} \times 30\%\ \text{sector reduction} \\ &= 36\ \text{MT}\ CO_2e\ \text{reduction}\end{aligned}$$

$$\text{Absolute Reduction}_{\text{Waste}} = 10\ \text{MT}\ CO_2e$$

$$\text{Absolute Reduction}_{\text{Total}} = 100\ \text{MT}\ CO_2e + 36\ \text{MT}\ CO_2e + 10\ \text{MT}\ CO_2e = 146\ \text{MT}\ CO_2e$$

Limitations and Uncertainty

There are uncertainties associated with any type of estimation method. It is important to understand the limitations to properly apply the quantification methods presented in this Handbook. The following briefly discusses key limitations for user awareness and consideration.

Combination of Data Sources

Developing quantification methods for some of the measures required the use of multiple sources of data. Any time data are derived from different sources, there may be slight discrepancies in the underlying methodologies and data. When the information between two data sets is combined, the discrepancies may affect the ultimate quantification of emissions, either over- or underestimating them. It is not possible to determine the precise magnitude of error that combining data sets induces in the final quantification; however, every effort has been made to minimize potential errors through thorough review of available data and exclusion of incompatible data sets.

Level of Detail for Underlying Assumptions

Many of the calculations require users to input project-specific data or assumptions. Certain information about a project may not be known to the user and must be either estimated or assumed based on standard procedures. Likewise, users may rely on the available defaults provided in the Handbook to enable emissions quantification of applicable measures. While defaults provided in this Handbook are based on credible sources for use in emissions quantification, they are often based on historical regional, state, and national-level data and may produce an inaccurate representation of project-specific conditions or lead to an overestimate or underestimate of associated emissions. This limitation can be minimized to the extent the user can provide better quality data.

Use of Case Studies

Case studies generally have detailed information on reductions that may be achieved in practice by a measure. While these studies provide valuable insight that can support measure quantification, there may be features or characteristics in the case study that do not translate to a specific project and, therefore, may over- or underestimate the GHG emission reductions. Where case studies were used, they were carefully reviewed to ensure the study methods and data meet the quality requirements of this Handbook.

Prediction of Future Behavior

Some of these methods predict future behavior (e.g., water use and energy consumption) using historical data and trends. Although this is a commonly accepted practice, current behavior is not likely to remain constant over time due to technological improvements and increasing awareness of resource conservation. This limitation can be minimized to the extent the user can provide better quality data.

Combining Multiple Measures

Projects may involve the application of more than one measure. As discussed above, combining measures can have an additive effect on GHG reductions, or result in diminishing returns. This limitation is minimized through the establishment of sector and measure reduction caps, as described within the individual measure methods, as applicable. However, users should still exercise good judgement when selecting measures to ensure that the resulting quantification is appropriate and accurate.

Exclusion of Lifecycle and Biogenic CO_2 Emissions

Except for solid waste measures and certain measures in the energy, refrigerants and transportation sectors, the quantification methods do not include analysis of full lifecycle emissions, which are those that are emitted from the energy and resources used throughout the lifecycle of a product or material. Lifecycle emissions include the extraction of raw resources, physical distribution, use of the product or material, and disposal at the end of a product's life. It is challenging to quantify these lifecycle emissions because identifying all the inputs that are necessary, especially for a generalized guidance document such as this Handbook, is infeasible. Because of these difficulties, lifecycle considerations are only included in the quantitative methods for those measures that cannot be quantified without a lifecycle analysis. The *Transportation*, *Energy*, *Solid Waste*, and *Refrigerants* sections discuss lifecycle considerations specific to those sectors. For all other measures, the quantification methods do not include analysis of full lifecycle emissions.

Except for Measure E-14, *Limit Wood Burning Devices and Natural Gas/Propane Fireplaces in Residential Development*, the methods do not address biogenic CO_2 emissions. Biogenic CO_2 emissions result from materials that are derived from living cells, as opposed to CO_2 emissions derived from fossil fuels, limestone, and other materials that have been transformed by geological processes. Biogenic CO_2 contains carbon that is present in organic materials, including wood, paper, vegetable oils, animal fat, and waste from food, animals, and vegetation (such as yard or forest waste). Biogenic CO_2 emissions are excluded from these GHG emissions quantification methods because they are the result of materials in the biological/physical carbon cycle, rather than the geological or anthropogenic carbon cycle.

Extent Reductions are Achieved in Practice

The reduction methods presented in this Handbook are based on specific underlying data and assumptions for how each measure should be implemented. The quantification methods will yield the most accurate and reliable results when the user adheres to all implementation requirements described in this Handbook. In practice, there is likely to be a wide range of how individual measures are implemented given project-specific considerations, such as cost to implement the measure, physical constraints, availability of technology, and regulatory restrictions.

GHG Reduction Measure Factsheets and Quantification Methods

Anatomy of the Factsheets

All quantified GHG reduction measures in this Handbook include a one-page measure factsheet. The factsheet highlights important considerations for each measure. They describe the measure, locational context, scale of application, implementation requirements, cost considerations, and options to expand measure effectiveness. The factsheets also show key measure indicators, such as the GHG reduction potential, co-benefits, and considerations for climate resilience and health and equity. Where available, the GHG reduction potential is provided as the estimated maximum percent reduction in emissions. For those measures where GHG reductions are calculated as absolute emissions, the GHG reduction potential is identified as small, moderate, large, or varies. This qualitative ranking characterizes the estimated quantity of reductions relative to the magnitude of emissions generated by the source. For example, Measure E-15, *Require All-Electric Development*, has the potential for a large reduction in GHG emissions from building energy use if all end uses are electrified and the local utility provides zero-carbon electricity. It's important to note that, while this measure could achieve a "large" reduction in building energy emissions, the overall reduction in project emissions could be small if building energy emissions are only a fraction of the project total.

Figure 3-2 illustrates the factsheet layout and annotates key content.

Figure 3-2. Annotated Outline of the Measure Factsheet

Each measure is numbered alphanumerically with the first letter of the emissions sector serving as the letter code (e.g., E = Energy).

Each measure includes a descriptive title

T-25. Extend Transit Network Coverage or Hours

GHG Mitigation Potential — Provides an overview of each measure's reduction potential.

4.6%

Up to 4.6% of GHG emissions from vehicle travel in the plan/community

Co-Benefits (icon key on pg. 34) — Identifies benefits that may be achieved by the measure.

Climate Resilience — Considerations relevant to climate risk reduction.

Increasing transit network coverage or hours improves the reliability of the transportation network and allows redundancy to exist even if an extreme event disrupts part of the system. They could also incentivize more people to use transit, resulting in less traffic and better allowing emergency responders to access a hazard site during an extreme weather event.

Health and Equity Considerations — Considerations relevant to health and equity.

This measure increases access to social, educational, and employment opportunities. Expansion of transit networks need to ensure equitable access by all communities to the transit system.

Measure Description — Summarizes the measure at a high level and explains how the measure reduces GHG.

This measure will expand the local transit network by either adding or modifying existing transit service or extending the operation hours to enhance the service near the project site. Starting services earlier in the morning and/or extending services to late-night hours can accommodate the commuting times of alternative-shift workers. This will encourage the use of transit and therefore reduce VMT and associated GHG emissions.

Subsector — Identifies the measure subsector (Transportation and Energy sector measures only).

Transit

Locational Context — Outlines considerations for measure implementation and application that are locationally relevant (Transportation sector measures only).

Urban, suburban

Scale of Application — Identifies whether the measure is applicable at the Project/Site, Plan/Community, or both.

Plan/Community

Implementation Requirements — Provides key implementation requirements that must be met to achieve the cited GHG reductions.

There are two primary means of expanding the transit network: by increasing the frequency of service, thereby reducing average wait times and increasing convenience, or by extending service to cover new areas and times.

Cost Considerations — Considerations relevant to measure costs and savings.

Infrastructure costs for extending the physical network coverage of a transit system can be significant. Costs to expand of track-dependent transit, such as light rail and passenger rail, are high and can require resource- and time-intensive advanced planning. Costs to expand vehicle-dependent transit, such as busses, are likewise high but may be limited to procurement of additional vehicles. Any expansion of transit, including just service hours, would increase staffing and potentially maintenance costs. A portion of these costs may be offset by increased transit usage and associated income. Commuters who may more easily be able to travel without a car may also observe cost savings from reduce vehicle usage or ownership.

Expanded Mitigation Options — Shows potential variations for how a measure could be implemented to achieve additional reductions or co-benefits.

This measure is focused on providing additional transit network coverage, with no changes to transit frequency. This measure can be paired with Measure T-26, *Increase Transit Service Frequency*, which is focused on increasing transit service frequency, for increased reductions.

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Following each measure's factsheet is the measure's quantification method. Accurate and reliable quantification of GHG reduction measures depends on properly identifying and understanding the important variables that affect the emissions from a source or activity. A consistent framework and presentation are used for all measure quantification methods to provide a clear summary of quantification variables and usable instructions on appropriate application of the method.

The quantification methodology for each measure is comprised of the mathematical formula(s), summary of all variables used in the formula, explanation of any calculation caps or maximums, an example calculation, and information on quantified co-benefits. The variables in the GHG reduction formula(s) are shown as letters (e.g., A, B) and are defined in the table that immediately follows the equation. The table categorizes variables as outputs, user inputs, or constants, assumptions, and defaults. Bolded variables are required user inputs (i.e., variables for which no defaults are available).

Only those measures with literature to defensibly support emissions quantification are discussed in this Handbook. Examples of credible sources consulted for this Handbook include government agency-sponsored studies, peer-reviewed scientific literature, case studies, government-approved modeling software, and widely adopted protocols. Additional measures for user consideration are presented in *Supporting or Non-Quantified GHG Reduction Measures.* Methods for quantifying these measures have not yet been developed, are not fully supported by available research, or require specific details that are difficult to address under a methodology with general applicability. Users are encouraged to consider including these non-quantified measures into their projects, as described further below.

The measure factsheets and quantification methods follow *Supporting or Non-Quantified GHG Reduction Measures*. As discussed above, measures are grouped into nine emission sectors. Information relevant to the general quantification of all measures within a sector is presented at the introduction of each sector. Users may manually scroll through the factsheets in this chapter or use Figure 3-1 (above) to automatically navigate to a specific measure's factsheet.

Supporting or Non-Quantified GHG Reduction Measures

As a supplement to the GHG reduction measures shown in the factsheets, there are supporting or non-quantified measures that may be of interest to users. Although not quantitatively evaluated in the Handbook, supporting or non-quantified measures may achieve emissions reductions and co-benefits on their own or may enhance the ability of quantified measures to attain expanded reductions and co-benefits. These measures may, therefore, strengthen implementation of a project mitigation strategy or community plan.

Beyond their potential to expand the efficacy of a reduction plan, supporting or non-quantified measures provide users with more options to develop a comprehensive set of mitigation strategies. For example, this section can be used as a resource for expanded CEQA mitigation to identify additional measures that may be feasible and applicable to a specific project. Local governments developing a climate action plan or update to their general plan may also find this section useful as inspiration for new or more comprehensive policies. Many of the measures will achieve co-benefits (e.g., water conservation), in addition to GHG reductions, and may therefore be impactful throughout several elements of a local general plan (e.g., air quality, conservation, environmental justice).

While benefits of supporting or non-quantified measures may not be quantitively captured (or fully captured), the measures can be implemented using many of the same mechanisms as for quantified measures. When identified in a CEQA document, measures can be incorporated into a project's mitigation monitoring and reporting program to ensure that they are implemented and enforced. Cities and counties can update their municipal codes to require measures or certain measure components, which would ensure that the measures are implemented through new development or renovations in existing development. Measures can also be included as a set of best management practices that a local government or project sponsor encourages or incentivizes.

Table 3-1 presents the list of supporting or non-quantified GHG reduction measures. In general, these measures are numbered sequentially to follow the quantified measures within each sector (refer to the measure factsheets at the conclusion of this section). In some cases, formerly non-quantified measures have been moved into the quantified measures list but not renumbered because those measures were found to be quantifiable in newer versions of this Handbook. Thus, the non-quantified measure numbering scheme is not perfectly sequential. The table defines the measure's sector, scale of application, locational context, and likely co-benefits. For simplicity, these measure "descriptors" have been abbreviated in Table 3-1 as follows.

- Shaded rows identify the sector and subsector (in parentheses, where applicable) for each group of measures. For example, "Transportation (Land Use)."
- The scale of application is abbreviated as one of the following:
  - P/S = Project/Site
  - P/C = Plan/Community
  - All = Project/Site and Plan/Community
- For transportation measures, abbreviations for locational context refer to the level of development at the census tract level. The three locational contexts identified in the Handbook are suburban (S), urban (U), and rural (R). Most transportation measures are applicable to development within at least one of these three locational context areas.

  The three locational contexts were developed from the eight neighborhood types described in *Quantifying the Effect of Local Government Actions on VMT* (Salon 2014), as summarized below.
  - S = suburb with multifamily housing; suburb with single-family homes
  - U = urban low transit; central city urban; urban high transit
  - R = rural; rural-in-urban

- Remaining columns identify co-benefits that may be achieved by the measure where:
  - ●= may be achieved by the measure
  - ⦿= may be achieved by the measure depending on local implementation specifics
  - ○= likely not achieved by the measure

Table 3-2 includes a more detailed description of each non-quantified measure, including equity considerations that lead agencies and project sponsors should review to ensure that measure implementation is as equitable as possible. Users should also refer to Chapter 4, *Assessing Climate Exposures and Measures to Reduce Vulnerabilities*, and Chapter 5, *Measures for Advancing Health and Equity*, for additional context on adaptation and equity that is also relevant to the supporting or non-quantified measures.

LOCATIONAL CONTEXT

The following neighborhoods are provided as representative examples for the three locational context areas.

Suburban — Malibu, Davis, Santee

Urban — Central Berkeley, Downtown Los Angeles, Downtown San Jose

Rural — Coronado, Mather, most of Alpine County

Finally, note that the inclusion of a measure in this section does not preclude it from quantification or indicate that it is impossible to quantify the benefits of the measure. If a user has access to specific data or methods, or if quantification guidance becomes available in the future, then users can quantitatively evaluate measures in those circumstances, if desired.

Table 3-1. Summary of Supporting or Non-Quantified GHG Reduction Measures and Descriptors

#	Measure Title	Scale of Application	Locational Context	Co-Benefits: Improved Air Quality	Energy and Fuel Savings	VMT Reductions	Water Conservation	Enhanced Pedestrian or Traffic Safety	Improved Public Health	Improved Ecosystem Health	Enhanced Energy Security	Enhanced Food Security	Social Equity
Transportation (Land Use)													
T-31-A	Locate Project in Area with High Destination Accessibility	P/S	U, S	●	●	●	○	●	●	○	○	○	⊙
T-31-B	Improve Destination Accessibility in Underserved Areas	P/C	U, S	●	●	●	○	●	●	○	○	○	●
T-32	Orient Project Toward Transit, Bicycle, or Pedestrian Facility	P/S	U, S, R [a], R [b], R [c]	●	●	●	○	●	●	○	○	○	⊙
T-33	Locate Project near Bike Path/Bike Lane	P/S	U, S	●	●	●	○	●	●	○	○	○	⊙
Transportation (Neighborhood Design)													
T-34	Provide Bike Parking	All	All	●	●	●	○	●	●	○	○	○	⊙
T-35	Provide Traffic Calming Measures	P/C	All	●	●	●	○	●	●	○	○	○	⊙
T-36	Create Urban Non-Motorized Zones	P/C	U	●	●	●	○	●	●	○	○	○	⊙
T-37	Dedicate Land for Bike Trails	P/C	All	●	●	●	○	●	●	○	○	○	⊙
Transportation (Trip Reduction Programs)													
T-38	Provide First and Last Mile TNC Incentives	P/C	U, S, R [b]	●	●	●	○	●	●	○	○	○	⊙
T-39	Implement Preferential Parking Permit Program	P/S	U, S	●	●	●	○	●	●	○	○	○	○

				Co-Benefits									
#	Measure Title	Scale of Application	Locational Context	Improved Air Quality	Energy and Fuel Savings	VMT Reductions	Water Conservation	Enhanced Pedestrian or Traffic Safety	Improved Public Health	Improved Ecosystem Health	Enhanced Energy Security	Enhanced Food Security	Social Equity
T-41	Implement a School Pool Program	P/S	All	●	●	●	○	●	●	○	○	○	⦿
T-42	Implement Telecommute and/or Alternative Work Schedule Program	P/S	All	⦿	⦿	⦿	○	⦿	⦿	○	○	○	⦿
Transportation (Transit)													
T-43	Provide Real-Time Transit Information	P/C	All	●	●	●	○	●	●	○	○	○	⦿
T-44	Provide Shuttles (Gas or Electric)	P/S	U, S	●	●	●	○	●	●	○	○	○	⦿
T-45	Provide On-Demand Microtransit	All	U, S	●	●	●	○	●	●	○	○	○	⦿
T-47	Provide Bike Parking Near Transit	P/C	U, S	●	●	●	○	●	●	○	○	○	⦿
Transportation (Parking or Road Pricing/Management)													
T-48	Implement Area or Cordon Pricing	P/C	U	●	●	●	○	●	●	○	○	○	○
T-49	Replace Traffic Controls with Roundabout	P/C	All	●	●	●	○	●	●	○	○	○	○
T-50	Required Project Contributions to Transportation Infrastructure Improvement	P/C	All	●	●	●	○	●	●	○	○	○	○
T-51	Install Park-and-Ride Lots	P/C	S, R	●	●	●	○	●	●	○	○	○	⦿
T-52	Designate Zero Emissions Delivery Zones	P/C	U	●	●	●	○	●	●	○	○	○	⦿

#	Measure Title	Scale of Application	Locational Context	Co-Benefits: Improved Air Quality	Energy and Fuel Savings	VMT Reductions	Water Conservation	Enhanced Pedestrian or Traffic Safety	Improved Public Health	Improved Ecosystem Health	Enhanced Energy Security	Enhanced Food Security	Social Equity
Transportation (Clean Vehicles and Fuels)													
T-53	Electrify Loading Docks	P/S	All	●	●	●	○	○	○	○	●	○	⊙
T-54	Install Hydrogen Fueling Infrastructure	All	—	●	●	○	○	○	●	○	●	○	○
Energy (Energy Efficiency Improvements)													
E-20	Install Whole-House Fans	P/S	—	○	●	○	○	○	○	○	●	○	⊙
E-22	Obtain Third-party HVAC Commissioning and Verification of Energy Savings	P/S	—	○	●	○	○	○	○	○	●	○	⊙
Energy (Renewable Energy Generation)													
E-23	Use Microgrids and Energy Storage	All	—	⊙	●	○	○	○	●	○	●	○	⊙
E-24	Provide Battery Storage	All	—	⊙	●	○	○	○	●	○	●	○	⊙
Energy (Building Decarbonization)													
E-25	Install Electric Heat Pumps	All	—	●	●	○	○	○	●	○	⊙	○	⊙
Lawn and Landscaping													
LL-2	Implement Yard Equipment Exchange Program	P/S	—	●	●	○	○	○	●	●	●	○	⊙
LL-3	Electric Yard Equipment Compatibility	P/S	—	○	○	○	○	○	●	○	○	○	○

				Co-Benefits									
#	Measure Title	Scale of Application	Locational Context	Improved Air Quality	Energy and Fuel Savings	VMT Reductions	Water Conservation	Enhanced Pedestrian or Traffic Safety	Improved Public Health	Improved Ecosystem Health	Enhanced Energy Security	Enhanced Food Security	Social Equity
Solid Waste													
S-4	Recycle Demolished Construction Material	P/S	—	○	●	○	○	○	○	⊙	○	○	○
S-5	Source Wood Materials from Urban Wood Re-Use Program	All	—	○	●	●	●	○	○	●	○	○	○
Natural and Working Lands													
N-5	Establish a Local Farmer's Market	P/C	—	●	●	●	○	●	●	○	○	●	⊙
N-6	Establish Community Gardens	P/C	—	●	○	⊙	○	○	●	●	○	●	⊙
Construction													
C-4	Use Local and Sustainable Building Materials	All	—	○	●	●	○	○	○	⊙	○	○	○
Miscellaneous													
M-4	Require Environmentally Responsible Purchasing	P/S	—	⊙	⊙	○	⊙	○	○	⊙	○	○	○
M-5	Fund Incentives for Green Technologies	P/C	—	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙	⊙

Sector abbreviations: T = transportation; E = energy; W = water; LL = lawn and landscaping; S = solid waste; N = natural and working lands; C = construction; M = miscellaneous.

Scale of application column abbreviations: P/S = Project/Site; P/C = Plan/Community; All.

Locational context column abbreviations: — = non-applicable; R = rural; S = suburban; U = urban. Where applicable, the Handbook provides three land use distinctions within the R locational context category, where R [a] = rural only if the project is in master-planned community; R [b] = rural only if the project is adjacent to commuter a rail station with convenient rail service to a major employment center; R [c] = rural only if there is available transit and the project is close to jobs/services.

Co-benefits columns symbols: ● = may be achieved by the measure; ⊙ = may be achieved by the measure depending on local implementation specifics; ○ = likely not achieved by the measure.

Table 3-2. Description of Supporting or Non-Quantified GHG Reduction Measures

Transportation (Land Use)

T-31-A. Locate Project in Area with High Destination Accessibility

The measure requires development in an area with high accessibility to destinations. Destination accessibility is measured in terms of the number of jobs or other attractions (e.g., schools, supermarkets, and health care services) that are reachable within a given travel time or travel distance and tends to be highest at central locations and lowest at peripheral ones. When destinations are nearby, the travel time between them is less, thus increasing the potential for people to walk and bike to those destinations and, therefore, reducing the vehicle miles traveled (VMT) and associated greenhouse gas (GHG) emissions. As an implementation consideration, projects should consider accessibility by people of all functional abilities and incorporate design principles such as Universal Design.[4] See Measure T-31-B for a variation of this measure.

T-31-B. Improve Destination Accessibility in Underserved Areas

This measure accounts for the VMT reduction that would be achieved by constructing job centers or other attractions (e.g., schools, supermarkets, and health care services) for residents in underserved areas (e.g., food deserts). When destinations are nearby, the travel time between them is less, thus increasing the potential for people to walk and bike to those destinations, reducing VMT and associated GHG emissions. As an implementation consideration, projects should consider accessibility by people of all functional abilities and incorporate design principles such as Universal Design. See Measure T-31-A for a variation of this measure.

T-32. Orient Project Toward Transit, Bicycle, or Pedestrian Facility

This measure requires projects to minimize setback distance between the project and planned or existing transit, bicycle, or pedestrian corridors. A project that is designed around an existing or planned transit, bicycle, or pedestrian corridor encourages sustainable mode use. As an implementation consideration, projects should consider accessibility by people of all functional abilities and incorporate design principles such as Universal Design.

T-33. Locate Project near Bike Path/Bike Lane

This measure requires projects to be located within 0.5-mile bicycling distance to an existing Class I or IV path or Class II bike lane. A project that is designed around an existing or planned bicycle facility encourages sustainable mode use. The project design should include a comparable network that connects the project uses to the existing off-site facilities that connect to work/retail destinations. As an implementation consideration, projects should provide sufficient and convenient bicycle parking and long-term storage, ideally near the bike lane itself, for residents, employees, and visitors, and a bicycle repair station with tools and equipment. This measure can be implemented with Measure T-9.

Transportation (Neighborhood Design)

T-34. Provide Bike Parking

This measure requires projects to provide short-term and long-term bicycle parking facilities to meet peak season maximum demand. Parking can be provided in designated areas or added within rights-of-way, including by replacing parking spaces with bike parking corrals. Ensure that bike parking can be accessed by all, not just project employees or residents.

[4] Universal Design is a concept that is comprised of seven principles that seek to make buildings and infrastructure accessible to all people. Accessibility is achieved by considering and implementing each principle during the design process. A project designed by Universal Design standards would ensure that adjacent transit facilities are accessible to people with diverse abilities, preferences, and language skills.

T-35. Provide Traffic Calming Measures

This measure requires projects to include pedestrian/bicycle safety and traffic calming measures above jurisdictional requirements. Roadways should also be designed to reduce motor vehicle speeds and encourage pedestrian and bicycle trips with traffic calming features. Traffic calming features may include marked crosswalks, count-down signal timers, curb extensions, speed tables, raised crosswalks, raised intersections, median islands, tight corner radii, roundabouts or mini-circles, on-street parking, planter strips with street trees, chicanes/chokers, and others. Providing traffic calming measures encourages people to walk or bike instead of using a vehicle. This mode shift will result in a decrease in vehicle miles traveled. In 2017, 3,904 people were killed and 277,160 injured by vehicle collisions in California; traffic calming can reduce injuries and death, which improves health (State of California et al., 2018). Traffic calming also promotes active transportation, which improves physical health.

T-36. Create Urban Non-Motorized Zones

The measure requires projects to convert a percentage of its roadway miles to transit malls, linear parks, or other non-motorized zones. These features encourage non-motorized travel and thus a reduction in vehicle miles traveled. This measure is only applicable to projects located in urban environments. Consider access issues for paratransit users and those with mobility impairments.

T-37. Dedicate Land for Bike Trails

This measure requires projects to provide for, contribute to, or dedicate land for the provision of off-site bicycle trails linking the project to designated bicycle commuting routes in accordance with an adopted citywide or countywide bikeway plan. Existing desire paths can make good locations, as it represents a community-identified transportation need.

Transportation (Trip Reduction Programs)

T-38. Provide First and Last Mile TNC Incentives

This measure requires a first-last mile partnership between a municipality/transit agency and a transportation network company (TNC) for subsidized, shared TNC rides to or from the local transit station within a specific geographic area. This measure encourages a shift to transit mode for longer trips. Consider providing inclusive mechanisms so people without bank accounts, credit cards, or smart phones can access the incentives.

T-39. Implement Preferential Parking Permit Program

This measure requires projects provide preferential parking in terms of free or reduced parking fees, priority parking, or reserved parking in convenient locations (such as near public transportation or building entrances) for commuters who carpool, vanpool, ride-share or use sustainably fueled vehicles. Projects should also provide wide parking spaces to accommodate vanpool vehicles. Commercial preferential parking can accommodate workers who work non-standard hours by providing opportunities to participate. Residential preferential parking can consider an equitable distribution of permits, giving priority to owners of sustainably fueled vehicles.

T-41. Implement a School Pool Program

This measure requires projects create a ridesharing program for school children. Most school districts provide bussing services to public schools only. School pool helps match parents to transport students to private schools, or to schools where students cannot walk or bike but do not meet the requirements for bussing. A school pool program can help reduce onsite air pollutant emissions at the school by reducing private vehicle trips, especially if the pool vehicle is zero emissions.

T-42. Implement Telecommute and/or Alternative Work Schedule Program

This measure requires projects to permit employee telecommuting and/or alternative work schedules and monitor employee involvement to ensure forecasted participation matches observed participation. While this measure certainly reduces commute-related VMT, recent research has shown that total VMT from telecommuters can exceed VMT from non-telecommuters (Goulias et al. 2020). In addition, telecommuting affects commercial and residential electricity use, complicating the calculation of the net effect and attribution of emissions. More specifically, an office with fewer employees could result in a decrease in the project's energy used to operate equipment and provide space heating and air conditioning. Conversely, an increase in telecommuters using their private homes as workspaces could result in a residential increase in energy for those same end uses and appliances. While this measure is currently not quantified and, according to some studies, could result in total VMT increases and other disbenefits, it is recommended that users review the most recent literature at the time of their project initiation to see if new findings more conclusively support a quantifiable emissions reduction.

Transportation (Transit)

T-43. Provide Real-Time Transit Information

This measure requires projects provide real-time bus/train/ferry arrival time, travel time, alternative routings, or other transit information via electronic message signs, dedicated monitor or interactive electronic displays, websites, or mobile apps. This makes transit service more convenient and may result in a mode shift from auto to transit, which reduces VMT.

T-44. Provide Shuttles (Gas or Electric)

This measure will provide local shuttle service through coordination with the local transit operator or private contractor. The shuttles will provide service to and from commercial centers to nearby transit centers to help with first and last mile connectivity, thereby incentivizing a shift from private vehicles to transit, reducing associated GHG emissions. Electric shuttle vehicles provide a marginally more effective reduction to GHG emissions compared to gas- or diesel-fueled shuttles due to their use of less emissions-intensive electric power. Shuttles that serve only the project residents and/or employees may be seen as increasing gentrification and exclusionary. Consider allowing all people to use the shuttle, regardless of status. Note that this measure can also be implemented at the Project/Site scale by a large employer as part of a Trip Reduction Program.

T-45. Provide On-Demand Microtransit

This measure will provide small-scale, on-demand public transit services that can offer fixed routes and schedules or flexible routes and on-demand scheduling (e.g., Metro Micro) through coordination with the local transit operator or private contractor. Microtransit aims to offer shorter wait times and improved reliability compared to the bus and rail system to further incentivize alternative transportation modes that are less emissions-intensive than private vehicle trips. On-demand rides can be booked using smartphone applications or call centers. Note that this measure may also be applicable at the Project/Site scale for a large employer (e.g., Google's Via2G pilot) as part of a Trip Reduction Program.

T-47. Provide Bike Parking Near Transit

This measure requires the project to provide short-term and long-term bicycle parking near rail stations, transit stops, and freeway access points where there are commuter or rapid bus lines. Include locations for shared micromobility devices as well as higher-security parking for personal bicycles.

Transportation (Parking or Road Pricing/Management)

T-48. Implement Area or Cordon Pricing

This measure requires projects implement a cordon pricing scheme. The pricing scheme will set a cordon (boundary) around a specified area to charge a toll to enter the area by vehicle. The cordon location is usually the boundary of a central business district or urban center but could also apply to substantial development projects with limited points of access. The toll price can be based on a fixed schedule or be dynamic, responding to real-time congestion levels. It is critical to have an existing, high quality transit infrastructure for the implementation of this strategy to reach a significant level of effectiveness. The pricing signals will only cause mode shifts if alternative modes of travel are available and reliable. This measure should provide an exception for low-income residents or workers within the pricing zone.

T-49. Replace Traffic Controls with Roundabout

This measure requires projects install a roundabout as a traffic control device to smooth traffic flow, reduce idling, eliminate bottlenecks, and manage speed. In some cases, roundabouts can improve traffic flow and reduce emissions. The emission reduction depends heavily on what the roundabout is compared to (e.g., uncontrolled intersection, stop sign, traffic signal). Design roundabout so cyclists have the option to join traffic or bypass the roundabout with an adjacent path.

T-50. Required Project Contributions to Transportation Infrastructure Improvement

This measure requires projects contribute to traffic-flow improvements or other multi-modal infrastructure projects that reduce emissions and are not considered as substantially growth inducing. The local transportation agency should be consulted for specific needs. Larger projects may be required to contribute a proportionate share to the development and/or continuation of a regional transit system. Contributions may consist of dedicated right-of-way, capital improvements, or easements. Ensure the jurisdictional fee system does not disadvantage infill projects over greenfield projects.

T-51. Install Park-and-Ride Lots

This measure requires projects install park-and-ride lots near transit stops and high occupancy vehicle lanes. Park-and-ride lots also facilitate car- and vanpooling. Parking lots can also incorporate cool pavements, tree canopy, or solar photovoltaic shade canopies to reduce the urban heat island effect as well as evaporative emissions from parked vehicles and dedicated electric vehicle parking spots and/or charging infrastructure.

T-52. Designate Zero Emissions Delivery Zones

This measure requires the municipality to designate certain curbside locations as commercial loading zones exclusively available for zero-emission commercial delivery vehicles. Doing so replaces tailpipe diesel emissions from last-mile delivery vehicles as well as heavy duty drayage trucks moving goods with less emissions-intensive electric vehicles and potentially micromobility for food and parcel delivery. Locations should be prioritized based on land use density and existing exposure from air pollution.

Transportation (Clean Vehicles and Fuels)

T-53. Electrify Loading Docks

This measure will require that Transport Refrigeration Units and auxiliary power units (APUs) be plugged into the electric grid at the loading dock instead of running on diesel. The indirect GHG emission from electricity generation can partially offset the emissions reduction from fuel reductions. Electrifying loading docks can reduce exposure to air pollutants for workers and drivers.

T-54. Install Hydrogen Fueling Infrastructure

The measure requires projects to implement accessible hydrogen fuel cell fueling infrastructure. Drivers of fuel cell electric vehicles (FCEV), from individual passenger vehicles to haul truck fleets, will be able to refuel using this infrastructure. The expansion of hydrogen fueling locations indirectly supports the uptake of FCEV in place of the typical internal combustion engine vehicle fueled by carbon-emitting gasoline and diesel.

Energy (Energy Efficiency)

E-20. Install Whole-House Fans

This measure requires installation of whole-house fans. Whole-house fans draw cooler outdoor air through open windows, exhaust the warmer air into the attic, and then expel the air outside through attic vents. Whole-house cooling using a whole house fan can substitute for an air conditioner most of the year in most climates, resulting in a reduction in emissions associated with building energy use. Whole-house fans may be inappropriate in locations near sources that generate air pollutants during the evening hours, such as major roads and freeways.

E-22. Obtain Third-party HVAC Commissioning and Verification of Energy Savings

This measure requires third-party review of heating ventilation and air conditioning (HVAC) systems to ensure proper installation and construction of energy reduction features. A user can obtain HVAC commissioning and third-party verification of energy savings in thermal efficiency components including HVAC systems, insulation, windows, and water heating. Note that the 2019 Title 24 Standards requires Home Energy Rating System (HERS) verification for all new low-rise residential building (3 stories or less). Taller residential buildings and non-residential buildings may or may or not require a HERS verification depending on other buildings elements.

Energy (Renewable Energy Generation)

E-23. Use Microgrids and Energy Storage

This measure requires management of a microgrid. Microgrids offer the opportunity to deploy more zero-emission electricity sources, thereby reducing GHG emissions. The microgrid manager (e.g., local energy management system) can balance generation from non-controllable renewable power sources, such as solar, with distributed, controllable generation, such as natural gas-fueled combustion turbines. They can also use energy storage and the batteries in electric vehicles to balance energy distribution and usage within the microgrid. Reliable electricity is vital for public health, especially vulnerable populations and people dependent on medical equipment.

E-24. Provide Battery Storage

This measure requires strategically deployed battery storage. Energy storage has no direct emissions effect. When deployed strategically, energy storage can make the grid more flexible, unlocking renewable energy and reducing GHG emissions. When deployed non-strategically, owners of energy storage assets are more likely to charge their facilities during off-peak periods when power prices are lower, in order to supply power during more expensive peak hours. Off-peak generation times such as nighttime hours are more likely to be dominated by conventional power sources, which, with the exception of nuclear and hydropower, are likely to be more emissions-intensive (Bistline and Young 2020). In California, the value of energy storage stems primarily from its ability to reduce renewable curtailment, thereby displacing fossil-fueled generation (Arbabzadeh et al. 2019). While this measure is currently not quantified and, according to some studies, could result in regional GHG and criteria pollutant emissions increases, it is recommended that users (1) review the most recent literature at the time of their project initiation and (2) evaluate any changes in policy or market for renewable energy to see if new findings more conclusively support a quantifiable emissions reduction.

Energy (Building Decarbonization)

E-25. Install Electric Heat Pumps

This measure requires installation of electric heat pumps as alternatives to conventional furnaces or air conditioners. Electric heat pumps use electricity to transfer heat between cool and warm spaces to either provide cooling or heating. When cooling is needed during the summer months, the pumps move warmer inside air to outside. The pumps operate in reverse during the winter, moving warmer outdoor air into the building to provide heat. Because heat pumps move warm air instead of generating heat, they are more efficient than conventional heating and cooling systems. When electric heat pumps replace fossil-fuel heating or cooling sources, they achieve a dual efficiency and decarbonization benefit. The most common types of heat pumps collect heat from the air (are air-to-air), water (water-to-air), or ground (geothermal-to-air). The performance and emissions reductions achieved by electric heat pumps depend heavily on the system type, cooling and heating loads, climate zone, season, and other project-specific variables.

Lawn and Landscaping

LL-2. Implement Yard Equipment Exchange Program

This measure requires the project to participate in an established yard equipment exchange program, supplement an established program, or implement a new program. When conventional gasoline-powered yard equipment (e.g., lawn mowers, leaf blowers and vacuums, shredders, trimmers, and chain saw) are exchanged for electric and rechargeable battery-powered yard equipment, direct GHG emissions from fossil-fuel combustion are displaced by indirect GHG emissions associated with the generation of electricity used to power the equipment. Commercial users of yard equipment should be targeted for this measure given their comparatively low adoption rate of electric yard equipment relative to residential users. If the specific equipment being replaced through the program is known, reductions may be quantified using the method described under Measure LL-1.

LL-3. Electric Yard Equipment Compatibility

This measure requires projects to provide electrical outlets on the exterior of buildings as necessary for sufficient powering of electric lawnmowers and other landscaping equipment. For Measures LL-1 and LL-2 to be successfully implemented, electrical outlets on the exterior of buildings must be accessible so that the electric landscaping equipment can be charged.

Solid Waste

S-4. Recycle Demolished Construction Material

This measure requires recycling of construction waste. Recycling demolished construction material reduces GHGs by displacing new construction materials, thereby reducing the need for new raw material acquisition and manufacturing. If the process of recycling construction materials is less carbon-intensive than the processes required to harvest and produce new construction materials, recycling results in a net reduction in GHG emissions. Using local recycled construction material would also reduce emissions associated with the transportation of new construction materials, which are typically manufactured farther away from a project site. Finally, recycling avoids sending materials to landfills. Wood-based materials decompose in landfills and contribute to methane (CH_4) emissions. Ensure onsite processing does not create nuisance issues for nearby residents.

S-5. Source Wood Materials from Urban Wood Re-Use Program

This measure requires projects to source wood materials from urban wood re-use programs. In areas where removed trees are sent to landfills, they decompose and contribute to CH_4 emissions. Wood re-use programs extend a tree's lifetime by converting it into a range of products and prolonging the sequestration benefit. Re-uses range from logs, lumber, woodchips, mulch, compost, biochar, animal fuel, paper products, engineered wood, furniture, and cellulosic ethanol.

Natural and Working Lands

N-5. Establish a Local Farmer's Market

This measure would establish a local farmer's market to provide project residents with a more local source of food, potentially reducing the number of trips and VMT by both consumers and food distribution to grocery stores and supermarkets. If the food sold at the local farmer's market is produced organically, it can also contribute to GHG reductions by displacing carbon-intensive food production practices. Work with local non-profits or foundations to provide Electronic Benefit Transfer (EBT) acceptance at the market, which facilitates access for lower-income populations. The USDA offers resource and guidance for farmer's markets accepting EBT, while some foundations offer multiplier programs, in which $1 of EBT funds becomes a greater value if spent at a farmer's market.

N-6. Establish Community Gardens

This measure would establish a community garden to provide project residents with locally sourced food, potentially reducing the number of trips and VMT by both consumers and food distribution to grocery stores and supermarkets. Community gardens can also contribute to GHG reductions by displacing carbon-intensive food production practices. Work with community residents and community-based organizations to make sure the gardens are designed inclusively and are open to all residents.

Construction

C-4. Use Local and Sustainable Building Materials

This measure requires using building materials that are locally sourced and processed (i.e., close to the project site, as opposed to in another state or country). This reduces VMT and therefore GHG emissions from fuel combustion. Using sustainable building materials, such as recycled concrete or sustainably harvested wood, also reduces GHG emissions due to the less carbon-intensive production process. Unlike measures that reduce GHG emissions during the operational lifetime of a project, using local and sustainable building materials mitigates emissions prior to the actual operational lifetime of a project.

Miscellaneous

M-4. Require Environmentally Responsible Purchasing

This measure requires projects to implement an environmentally responsible purchasing plan. Examples of environmentally responsible purchases include but are not limited to: purchasing products made from recycled materials or with sustainable packaging; purchasing post-consumer recycled paper, paper towels, and stationery; purchasing and stocking communal kitchens with reusable dishes and utensils; choosing sustainable cleaning supplies; purchasing products from restaurants, farms, or ranches that source materials or goods from locations that use soil conservation practices; and leasing equipment from manufacturers who will recycle the components at their end of life. Choosing locally made and distributed products reduces the distance required to transport the products from the distribution or manufacturing center to the project, thus reducing GHG emissions associated with transportation.

M-5. Fund Incentives for Green Technologies

This measure would fund incentives for green technologies. Examples of green technologies include energy-efficient and zero-emission vehicle fleets and off-road equipment, building electrification upgrades, low-flow fixtures in buildings, or energy-efficient stationary sources. The user may choose to contribute to an existing municipal energy fund or establish a new energy fund for the project. Recipients of energy fund grants could include neighborhood developers, home and commercial space builders, homeowners, and utilities. Energy funds allow recipients flexibility in choosing efficiency strategies while still achieving the desired effects of reduced energy use and associated GHG emissions. If coupled with local apprenticeship and job training, this measure can help provide workforce development in green jobs for the local community.

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Transportation

Fossil-fuel powered vehicles are the primary source of GHG emissions within the transportation sector. On-road vehicles traditionally use gasoline and diesel fuel and release emissions based on the amount of fuel combusted and the emission factor of the engine. Cleaner-fueled and electric powered vehicles can also generate GHG emissions, but often at far lower intensities.

Transportation emissions can be reduced by improving the emissions profile of the vehicle fleet or by reducing VMT. Most of the transportation measures quantified in this Handbook aim to reduce VMT and encourage mode shifts from single-occupancy vehicles to shared (e.g., transit) or active modes of transportation (e.g., bicycle). This can be accomplished by coordinating trip reduction or incentive programs; optimizing the land use of the project study area; enhancing road, bike and pedestrian networks; implementing parking policies; or improving transit systems.

WHAT'S ELASTICITY?

Elasticity refers to how much one variable changes, relative to a change in another variable. For example, the elasticity of a VMT reduction measure would measure how much VMT is reduced in proportion to the increase in bicycle lanes.

Most of the emission reductions are determined by evaluating the *elasticity* of a measure relative to the amount of VMT that may be reduced by the measure. A few transportation measures are aimed at improving the emissions profile of the vehicle fleet. These measures promote alternative fuels and vehicle types. The emission reductions from these measures are based on the improved emission factors and on changes to the assumed vehicle fleet mix.

This section provides guidance for combining emission reductions from transportation measures and adjusting VMT reductions to expected GHG savings. The measure factsheets and quantification methods for individual measures follow. Use the graphic on the following page to click on an individual measure to navigate directly to the measure's factsheet.

Selecting and Combining Transportation Measures

Depending on how VMT has been quantified for a project or program, users should exercise caution when selecting transportation measures to avoid double counting VMT benefits that may already be accounted for in the model used to produce the unmitigated or baseline VMT estimate. For example, regional travel demand models are generally sensitive to built environment and transit service variables (e.g., density, proximity to transit). VMT estimates developed for a project or program that use such models may, therefore, already account for VMT reductions associated with certain measures in this Handbook (e.g., T-1, *Increase Residential Density*).

Interactions between transportation measures are complex and sometimes counterintuitive, whereby combining measures can have a substantive impact on reported emission reductions. To safeguard the accuracy and reliability of the methods, while maintaining their ease of use, the following rules should be followed when combining reductions achieved by transportation measures.

Transportation

LAND USE

- T-1. Increase Residential Density
- T-2. Increase Job Density
- T-3. Provide Transit-Oriented Development
- T-4. Integrate Affordable and Below Market Rate Housing
- T-17. Improve Street Connectivity
- T-55. Infill Development

TRIP REDUCTION PROGRAMS

- T-5. Implement Commute Trip Reduction Program (Voluntary)
- T-6. Implement Commute Trip Reduction Program (Mandatory Implementation and Monitoring)
- T-7. Implement Commute Trip Reduction Marketing
- T-8. Provide Ridesharing Program
- T-9. Implement Subsidized or Discounted Transit Program
- T-10. Provide End-of-Trip Bicycle Facilities
- T-11. Provide Employer-Sponsored Vanpool
- T-12. Price Workplace Parking
- T-13. Implement Employee Parking Cash-Out
- T-23. Provide Community-Based Travel Planning

PARKING OR ROAD PRICING/MANAGEMENT

- T-14. Provide Electric Vehicle Charging Infrastructure
- T-15. Limit Residential Parking Supply
- T-16. Unbundle Residential Parking Costs from Property Cost
- T-24. Implement Market Price Public Parking (On-Street)

NEIGHBORHOOD DESIGN

- T-18. Provide Pedestrian Network Improvement
- T-19-A. Construct or Improve Bike Facility
- T-19-B. Construct or Improve Bike Boulevard
- T-20. Expand Bikeway Network
- T-21-A. Implement Conventional Carshare Program
- T-21-B. Implement Electric Carshare Program
- T-22-A. Implement Pedal (Non-Electric) Bikeshare Program
- T-22-B. Implement Electric Bikeshare Program
- T-22-C. Implement Scootershare Program
- T-22-D. Transition Conventional to Electric Bikeshare

TRANSIT

- T-25. Extend Transit Network Coverage or Hours
- T-26. Increase Transit Service Frequency
- T-27. Implement Transit-Supportive Roadway Treatments
- T-28. Provide Bus Rapid Transit
- T-29. Reduce Transit Fares
- T-46. Provide Transit Shelters

CLEAN VEHICLES AND FUELS

- T-30. Use Cleaner-Fuel Vehicles

SCHOOL PROGRAMS

- T-40 Establish a School Bus Program
- T-56. Active Modes of Transportation for Youth

Combining Measures Across Scales

The first level of organization for the transportation measures is the scale of application. There are 19 quantified measures at the Project/Site scale that can be combined with each other and 19 quantified measures at the Plan/Community scale that can be combined with each other.[4] *The GHG reductions of transportation measures from different scales of application should never be combined.* While it may be possible that a user's project involves measures that affect vehicle trips or VMT at both scales, it is likely that combining the percent reduction from measures of different scales would not be valid. This rule does not apply to non-transportation measures that calculate the emissions reduction in terms of absolute emissions.

Combining Measures within a Subsector

The second level of organization for the transportations measures is the subsector. Transportation measures are separated into seven subsectors: Land Use, Neighborhood Design, Trip Reduction Programs, Parking Management, Transit, Parking or Road Pricing/Management, Clean Vehicles and Fuels, and School Programs.

Effectiveness levels for multiple measures within a subsector may be multiplied to determine a combined effectiveness level. Because the combination of measures and independence of measures are complicated, this Handbook recommends that measure reductions within a subsector be multiplied unless the user can provide substantial evidence indicating that emission reductions are independent of one another and that they should therefore be added. This will take the following form:

$$\text{Reduction}_{\text{subsector}} = 1 - [(1 - A) \times (1 - B) \times (1 - C)]$$

Where A, B, and C are the individual measure reduction percentages for the measures to be combined in each subsector.

Each measure has a maximum allowable reduction, discussed in the quantification methods for each measure. The user should calculate the reduction from each measure, compare it to the individual measure maximum, and use the lower value of the two in the equation above.

In addition, each subsector has a maximum allowable reduction. These were derived by combining the maximum allowable reduction of each individual non–mutually-exclusive measure within the subsector using the above formula (see table below for more details). The subsector maximum is intended to ensure that emissions are not double counted when measures within the subsector are combined. The subsector maximums are provided in the below table by scale of application.

[4] There is one additional quantified transportation measure: Measure T-30, *Use Cleaner-Fuel Vehicles*. All below discussion related to combining measures and determining maximums does not apply to this measure, which is part of the Clean Vehicles and Fuels subsector.

Scale	Subsector	Quantified Measures [a]	Subsector Maximum [b, c, d, e, f]
P/S	Land Use	5	65%
	Neighborhood Design	—	—
	Trip Reduction Programs	9	45% commute VMT
	Parking or Road Pricing/ Management	3	35%
	Transit	—	—
	School Programs	2	72% school VMT
P/C	Land Use	1	30%
	Neighborhood Design	10	10%
	Trip Reduction Programs	1	2.3% commute VMT
	Parking or Road Pricing/ Management	1	30%
	Transit	6	15%
	School Programs	—	—

P/S = project/site; P/C = plan/community; VMT = vehicle miles traveled.

[a] Excludes Measure T-30, *Use Cleaner-Fuel Vehicles*, within the Clean Vehicles and Fuels subsector and all supporting or non-quantified measures from other subsectors.

[b] — = no measure within the subsector at the specified scale.

[c] Where a subsector consists of only one measure, the subsector maximum listed is the individual measure maximum.

[d] Most maximums were conservatively rounded down to the nearest multiple of five or whole number.

[e] Measure T-1 and Measure T-2 were assumed to be mutually exclusive for the purpose of deriving a project's single land use type maximum emissions reduction. More specifically, residential density (T-1) only applies to residential development, and job density only applies to commercial development (T-2). Similarly, Measure T-26, Measure T-27, and Measure T-46 were assumed to be mutually exclusive with Measure T-28 for the purpose of deriving a plan/community's total transit-related emissions reduction. Measure T-28 accounts for the VMT reduction associated with increased transit frequency (T-26), station improvements like shelters (T-46) and decreased transit travel time from transit supportive roadway treatments (T-27). It was assumed that bus rapid transit (BRT) (T-28) would cover all of the community's transit routes, and therefore no additional frequency, station, or time improvements would be attainable (T-26, T-27, and T-46).

[f] Measures within the Trip Reduction Programs and School Programs primarily reduce VMT from *employee commute* trips and *student commute* trips, respectively, whereas all other measures reduce VMT from *all* trips associated with the relevant land use type.

The user should calculate the reduction from each subsector, compare it to the corresponding sector maximum, and use the lower value of the two.

Combining Measures Across Subsectors

There is limited research directly analyzing the combined VMT impact on a project/site or plan/community from implementation of all, or a majority, of the non–mutually-exclusive transportation sector measures provided in this Handbook. However, a University of California, Davis study compared household VMT across different place types in California and found that the difference in average VMT in single-family suburban neighborhoods and central city neighborhoods was approximately 70 percent.[5] Central city neighborhoods are more likely to have implemented transportation strategies like those measures included in the Handbook, when

[5] Salon, D. 2014. *Quantifying the Effect of Local Government Actions on VMT.* Institute of Transportation Studies, University of California, Davis. Prepared for the California Air Resources Board and the California Environmental Protection Agency. February. Available: https://ww2.arb.ca.gov/sites/default/files/classic/research/apr/past/09-343.pdf. Accessed: October 2021.

compared to suburban neighborhoods. The Handbook therefore adopts 70 percent as a maximum for the combined VMT impact from the following four subsectors: Land Use, Neighborhood Design, Parking or Road Pricing/Management, and Transit.

$$\text{Reduction}_{\text{multi-subsector}} = 1 - [(1 - \text{Land}) \times (1 - \text{Design}) \times (1 - \text{Parking}) \times (1 - \text{Transit})] \leq 70\%$$

Note that this multi-subsector maximum purposefully excludes the Trip Reduction Program subsector. This is because measures in the Trip Reduction Program subsector are often implemented at the Project/Site scale based on the individual employer and are not as directly correlated with place type as the other subsectors. For example, all central city neighborhoods have a high residential and commercial density (i.e., Measure T-1 and Measure T-2 from the Land Use subsector), and most single-family suburban neighborhoods have low density. Conversely, not all employers in a central city neighborhood provide their employees with discounted transit passes (Measure T-9 from the Trip Reduction Program subsector), and the same is equally likely for the much smaller group of employers in a single-family suburban neighborhood.

Limitations of Maximums and Caps

The words *maximum* and *cap* are used interchangeably to describe either the highest percent reduction in GHG emissions or the highest expected value for a variable in the GHG reduction formula. Each subsector has a maximum allowable reduction and individual measures have a maximum allowable reduction, which is often based on one or more of the capped GHG reduction variables. In most instances, these values are a rule of thumb, or practical approximation, to limit the unrealistic influence of multiplicative measure variables. Where the maximum is derived based on a more precise methodology (e.g., research results), the source is cited. Users should always confirm the appropriateness of these maximums for their project.

Adjusting VMT Reductions to Emission Reductions

Most of the transportation measures in this Handbook reduce GHG emissions and criteria pollutants (co-benefit) by reducing the source metric of VMT.[6] The below equation highlights the main variables used to calculate VMT in a study area. Note that VMT decreases if any of the following occurs: (1) vehicle ownership declines, (2) vehicle trips are reduced, (3) vehicle trip lengths are reduced, or (4) any combination of these three variables.

$$\text{VMT} = \frac{\text{vehicles}}{\text{study area}} \times \frac{\text{trips}}{\text{vehicle}\cdot\text{day}} \times \frac{\text{distance (miles)}}{\text{trip}} = \frac{\text{miles}}{\text{study area}\cdot\text{day}}$$

Vehicles emit pollutants during all hours of the day. The magnitude of these emissions varies with the activity phase, such as running on the road, idling while stationary, sitting outside in the sun (evaporative), or starting up. The quantification methods presented in this Handbook account for emissions that occur during the three major emission processes of running, evaporation, and starting.[7]

[6] Exceptions include Measures T-14, *Provide Electric Charging Infrastructure*, and T-30, *Use Cleaner-Fuel Vehicles*.

[7] A fourth emission process is idling. EMFAC estimates idle exhaust emissions only for heavy-duty vehicles that idle for extended periods of time while loading or unloading goods. This document analyzes emissions primarily from passenger vehicles and thus focuses on the three relevant emission processes of evaporation, starting, and running.

Emissions generated by these processes are determined, in part,[8] by the above VMT variables: (1) emissions from evaporation are a factor of vehicle ownership, (2) emissions from starting are a factor of vehicle ownership and number of vehicle starts (i.e., trips), and (3) emissions from running are a factor of vehicle ownership and number of vehicle trips and distance per trip (i.e., VMT).

$$\text{Emissions}_{\text{total}} = \text{Emissions}_{\text{evap}} + \text{Emissions}_{\text{start}} + \text{Emissions}_{\text{run}}$$

$$\text{Emissions}_{\text{evap}} = \frac{\text{vehicles}}{\text{study area}} \times \frac{\text{pollutant mass (grams)}}{\text{vehicle}\cdot\text{day}} = \frac{\text{grams}}{\text{study area}\cdot\text{day}}$$

$$\text{Emissions}_{\text{start}} = \frac{\text{vehicles}}{\text{study area}} \times \frac{\text{trips}}{\text{vehicle}\cdot\text{day}} \times \frac{\text{pollutant mass (grams)}}{\text{trip}\cdot\text{day}} = \frac{\text{grams}}{\text{study area}\cdot\text{day}}$$

$$\text{Emissions}_{\text{run}} = \frac{\text{vehicles}}{\text{study area}} \times \frac{\text{trips}}{\text{vehicle}\cdot\text{day}} \times \frac{\text{miles}}{\text{trip}} \times \frac{\text{pollutant mass (grams)}}{\text{distance (miles)}} = \frac{\text{grams}}{\text{study area}\cdot\text{day}}$$

GHG and criteria pollutant reductions achieved by transportation measures are primarily presented in terms of a percent reduction, where the total emissions reduction was determined based on a ratio comparison to the VMT reduction. In other words, if a measure reduces VMT by some percent, the total emissions are reduced by the same percent (or a fraction of that percent, as described below). As discussed above, VMT can be reduced by decreasing any of the three variables of vehicle ownership, number of vehicle trips, and trip distance. The ratio comparison between reductions in VMT and emissions depends on the pollutant and which VMT variable(s) decrease with implementation of a transportation measure.

1. *Less vehicle ownership*. If a transportation measure reduces VMT by decreasing vehicle ownership, the measure would decrease running, starting, and evaporative emissions by the same rate.[9] The measures where this applies are Measures T-15, *Limit Residential Parking Supply*, and T-16, *Unbundle Residential Parking Costs from Property Cost*, where the VMT reduction is a function of avoided vehicle ownership in residents disincentivized to park offsite or pay the separate cost of parking for a vehicle. For these measures, there is a 1:1 relationship between reductions in VMT and emissions because these measures reduce all emission processes at the same rate, not just running emissions.

2. *Fewer vehicle trips*. If a transportation measure reduces VMT by decreasing the number of vehicle trips, the measure would decrease running emissions and starting emissions by approximately the same rate. This applies to all transportation measures except Measures T-14, *Provide Electric Vehicle Charging Infrastructure;* T-15, *Limit Residential Parking Supply;* T-16, *Unbundle Residential Parking Costs from Property Cost;* and T-30, *Use Cleaner-Fuel Vehicles*. This is because each measure would result in, at minimum,[10] fewer vehicle trips by promoting alternative modes of transportation in place of single-occupancy vehicles.

   These measures would not decrease evaporative emissions, which are a function of vehicle ownership. However, this does not affect the ratio comparison between reductions in VMT and GHG emissions because there are no evaporation GHG emissions (i.e., 100 percent of

[8] Vehicle emissions are also a function of the chosen analysis year, project location, and fleet mix. When using EMFAC, future year emissions decline over time, reflecting assumed changes in fleet mix for the location and cleaner engine and fuel technologies.

[9] Assuming emission factor variables are held constant.

[10] Many of these measures also result in shorter vehicle trips. In these instances, the VMT reduction is either largely a function of the reduction in vehicle trips or is an equal function of the reduction in vehicle trips and the reduction in trip distances. There are no measures where the VMT reduction is largely a function of the reduction in trip distances with a lesser contribution from the reduction in vehicle trips.

CO_2, CH_4, and nitrous oxide (N_2O) from vehicles are from running and starting). This is also true for nitrogen oxides (NOx) particulate matter (PM2.5 and PM10), carbon monoxide (CO), and sulfur dioxide (SOx). Therefore, for these measures and pollutants, there is a 1:1 relationship between reductions in VMT and emissions.

Reactive organic gases (ROG) from vehicles include not only running and starting emissions, but also evaporative emissions.[11] Running and starting ROG emissions represent approximately 87 percent of total ROG emissions in passenger vehicles.[12] This adjustment factor should be applied when converting the percent GHG reduction to the percent reduction in total ROG emission.

$$\% \text{ reduction in ROG emissions} = \% \text{ reduction in GHG} \times 87\%$$

This is noted in the co-benefits section of *Improved Air Quality* for each applicable transportation measure.

3. *Shorter vehicle trips*. If a transportation measure reduces VMT by only decreasing the distance of vehicle trips, the measure would not reduce starting or evaporative emissions. There are no transportation measures in this Handbook where this scenario occurs and, therefore, an adjustment factor is not developed.

The criteria pollutants CO, NO_2, SO_2, and PM are local pollutants that can potentially affect populations near the emissions source. Accordingly, measures that reduce localized criteria pollutant emissions can improve ambient air quality. Measures that reduce emissions of ozone precursors (NOx and ROG), which are regional pollutants, can improve regional air quality.

Note that the Handbook's use of a ratio comparison of VMT reduction to GHG and criteria pollutant reductions makes two key assumptions that may not be valid for every user's project. It is important users consider the validity of these assumptions on a project-by-project basis and either (1) perform any post-processing to the emissions reductions achieved by the transportation measures to better reflect their project conditions, or (2) provide a qualitative disclaimer about the accuracy of the estimated reductions considering the below assumptions.

1. *Vehicle class is assumed to remain unchanged with implementation of a measure*. Say a user is interested in calculating the plan/community-level GHG reduction from Measure T-22-B, *Implement Electric Bikeshare Program*. The user has community-level VMT without the measure and elects to calculate community-wide mobile emissions using EMFAC. The user calculates in EMFAC that the existing percent of the community VMT by vehicle class is 75 percent light-duty vehicles and 25 percent non-light-duty vehicles. In this example, the average emission factor for light-duty vehicles is 250 grams CO_2 per mile and for non–light-duty vehicles is 400 grams CO_2 per mile. The average community emission factor, as weighted by VMT, would be 288 grams per mile [(75% X 250 grams CO_2 per mile) + (25% X 400 grams CO_2 per mile)]. Users then estimate vehicle emissions prior to implementation of Measure T-22-B by applying this average vehicle emission factor to their community-level VMT.

   The user then implements Measure T-22-A, *Implement Pedal (Non-Electric) Bikeshare Program*, and reduces GHG emissions from vehicle travel by 4 percent by replacing vehicle

[11] See *EMFAC2017 User's Guide* for more detail on these emission processes. Available: https://ww3.arb.ca.gov/msei/downloads/emfac2017-volume-i-users-guide.pdf.

[12] Combined emissions from the EMFAC vehicle types of LDA, LDT1, and LDT2.

trips with bikeshare trips. The majority of those replaced vehicle trips are private trips as light-duty vehicles. As a result, the percent of the community VMT by vehicle class is now 70 percent light-duty vehicles and 30 percent non–light-duty vehicles, effectively increasing the community average vehicle emission factor, as weighted by VMT, from 288 grams per mile to 295 grams per mile [70% X 250 grams CO_2 per mile) + (30% X 400 grams CO_2 per mile)]. This increase in the community average vehicle emission factor lessens the GHG reduction that would be achieved from reduced vehicle trips.

Conversely, the circumstances could be such that a measure increases the GHG reduction that would be achieved from reduced vehicle trips. For example, Measure T-22-A may replace existing vehicle trips that are primarily from more emissions-intensive non–light-duty vehicles (e.g., transit buses). In this case, the percent of the community VMT by the less–emissions-intensive light-duty vehicle would be higher, reducing the community average vehicle emission factor. This decrease in the community average vehicle emission factor would increase the GHG reduction that would be achieved from reduced vehicle trips.

The Handbook method cannot predict or know how each measure could affect the user's specific fleet mix. Therefore, the fleet mix is assumed to remain constant before and after implementation of all transportation measures.

2. *Vehicle speeds are assumed to remain unchanged with implementation of a measure*. The logic of this assumption is similar to the first assumption. Say a user is interested in calculating the plan/community-level GHG reduction from Measure T-20, *Expand Bikeway Network*. The user elects to calculate community-wide mobile emissions prior to implementation of the measures using EMFAC and aggregated vehicle speeds. In this example, EMFAC aggregates the vehicle speeds in the user's community at approximately 30 miles per hour (mph).[13] The user implements Measure T-20 and expansion of the bikeway network reduces the average vehicle speed to approximately 25 mph. Because vehicles are slightly more GHG emissions-intensive at 25 mph compared to 30 mph, the GHG reduction achieved by the measure would be less if the impact of vehicle speeds were included in the quantification method.

   Conversely, the circumstances could be such that a measure increases the GHG reduction that would be achieved from reduced vehicle trips. For example, Measure T-11, *Provide Employer-Sponsored Vanpool*, replaces private vehicle trips with shared vanpool trips, reducing the number of cars on the road. If roadways are currently congested and causing vehicles to move at low speeds, implementation of this measure could alleviate roadway congestion and increase vehicle speeds to a speed in which they are less GHG emissions intensive. The decrease in the community average vehicle emission factor would increase the GHG reduction that would be achieved from reduced vehicle trips.

   The Handbook method cannot predict or know how each measure could affect vehicle speeds under the various use cases. Therefore, the vehicle speeds are assumed to remain constant before and after implementation of all transportation measures.

[13] Vehicle running emission factors are, in part, dependent on vehicle speed. Vehicles are generally more emissions-intensive at speeds that are very low (e.g., 5 mph) and very high (e.g., greater than 70 mph), though this varies by pollutant and vehicle class.

Use of Transportation Quantification Methodologies for Senate Bill 375 Compliance

As described in Appendix B, *Federal and State Planning Framework,* Senate Bill (SB) 375 requires metropolitan planning organizations (MPOs) to incorporate a SCS in their regional transportation plans (RTPs) and submit it to the California Air Resources Board (CARB) for review. The goal of the SCS is to reduce regional passenger vehicle VMT and associated GHG emissions through land use and transportation planning. CARB requires MPOs quantify the passenger vehicle VMT reductions achieved by their SCSs using a specific method. It is therefore not recommended that MPOs use the transportation measure quantification methodologies found in this Handbook when preparing their SCSs.

T-1. Increase Residential Density

GHG Mitigation Potential

30%

Up to 30.0% of GHG emissions from project VMT in the study area

Co-Benefits (icon key on pg. 34)

Climate Resilience

Increased density can put people closer to resources they may need to access during an extreme weather event. Increased density can also shorten commutes, decreasing the amount of time people are on the road and exposed to hazards such as extreme heat or flooding.

Health and Equity Considerations

Neighborhoods should include different types of housing to support a variety of household sizes, age ranges, and incomes.

Measure Description

This measure accounts for the VMT reduction achieved by a project that is designed with a higher density of dwelling units (du) compared to the average residential density in the U.S. Increased densities affect the distance people travel and provide greater options for the mode of travel they choose. Increasing residential density results in shorter and fewer trips by single-occupancy vehicles and thus a reduction in GHG emissions. This measure is best quantified when applied to larger developments and developments where the density is somewhat similar to the surrounding area due to the underlying research being founded in data from the neighborhood level.

Subsector

Land Use

Locational Context

Urban, suburban

Scale of Application

Project/Site

Implementation Requirements

This measure is most accurately quantified when applied to larger developments and/or developments where the density is somewhat similar to the surrounding neighborhood.

Cost Considerations

Depending on the location, increasing residential density may increase housing and development costs. However, the costs of providing public services, such as health care, education, policing, and transit, are generally lower in more dense areas where things are closer together. Infrastructure that provides drinking water and electricity also operates more efficiently when the service and transmission area is reduced. Local governments may provide approval streamlining benefits or financial incentives for infill and high-density residential projects.

Expanded Mitigation Options

When paired with Measure T-2, *Increase Job Density*, the cumulative densification from these measures can result in a highly walkable and bikeable area, yielding increased co-benefits in VMT reductions, improved public health, and social equity.

GHG Reduction Formula

$$A = \frac{B - C}{C} \times D$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from project VMT in study area	0–30.0	%	calculated
User Inputs				
B	Residential density of project development	[ ]	du/acre	user input
Constants, Assumptions, and Available Defaults				
C	Residential density of typical development	9.1	du/acre	Ewing et al. 2007
D	Elasticity of VMT with respect to residential density	-0.22	unitless	Stevens 2016

Further explanation of key variables:

- (C) – The residential density of typical development is based on the blended average density of residential development in the U.S. forecasted for 2025. This estimate includes apartments, condominiums, and townhouses, as well as detached single-family housing on both small and large lots. An acre in this context is defined as an acre of developed land, not including streets, school sites, parks, and other undevelopable land. If reductions are being calculated from a specific baseline derived from a travel demand forecasting model, the residential density of the relevant transportation analysis zone should be used instead of the value for a typical development.
- (D) – A meta-regression analysis of five studies that controlled for self-selection found that a 0.22 percent decrease in VMT occurs for every 1 percent increase in residential density (Stevens 2016).

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The percent reduction in GHG emissions (A) is capped at 30 percent. The purpose for the 30 percent cap is to limit the influence of any single built environmental factor (such as density). Projects that implement multiple land use strategies (e.g., density, design, diversity) will show more of a reduction than relying on improvements from a single built environment factor.

Subsector Maximum

($\sum A_{max_{T\text{-}1\ through\ T\text{-}4,\ T\text{-}55}} \leq 65\%$) This measure is in the Land Use subsector. This subcategory includes Measures T-1 through T-4 and T-55. The VMT reduction from the combined implementation of all measures within this subsector is capped at 65 percent.

Example GHG Reduction Quantification

The user reduces VMT by increasing the residential density of the project study area. In this example, the project's residential density would be 15 du per acre (B), which would reduce GHG emissions from project VMT by 14.2 percent.

$$A = \frac{15\ \frac{du}{ac} - 9.1\ \frac{du}{ac}}{9.1\ \frac{du}{ac}} \times -0.22 = -14.2\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

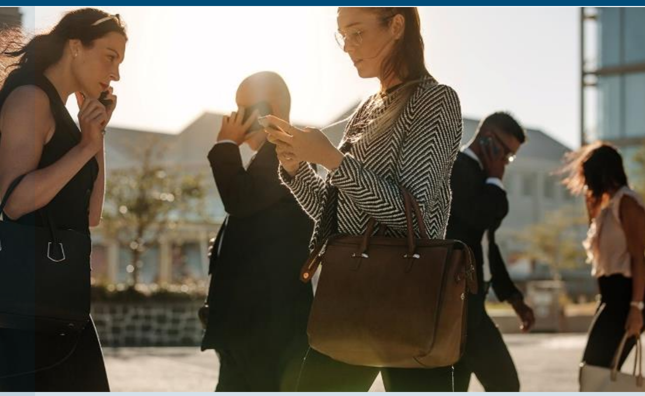
VMT Reductions

The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A).

Sources

- Ewing, R., K. Bartholomew, S. Winkelman, J. Walters, and D. Chen. 2007. *Growing Cooler: The Evidence on Urban Development and Climate Change*. October. Available: https://www.nrdc.org/sites/default/files/cit_07092401a.pdf. Accessed: January 2021.
- Stevens, M. 2016. Does Compact Development Make People Drive Less? *Journal of the American Planning Association* 83:1(7–18), DOI: 10.1080/01944363.2016.1240044. November. Available: https://www.researchgate.net/publication/309890412_Does_Compact_Development_Make_People_Drive_Less. Accessed: January 2021.

T-2. Increase Job Density



GHG Mitigation Potential

30%

Up to 30.0% of GHG emissions from project VMT in the study area

Co-Benefits (icon key on pg. 34)

Climate Resilience

Increased density can put people closer to resources they may need to access during an extreme weather event. Increased density can also shorten commutes, decreasing the amount of time people are on the road and exposed to hazards such as extreme heat or flooding.

Health and Equity Considerations

Increased job density may increase nearby housing prices. Jurisdictions should consider the jobs-housing balance and consider measures to reduce displacement and increase affordable housing.

Measure Description

This measure accounts for the VMT reduction achieved by a project that is designed with a higher density of jobs compared to the average job density in the U.S. Increased densities affect the distance people travel and provide greater options for the mode of travel they choose. Increasing job density results in shorter and fewer trips by single-occupancy vehicles and thus a reduction in GHG emissions.

Subsector

Land Use

Locational Context

Urban, suburban

Scale of Application

Project/Site

Implementation Requirements

This measure is most accurately quantified when applied to larger developments and/or developments where the density is somewhat similar to the surrounding neighborhood.

Cost Considerations

Areas with increased job density generally have higher economic gross metropolitan product (GMP) and job growth. Prosperity, measured as GMP per job, also grows faster in areas with increased job density. Decreased commute times and car use may also generate funds for public transit and reduce the need for infrastructure spending on road maintenance.

Expanded Mitigation Options

When paired with Measure T-1, *Increase Residential Density*, the cumulative densification from these measures can result in a highly walkable and bikeable area, yielding increased co-benefits in VMT reductions, improved public health, and social equity.

GHG Reduction Formula

$$A = \frac{B - C}{C} \times D$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from project VMT in study area	0–30.0	%	calculated
User Inputs				
B	Job density of project development	[ ]	jobs per acre	user input
Constants, Assumptions, and Available Defaults				
C	Job density of typical development	145	jobs per acre	ITE 2020
D	Elasticity of VMT with respect to job density	-0.07	unitless	Stevens 2016

Further explanation of key variables:

- (C) – The jobs density is based on the calculated density of a development with a floor-area ratio of 1.0 and 300 square feet (sf) of building space per employee:

$$\frac{43{,}560\ \frac{sf}{acre}}{300\ \frac{sf}{employee}} \times 1.0\frac{sf}{acre} = 145\frac{employees}{acre}$$

  If reductions are being calculated from a specific baseline derived from a travel demand forecasting model, the job density of the relevant transportation analysis zone should be used for this variable instead of the default value presented above.

- (D) – A meta-regression analysis of two studies that controlled for self-selection found that a 0.07 percent decrease in VMT occurs for every 1 percent increase in job density (Stevens 2016).

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The percent reduction in GHG emissions (A) is capped at 30 percent. The purpose for the 30 percent cap is to limit the influence of any single built environmental factor (such as density). Projects that implement multiple land use strategies (e.g., density, design, diversity) will show more of a reduction than relying on improvements from a single built environment factor.

Subsector Maximum

$(\sum A_{max_{T\text{-}1\text{ through }T\text{-}4,\ T\text{-}55}} \leq 65\%)$ This measure is in the Land Use subsector. This subcategory includes Measures T-1 through T-4 and T-55. The VMT reduction from the combined implementation of all measures within this subsector is capped at 65 percent.

Example GHG Reduction Quantification

The user reduces VMT by increasing the job density of the project study area. In this example, the project's job density would be 400 jobs per acre (B), which would reduce GHG emissions from project VMT by 12.3 percent.

$$A = \frac{400\ \frac{job}{acre} - 145\ \frac{job}{acre}}{145\ \frac{job}{acre}} \times -0.07 = -12.3\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A).

Sources

- Institute of Transportation Engineers (ITE). *Trip Generation Manual.* 10th Edition. Available: https://www.ite.org/technical-resources/topics/trip-and-parking-generation/trip-generation-10th-edition-formats/. Accessed: January 2021.
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T-3. Provide Transit-Oriented Development

GHG Mitigation Potential

31%

Up to 31.0% of GHG emissions from project VMT in study area

Co-Benefits (icon key on pg. 34)

Climate Resilience

Providing TOD puts a large number of people close to reliable public transportation, diversifying their transportation options during an extreme weather event.

Health and Equity Considerations

TOD may increase housing prices, leading to gentrification and displacement. Please refer to the *Accountability and Anti-Displacement and Housing* section in Chapter 5, *Measures for Advancing Health and Equity*, for potential strategies to minimize disruption to existing residents. TOD coupled with affordable housing options can help to support equity by helping to lower transportation costs for residents and increase active mobility.

Measure Description

This measure would reduce project VMT in the study area relative to the same project sited in a non-transit-oriented development (TOD) location. TOD refers to projects built in compact, walkable areas that have easy access to public transit, ideally in a location with a mix of uses, including housing, retail offices, and community facilities. Project site residents, employees, and visitors would have easy access to high-quality public transit, thereby encouraging transit ridership and reducing the number of single-occupancy vehicle trips and associated GHG emissions.

Subsector

Land Use

Locational Context

Urban and suburban. Rural only if adjacent to commuter rail station with convenient rail service to a major employment center.

Scale of Application

Project/Site

Implementation Requirements

To qualify as a TOD, the development must be a residential or office project that is within a 10-minute walk (0.5 mile) of a high frequency transit station (either rail, or bus rapid transit with headways less than 15 minutes). Ideally, the distance should be no more than 0.25 to 0.3 of a mile but could be up to 0.5 mile if the walking route to station can be accessed by pedestrian-friendly routes. Users should confirm "unmitigated" or "baseline" VMT does not already account for reductions from transit proximity.

Cost Considerations

TOD reduces car use and car ownership rates, providing cost savings to residents. It can also increase property values and public transit use rates, providing additional revenue to municipalities, as well as open new markets for business development. Increased transit use will likely necessitate increased spending on maintaining and improving public transit systems, the costs of which may be high.

Expanded Mitigation Options

When building TOD, a best practice is to incorporate bike and pedestrian access into the larger network to increase the likelihood of transit use.

GHG Reduction Formula

$$A = \frac{(B \times C)}{-D}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from project VMT in study area	6.9–31.0	%	calculated
User Inputs				
	None			
Constants, Assumptions, and Available Defaults				
B	Transit mode share in surrounding city	Table T-3.1	%	FHWA 2017a
C	Ratio of transit mode share for TOD area with measure compared to existing transit mode share in surrounding city	4.9	unitless	Lund et al. 2004
D	Auto mode share in surrounding city	Table T-3.1	%	FHWA 2017b

Further explanation of key variables:

- (B and D) – Ideally, the user will calculate transit and auto mode share for a Project/Site at a scale no larger than a census tract. Ideally, variables B and D will reflect travel behavior in locations that are *not* already within 0.5 mile of a high-quality transit stop and may instead substitute data from nearby tracts further from transit if such locations exist. Potential data sources include the U.S. Census, California Household Travel Survey (preferred), or local survey efforts. If the user is not able to provide a project-specific value using one of these data sources, they have the option to input the mode share for one of the six most populated core-based statistical areas (CBSAs) in California, as presented in Table T-3.1 in Appendix C, *Emission Factors and Data Tables*. Transit mode share is likely to be smaller for areas not covered by the listed CBSAs, which represent the most transit-accessible areas of the state. Conversely, auto mode share is likely to be larger.
- (C) – A study of people living in TODs in California found that, on average, transit shares for TOD residents exceed the surrounding city by a factor of 4.9 (Lund et al. 2004).

GHG Calculation Caps or Maximums

Measure Maximum

$((B \times C)_{max})$ The transit mode share in the project study area with the measure is capped at 27 percent. This is based on the weighted average transit commute mode share of five surveyed sites in California where residents lived within 3 miles of rail stations (Lund et al. 2004). As transit mode share is typically higher for commute trips compared to all trips, 27 percent represents a reasonable upper bound for expected transit mode share in a TOD area. Projects in the CBSAs of San Francisco-Oakland-Hayward and San Jose-Sunnyvale-Santa Clara would have their transit mode share capped at 27 percent in the formula.

(A_{max}) For projects that use default CBSA data from Table T-3.1 in Appendix C, the maximum percent reduction in GHG emissions (A) is 31.0 percent. This is based on a project in the CBSA of San Francisco-Oakland-Hayward with a transit mode share that reaches the cap ($(B \times C)_{max}$). This maximum scenario is presented in the below example quantification.

Subsector Maximum

($\sum A_{max_{T\text{-}1 \text{ through } T\text{-}4,\, T\text{-}55}} \leq 65\%$) This measure is in the Land Use subsector. This subcategory includes Measures T-1 through T-4 and T-55. The VMT reduction from the combined implementation of all measures within this subsector is capped at 65 percent.

Example GHG Reduction Quantification

The user reduces VMT by locating their project in a TOD location. Project site residents, employees, and visitors would have easy access to high-quality public transit, thereby encouraging transit use and reducing single occupancy vehicle travel. In this example, the project is within the San Jose-Sunnyvale-Santa Clara CBSA with an existing transit mode share (B) of 6.69 percent. Applying a 4.9 ratio of transit mode share for TOD area with the measure compared to existing transit mode share in the surrounding city yields 33 percent, which exceeds the 27 percent cap ($(B \times C)_{max}$). Therefore, 27 percent is used to define ($B \times C$). The existing vehicle mode share is 86.96 percent (D). The user would reduce GHG emissions from project study area VMT (as compared to the same project in a non-TOD location) by 31 percent.

$$A = \frac{27\%}{-86.96\%} = -31\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A).

Sources

- Federal Highway Administration. 2017a. *National Household Travel Survey–2017 Table Designer. Travel Day PMT by TRPTRANS by HH_CBSA*. Available: https://nhts.ornl.gov/. Accessed: January 2021.
- Federal Highway Administration. 2017b. *National Household Travel Survey – 2017 Table Designer. Average Vehicle Occupancy by HHSTFIPS*. Available: https://nhts.ornl.gov/. Accessed: January 2021.
- Lund, H., R. Cervero, and R. Wilson. 2004. *Travel Characteristics of Transit-Oriented Development in California*. January. Available: https://community-wealth.org/sites/clone.community-wealth.org/files/downloads/report-lund-cerv-wil.pdf. Accessed: January 2021.

T-4. Integrate Affordable and Below Market Rate Housing

GHG Mitigation Potential

28.6%

Up to 28.6% of GHG emissions from project/site multifamily residential VMT

Co-Benefits (icon key on pg. 34)

Climate Resilience

Increasing affordable housing creates the opportunity for a greater diversity of people to be closer to their desired destinations and the resources they may need to access during an extreme weather event. Close proximity to destinations allows for more opportunities to use active transportation and transit and to be less reliant on private vehicles. Alleviating the housing-cost burden also enables more people to remain housed, and increases people's capacity to respond to disruptions, including climate impacts.

Health and Equity Considerations

Neighborhoods should include different types of housing to support a variety of household sizes, age ranges, abilities, and incomes.

Measure Description

This measure requires below market rate (BMR) housing. BMR housing provides greater opportunity for lower income families to live closer to job centers and achieve a jobs/housing match near transit. It is also an important strategy to address the limited availability of affordable housing that might force residents to live far away from jobs or school, requiring longer commutes. The quantification method for this measure accounts for VMT reductions achieved for multifamily residential projects that are deed restricted or otherwise permanently dedicated as affordable housing.

Subsector

Land Use

Locational Context

Urban, suburban

Scale of Application

Project/Site

Implementation Requirements

Multifamily residential units must be permanently dedicated as affordable for lower income families. The California Department of Housing and Community Development (2021) defines lower-income as 80 percent of area median income or below, and affordable housing as costing 30 percent of gross household income or less.

Cost Considerations

Depending on the source of the affordable subsidy, BMR housing may have implications for development costs but would also have the benefit of reducing costs for public services, similar to Measure T-1, *Increase Residential Density*.

Expanded Mitigation Options

Pair with Measure T-1, *Increase Residential Density*, and Measure T-2, *Increase Job Density*, to achieve greater population and employment diversity.

GHG Reduction Formula

A = **B** × C

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from Project/Site VMT for multifamily residential developments	0–28.6	%	calculated
User Inputs				
B	Percent of multifamily units permanently dedicated as affordable	0–100	%	user input
Constants, Assumptions, and Available Defaults				
C	Percent reduction in VMT for qualified units compared to market rate units	-28.6	%	ITE 2021

Further explanation of key variables:

- (B) – This refers to percent of multifamily units in the project that are deed restricted or otherwise permanently dedicated as affordable.
- (C) – The 11th Edition of the *ITE Trip Generation Manual* (ITE 2021) contains daily vehicle trip rates for market rate multifamily housing that is low-rise and not close to transit (ITE code 221) as well as affordable multifamily housing (ITE code 223). While these rates do not account for trip length, they serve as a proxy for the expected difference in vehicle trip generation and VMT generation presuming similar trip lengths for both types of land use. If the user has information about trip length differences between market rate and affordable housing, then adjusting the percent reduction accordingly is recommended.

  Users should note that the ITE trip rate estimates are based on a small sample of studies for the affordable housing rate and that no stratification of affordable housing by number of stories was available. This is an important distinction since the multifamily low-rise vehicle trip rate applies to four or fewer stories. Therefore, this measure may not apply to affordable housing projects with more than four stories.

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The maximum GHG reduction from this measure is 28.6 percent. This maximum scenario is presented in the below example quantification.

Subsector Maximum

($\sum A_{max_{T\text{-}1 \text{ through } T\text{-}4,\ T\text{-}55}} \leq 65\%$) This measure is in the Land Use subsector. This subsector includes Measures T-1 through T-4 and T-55. The VMT reduction from the combined implementation of all measures within this subsector is capped at 65 percent.

Example GHG Reduction Quantification

The user reduces project VMT by requiring a portion of the multifamily residential units to be permanently dedicated as affordable. In this example, the percent of units (B) is 100 percent, which would reduce GHG emissions from VMT by 28.6 percent.

$$A = \mathbf{100\%} \times -28.6\% = -28.6\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A).

Sources

- California Department of Housing and Community Development. 2021. *Income Limits*. Available: https://www.hcd.ca.gov/grants-funding/income-limits/index.shtml#:~:text=%E2%80%9CAffordable%20housing%20cost%E2%80%9D%20for%20lower,of%20gross%20income%2C%20with%20variations. Accessed; November 2021.
- Institute of Transportation Engineers (ITE). 2021. *Trip Generation Manual*. 11th Edition. Available: https://www.ite.org/technical-resources/topics/trip-and-parking-generation/. Accessed; November 2021.

T-5. Implement Commute Trip Reduction Program (Voluntary)

GHG Mitigation Potential

4%

Up to 4.0% of GHG emissions from project/site employee commute VMT

Co-Benefits (icon key on pg. 34)

Climate Resilience

CTR programs could result in less traffic, potentially reducing congestion or delays on major roads during peak AM and PM traffic periods. When this reduction occurs during extreme weather events, it better allows emergency responders to access a hazard site. Lower transportation costs would also increase community resilience by freeing up resources for other purposes.

Health and Equity Considerations

Design of CTR programs need to ensure equitable access and benefits to all employees are provided considering disparate existing mobility options in diverse communities.

Measure Description

This measure will implement a voluntary commute trip reduction (CTR) program with employers. CTR programs discourage single-occupancy vehicle trips and encourage alternative modes of transportation such as carpooling, taking transit, walking, and biking, thereby reducing VMT and GHG emissions. Voluntary implementation elements are described in this measure.

Subsector

Trip Reduction Programs

Locational Context

Urban, suburban

Scale of Application

Project/Site

Implementation Requirements

Voluntary CTR programs must include the following elements to apply the VMT reductions reported in literature.

- Employer-provided services, infrastructure, and incentives for alternative modes such as ridesharing (Measure T-8), discounted transit (Measure T-9), bicycling (Measure T-10), vanpool (Measure T-11), and guaranteed ride home.
- Information, coordination, and marketing for said services, infrastructure, and incentives (Measure T-7).

Cost Considerations

Employer costs may include recurring costs for transit subsidies, capital and maintenance costs for the alternative transportation infrastructure, and labor costs for staff to manage the program. Where the local municipality has a VMT reduction ordinance, costs may include the labor costs for government staff to track the efficacy of the program.

Expanded Mitigation Options

Other strategies may also be included as part of a voluntary CTR program, though they are not included in the VMT reductions reported by literature and thus are not incorporated in the VMT reductions for this measure.

This program typically serves as a complement to the more effective workplace CTR measures such as pricing workplace parking (Measure T-12) or implementing employee parking "cash-out" (Measure T-13).

GHG Reduction Formula

$A = B \times C$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from project/site employee commute VMT	0–4.0	%	calculated
User Inputs				
B	Percent of employees eligible for program	0–100	%	user input
Constants, Assumptions, and Available Defaults				
C	Percent reduction in commute VMT from eligible employees	-4	%	Boarnet et al. 2014

Further explanation of key variables:

- (B) – This refers to the percent of employees that would be able to participate in the program. Employees who might not be able to participate could include those who work nighttime hours when transit and rideshare services are not available or employees who are required to drive to work as part of their job duties. This input does not refer to the percent of employees who participate in the program.
- (C) – A policy brief summarizing the results of employer-based trip reduction studies concluded that these programs reduce total commute VMT for employees at participating work sites by 4 to 6 percent (Boarnet et al. 2014). To be conservative, the low end of the range is cited.

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The maximum GHG reduction from this measure is 4 percent. This maximum scenario is presented in the below example quantification.

Subsector Maximum

($\sum A_{max_{T\text{-}5 \text{ through } T\text{-}13}} \leq 45\%$) This measure is in the Trip Reduction Programs subsector. This subcategory includes Measures T-5 through T-13. The employee commute VMT reduction from the combined implementation of all measures within this subsector is capped at 45 percent.

Mutually Exclusive Measures

If this measure is selected, the user may not also take credit for Measure T-6, which represents the same implementation activities as Measure T-5, except that the CTR program would be mandatory. Users should select either Measure T-5 or T-6.

If this measure is selected, the user may not also take credit for Measures T-7 through T-11. Measure T-5 accounts for the combined GHG reductions achieved by each of these individual measures. To combine the GHG reductions from T-5 with any of these measures would be considered double counting. However, the user may take credit for Measures T-12 through T-13 within the larger CTR subcategory, so long as the combined VMT reduction does not exceed 45 percent, as noted above.

Example GHG Reduction Quantification

The user reduces employee commute VMT by requiring that employers of a project offer a voluntary commute trip reduction program to their employees. In this example, the percent of employees eligible (B) is 100 percent, which would reduce GHG emissions from employee commute VMT by 4 percent.

$$A = \mathbf{100\%} \times -4\% = -4\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A).

Sources

- Boarnet, M., H. Hsu, and S. Handy. 2014. *Impacts of Employer-Based Trip Reduction Programs and Vanpools on Passenger Vehicle Use and Greenhouse Gas Emissions*. September. Available: https://ww2.arb.ca.gov/sites/default/files/2020-06/Impacts_of_Employer-Based_Trip_Reduction_Programs_and_Vanpools_on_Passenger_Vehicle_Use_and_Greenhouse_Gas_Emissions_Policy_Brief.pdf. Accessed: January 2021.

T-6. Implement Commute Trip Reduction Program (Mandatory Implementation and Monitoring)

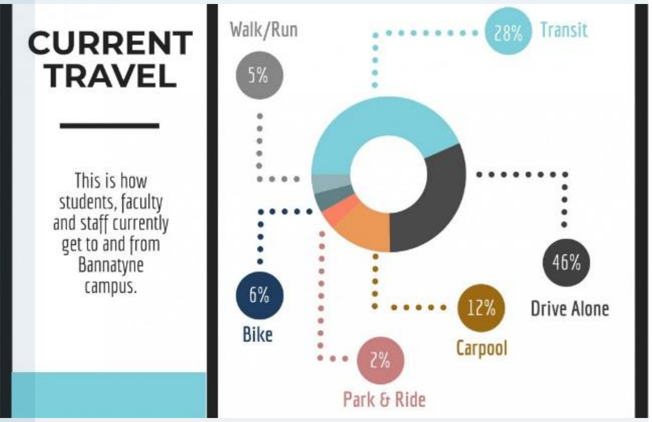


Photo Credit: University of Manitoba, 2018

GHG Mitigation Potential

26%

Up to 26.0% of GHG emissions from project/site employee commute VMT

Co-Benefits (icon key on pg. 34)

Climate Resilience

Commute trip reduction programs could result in less traffic, potentially reducing congestion or delays on major roads during peak AM and PM traffic periods. When this reduction occurs during extreme weather events, it better allows emergency responders to access a hazard site. Lower transportation costs would also increase community resilience by freeing up resources for other purposes.

Health and Equity Considerations

Design of CTR programs needs to consider existing mobility options in diverse communities and ensure equitable access and benefit to all employees.

Measure Description

This measure will implement a mandatory CTR program with employers. CTR programs discourage single-occupancy vehicle trips and encourage alternative modes of transportation such as carpooling, taking transit, walking, and biking, thereby reducing VMT and GHG emissions.

Subsector

Trip Reduction Programs

Locational Context

Urban, suburban

Scale of Application

Project/Site

Implementation Requirements

The mandatory CTR program must include all other elements (i.e., Measures T-7 through T-11) described for the voluntary program (Measure T-5) plus include mandatory trip reduction requirements (including penalties for non-compliance) and regular monitoring and reporting to ensure the calculated VMT reduction matches the observed VMT reduction.

Cost Considerations

Employer costs may include recurring, direct costs for transit subsidies, capital and maintenance costs for alternative transportation infrastructure, and labor costs for staff to manage the program. If the local municipality has a mandatory VMT reduction ordinance, additional employer costs could include non-compliance penalties if the municipality fines CTR programs that do not meet a VMT goal. Municipal costs may include the labor costs for government staff to track the efficacy of the program, which may be outweighed by revenue generated from fines collected from non-compliant businesses.

Expanded Mitigation Options

This program typically serves as a complement to the more effective workplace CTR measures, such as pricing workplace parking (Measure T-12) or implementing employee parking "cash-out" (Measure T-13).

GHG Reduction Formula

$A = B \times C \times D$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from project/site employee commute VMT	0–26.0	%	calculated
User Inputs				
B	Percent of employees eligible for program	0–100	%	user input
Constants, Assumptions, and Available Defaults				
C	Percent reduction in vehicle mode share of employee commute trips	-26	%	Nelson\Nygaard Consulting Associates 2015
D	Adjustment from vehicle mode share to commute VMT	1	unitless	assumed

Further explanation of key variables:

- (B) – This refers to the percent of employees that would be able to participate in the program. This will usually be 100 percent. Employees who might not be able to participate could include those who work nighttime hours when transit and rideshare services are not available or employees who are required to drive to work as part of their job duties. This input does not refer to the percent of employees who participate in the program.
- (C) – A multiyear study of mode share on Genentech's South San Francisco campuses tracked the long-run change in employee commute mode share with implementation of mandatory CTR. Between 2006 and 2014, employee vehicle mode share (includes single-occupied vehicles and carpools) decreased from approximately 90 percent to 64 percent, which is a 26 percent reduction (Nelson\Nygaard Consulting Associates 2015).
- (D) – The adjustment factor from vehicle mode share to commute VMT is 1. This assumes that all vehicle trips will average out to typical trip length. Thus, it can be assumed that a percentage reduction in vehicle trips will equal the same percentage reduction in VMT.

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The maximum GHG reduction from this measure is 26 percent. This maximum scenario is presented in the below example quantification.

Subsector Maximum

($\sum A_{max_{T\text{-}5 \text{ through } T\text{-}13}} \leq 45\%$) This measure is in the Trip Reduction Programs subsector. This subcategory includes Measures T-5 through T-13. The employee commute VMT reduction from the combined implementation of all measures within this subsector is capped at 45 percent.

Mutually Exclusive Measures

If this measure is selected, the user may not also take credit for Measure T-5, which represents the same implementation activities as Measure T-5, except that the CTR program would be mandatory. Users should select either Measure T-5 or T-6.

If this measure is selected, the user may not also take credit for Measures T-7 through T-11. Measure T-6 accounts for the combined GHG reductions achieved by each of these individual measures. To combine the GHG reductions from T-6 with any of these measures would be considered double counting. However, the user may take credit for Measure T-12 and T-13 within the larger CTR subcategory, so long as the combined VMT reduction does not exceed 45 percent, as noted above.

Example GHG Reduction Quantification

The user reduces employee commute VMT by requiring that the employer of the proposed project offer a mandatory CTR program to their employees. In this example, the percent of employees eligible (B) is 100 percent, which would reduce GHG emissions from employee commute VMT by 26 percent.

$A = \mathbf{100\%} \times -26\% \times 1 = -26\%$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A).

Sources

- Nelson/Nygaard Consulting Associates. 2015. *Genentech–South San Francisco Campus TDM and Parking Report*. June. Available: http://ci-ssf-ca.granicus.com/MetaViewer.php?view_id=2&clip_id=859&meta_id=62028. Accessed: January 2021.

T-7. Implement Commute Trip Reduction Marketing

Photo Credit: Sacramento Area Council of Governments, 2012

GHG Mitigation Potential

4%

Up to 4.0% of GHG emissions from project/site employee commute VMT

Co-Benefits (icon key on pg. 34)

Climate Resilience

Commute trip reduction programs could result in less traffic, potentially reducing congestion or delays on major roads during peak AM and PM traffic periods. When this reduction occurs during extreme weather events, it better allows emergency responders to access a hazard site. Lower transportation costs would also increase community resilience by freeing up resources for other purposes.

Health and Equity Considerations

Design of CTR programs needs to consider existing mobility options in diverse communities and ensure equitable access and benefit to all employees. CTR programs may need to include multi-language materials.

Measure Description

This measure will implement a marketing strategy to promote the project site employer's CTR program. Information sharing and marketing promote and educate employees about their travel choices to the employment location beyond driving such as carpooling, taking transit, walking, and biking, thereby reducing VMT and GHG emissions.

Subsector

Trip Reduction Programs

Locational Context

Urban, suburban

Scale of Application

Project/Site

Implementation Requirements

The following features (or similar alternatives) of the marketing strategy are essential for effectiveness.

- Onsite or online commuter information services.
- Employee transportation coordinators.
- Onsite or online transit pass sales.
- Guaranteed ride home service.

Cost Considerations

Employer costs include labor and materials for development and distribution of survey and marketing materials to promote the program and educate potential participants.

Expanded Mitigation Options

This measure could be packaged with other commute trip reduction measures (Measures T-8 through T-13) as a comprehensive CTR program (Measure T-5 or T-6).

GHG Reduction Formula

$A = B \times C \times D$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from project/site employee commute VMT	0–4.0	%	calculated
User Inputs				
B	Percent of employees eligible for program	0–100	%	user input
Constants, Assumptions, and Available Defaults				
C	Percent reduction in employee commute vehicle trips	-4	%	TRB 2010
D	Adjustment from vehicle trips to VMT	1	unitless	assumed

Further explanation of key variables:

- (B) – This refers to the percent of employees that would be able to participate in the program. This will usually be 100 percent. Employees who might not be able to participate could include those who work nighttime hours when transit and rideshare services are not available or employees who are required to drive to work as part of their job duties. This input does not refer to the percent of employees who actually participate in the program.
- (C) – A review of studies measuring the effect of transportation demand management measures on traveler behavior notes that the average empirically-based estimate of reductions in vehicle trips for full-scale, site-specific employer support programs is 4 to 5 percent. To be conservative, the low end of the range is cited (TRB 2010).
- (D) – The adjustment factor from vehicle trips to VMT is 1. This assumes that all vehicle trips will average out to typical trip length ("assumes all trip lengths are equal"). Thus, it can be assumed that a percentage reduction in vehicle trips will equal the same percentage reduction in VMT.

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The maximum GHG reduction from this measure is 4 percent. This maximum scenario is presented in the below example quantification.

Subsector Maximum

($\sum A_{max_{T\text{-}5\text{ through }T\text{-}13}} \leq 45\%$) This measure is in the Trip Reduction Programs subsector. This subcategory includes Measures T-5 through T-13. The employee commute VMT reduction from the combined implementation of all measures within this subsector is capped at 45 percent.

Mutually Exclusive Measures

If this measure is selected, the user may not also take credit for either Measure T-5 or T-6. However, this measure may be implemented alongside other individual CTR measures (Measures T-8 through T-13). The efficacy of individual programs may vary highly based on individual employers and local contexts.

Example GHG Reduction Quantification

The user reduces employee commute VMT by requiring that employers of a project market to employees travel options for modes alternative to single-occupied vehicles. In this example, the percent of employees eligible (B) is 100 percent, which would reduce GHG emissions from employee commute VMT by 4 percent.

$$A = \mathbf{100\%} \times -4\% \times 1 = -4\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A).

Sources

- Transportation Research Board (TRB). 2010. *Traveler Response to Transportation System Changes Handbook, Third Edition: Chapter 19, Employer and Institutional TDM Strategies*. June. Available: http://www.trb.org/Publications/Blurbs/163781.aspx. Accessed: January 2021.

T-8. Provide Ridesharing Program

GHG Mitigation Potential

8%

Up to 8.0% of GHG emissions from project/site employee commute VMT

Co-Benefits (icon key on pg. 34)

Climate Resilience

Ridesharing programs could result in less traffic, potentially reducing congestion or delays on major roads during peak AM and PM traffic periods. When this reduction occurs during extreme weather events, it better allows emergency responders to access a hazard site. Lower transportation costs would also increase community resilience by freeing up resources for other purposes.

Health and Equity Considerations

Program should include all onsite workers, such as contractors, interns, and service workers. Because ridesharing is vehicle-based, and some employees may not be in areas with feasible rideshare networks, design of programs need to ensure equitable benefits to those with and without access to rideshare opportunities.

Measure Description

This measure will implement a ridesharing program and establish a permanent transportation management association with funding requirements for employers. Ridesharing encourages carpooled vehicle trips in place of single-occupied vehicle trips, thereby reducing the number of trips, VMT, and GHG emissions.

Subsector

Trip Reduction Programs

Locational Context

Urban, suburban

Scale of Application

Project/Site

Implementation Requirements

Ridesharing must be promoted through a multifaceted approach. Examples include the following.

- Designating a certain percentage of desirable parking spaces for ridesharing vehicles.
- Designating adequate passenger loading and unloading and waiting areas for ridesharing vehicles.
- Providing an app or website for coordinating rides.

Cost Considerations

Costs of developing, implementing, and maintaining a rideshare program in a way that encourages participation are generally borne by municipalities or employers. The beneficiaries include the program participants saving on commuting costs, the employer reducing onsite parking expenses, and the municipality reducing cars on the road, which leads to lower infrastructure and roadway maintenance costs.

Expanded Mitigation Options

When providing a ridesharing program, a best practice is to establish funding by a non-revocable funding mechanism for employer-provided subsidies. In addition, encourage use of low-emission ridesharing vehicles (e.g., shared Uber Green).

This measure could be paired with any combination of the other commute trip reduction strategies (Measures T-7 through T-13) for increased reductions.

GHG Reduction Formula

$A = B \times C$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from project/site employee commute VMT	0–8.0	%	calculated
User Inputs				
B	Percent of employees eligible for program	0–100	%	user input
Constants, Assumptions, and Available Defaults				
C	Percent reduction in employee commute VMT	Table T-8.1	%	SANDAG 2019

Further explanation of key variables:

- (B) – This refers to the percent of employees that would be able to participate in the program. This will usually be 100 percent. Employees who might not be able to participate could include those who work nighttime hours when transit and rideshare services are not available or employees who are required to drive to work as part of their job duties. This input does not refer to the percent of employees who actually participate in the program.
- (C) – The percent reduction in employee commute VMT by place type is provided in Table T-8.1 in Appendix C. The reduction differs by place type because the willingness and ability to participate in carpooling is higher in urban areas than in suburban areas. Note that this measure is not applicable for implementation in rural areas (SANDAG 2019).

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The maximum GHG reduction from this measure is 8 percent.

Subsector Maximum

($\sum A_{max_{T\text{-}5 \text{ through } T\text{-}13}} \leq 45\%$) This measure is in the Trip Reduction Programs subsector. This subcategory includes Measures T-5 through T-13. The employee commute VMT reduction from the combined implementation of all measures within this subsector is capped at 45 percent.

Mutually Exclusive Measures

If this measure is selected, the user may not also take credit for either Measure T-5 or T-6. However, this measure may be implemented alongside other individual CTR measures (Measures T-7 and T-9 through T-13). The efficacy of individual programs may vary highly based on individual employers and local contexts.

Example GHG Reduction Quantification

The user reduces employee commute VMT by requiring that employers of a project provide a ridesharing program to their employees. In this example, the percent of employees eligible (B) at a packaging and distribution center is 50 percent and the place type of the project is urban (C). GHG emissions from employee commute VMT would be reduced by 4 percent.

$A = \mathbf{50\%} \times -8\% = -4\%$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A).

Sources

- San Diego Association of Governments (SANDAG). 2019. *Mobility Management VMT Reduction Calculator Tool–Design Document.* June. Available: https://www.icommutesd.com/docs/default-source/planning/tool-design-document_final_7-17-19.pdf?sfvrsn=ec39eb3b_2. Accessed: January 2021.

T-9. Implement Subsidized or Discounted Transit Program

GHG Mitigation Potential

5.5 %

Up to 5.5% of emissions from employee/resident vehicles accessing the site

Co-Benefits (icon key on pg. 34)

Climate Resilience

Subsidized and discounted transit programs increase the capacity of low-income populations to use transit to evacuate or access resources during an extreme weather event. They could also incentivize more people to use transit, resulting in less traffic and better allowing emergency responders to access a hazard site during an extreme weather event. Lower overall out-of-pocket costs would also help increase community resilience by freeing up resources for other purposes.

Health and Equity Considerations

Program should include all onsite workers, such as contractors, interns, and service workers.

Measure Description

This measure will provide subsidized or discounted, or free transit passes for employees and/or residents. Reducing the out-of-pocket cost for choosing transit improves the competitiveness of transit against driving, increasing the total number of transit trips and decreasing vehicle trips. This decrease in vehicle trips results in reduced VMT and thus a reduction in GHG emissions.

Subsector

Trip Reduction Programs

Locational Context

Urban, suburban

Scale of Application

Project/Site

Implementation Requirements

The project should be accessible either within 1 mile of high-quality transit service (rail or bus with headways of less than 15 minutes), 0.5 mile of local or less frequent transit service, or along a designated shuttle route providing last-mile connections to rail service. If a well-established bikeshare service (Measure T-22-A) is available, the site may be located up to 2 miles from a high-quality transit service.

If more than one transit agency serves the site, subsidies should be provided that can be applied to each of the services available. If subsidies are applied for only one service, all variable inputs below should also pertain only to the service that is subsidized.

Cost Considerations

The employer cost is the recurring, direct cost for transit subsidies. The subsidies will lower the per capita income of the transit service, decreasing the revenue of the local transit agency. This cost may be offset by increased revenue from increased ridership. The beneficiaries include the program participants saving on commuting cost, the employer reducing onsite parking expenses, and the municipality reducing cars on the road, which leads to lower infrastructure and roadway maintenance costs.

Expanded Mitigation Options

This measure could be paired with any combination of the other commute trip reduction strategies (Measures T-7 through T-13) for increased reductions.

GHG Reduction Formula

$$A = \frac{C}{B} \times G \times D \times E \times F \times H \times I$$

GHG Calculation Variables

If subsidies or discounts target employees, the GHG reduction from this measure may be limited to work-related employee trips only (i.e., home-to- work) and work-to-other, where at least one trip end is work). If residents are targeted, the GHG reductions extend to all trips.

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from employee/resident vehicles accessing the site	0–5.5	%	calculated
User Inputs				
B	Average transit fare without subsidy	[ ]	$	user input
C	Subsidy amount	[ ]	$	user input
D	Percent of employees/residents eligible for subsidy	0–100	%	user input
E	Percent of project-generated VMT from employees/residents	0–100	%	user input
Constants, Assumptions, and Available Defaults				
F	Transit mode share of all trips or work trips	Table T-3.1 or Table T-9.1	%	FHWA 2017
G	Elasticity of transit boardings with respect to transit fare price	-0.43	unitless	Taylor et al. 2008
H	Percent of transit trips that would otherwise be made in a vehicle	50	%	Handy & Boarnet 2013
I	Conversion factor of vehicle trips to VMT	1.0	unitless	assumption

Further explanation of key variables:

- (B and C) – The average transit fare and subsidy amount can be presented as either a fare per ride, or the cost of a monthly pass for typical transit service near the site. Pricing should be based on the expected means of subsidy implementation; for instance, if a monthly pass is provided to all residents, prices should be input on a monthly basis.
- (D) – The percentage of employees/residents associated with the site who have access to the subsidy. If subsidy is provided as an employee benefit, care should be taken to account for any contract or temporary workers who do not receive such benefits.
- (E) – The percentage of project-generated VMT from employees/residents is used to adjust the percent reduction in GHG emissions from the scale of employee and/or resident-generated VMT to project-generated VMT. If subsidies or discounts target employees at an office development, this value would simply be 100 percent. If the project site is a multifamily development with no onsite workers, this value would also be

100 percent. If the project site is a retail development, this value would be less than 100 percent, as it does not account for retail shopper trips to the site. The share of total VMT generated by employees for visitor-intensive uses, such as retail or medical offices, can be roughly estimated by multiplying the total number of employees by two (to account for both arrival and departure), divided by the total number of daily trips.

- (F) – Ideally, the user will calculate transit mode share for work trips or all trips of a Project/Site at a scale no larger than a census tract. Potential data sources include the U.S. Census, California Household Travel Survey (preferred), or local survey efforts. Care should be taken *not* to present the reported commute mode share as retrieved from the American Community Survey (ACS), unless the land use is office or employment based and the tables are based on work location (rather than home location). If the subsidies or discounts target employees and their commute trips, then the mode share should use the home-to-work trip purpose. If the user is not able to provide a project-specific value using one of the data sources described above, they have the option to input the transit mode share for one of the six most populated CBSAs in California. The transit mode share for work trips by CBSA is presented in Table T-9.1 in Appendix C (FHWA 2017). The transit mode share for all trips is provided in Table T-3.1 in Appendix C.
- (G) – A cross-sectional analysis of transit use in 265 urbanized areas in the U.S. found that a 0.43 percent decrease in transit boardings occurs for every 1 percent increase in transit fare price (Taylor et al. 2008). A policy brief summarizing the results of transit service strategies found this analysis to fall in the mid-point of observed, short-term values (Handy & Boarnet 2013). Price elasticities of transit demand vary based on both long-term and short-term demand, service type, and service location (Litman 2020 and Handy & Boarnet 2013).
- (H) – Not all new transit trips replace a vehicle trip. The share of transit trips that would otherwise be made by private vehicle ranges from less than 5 percent to 50 percent across studies. This assumption is based on observed values for high quality BRT service under the assumption that this measure is implemented alongside marketing measures and is targeted primarily at reducing vehicle commute trips. (Handy & Boarnet 2013). Note that this study looked at service improvements rather than fare changes and is used as a proxy variable. If project-specific or location-specific information is available, it should be substituted for this assumptive variable.
- (I) – The adjustment factor from vehicle trips to VMT is 1. This assumes that all vehicle trips will average out to typical trip length ("assumes all trip lengths are equal"). Thus, it can be assumed that a percentage reduction in vehicle trips will equal the same percentage reduction in VMT. Subsidies or discounts targeting commute trips may have a higher factor as they are generally longer than the trip lengths for other purposes.

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The GHG reduction is capped at 5.5 percent, which is based on the following assumptions:

- (C=B) – The subsidy coverage is capped at 100 percent of the typical transit fare.
- (D) – All employees are eligible for the subsidy.

- (E) – All project-generated VMT is from employee-generated VMT.
- (F) – Employees at an office development in the San Francisco-Oakland-Hayward CBSA have a default transit mode share for work trips of 25.60 percent.

Subsector Maximum

($\sum A_{max_{T\text{-}5\ through\ T\text{-}13}} \leq 45\%$) This measure is in the Trip Reduction Programs subsector. This subcategory includes Measures T-5 through T-13. The employee commute VMT reduction from the combined implementation of all measures within this subsector is capped at 45 percent.

Mutually Exclusive Measures

If this measure is selected, the user may not also take credit for either Measure T-5 or T-6. However, this measure may be implemented alongside other individual CTR measures (Measures T-7, T-8, T-10 through T-13). The efficacy of individual programs may vary highly based on individual employers and local contexts.

Example GHG Reduction Quantification

In this example, the user reduces VMT by providing all employees (D) of a proposed office development in the San Francisco-Oakland-Hayward CBSA a 100 percent transit subsidy in the form of a \$100 monthly transit pass (C=B). The user would reduce GHG emissions from VMT by 5.5 percent.

$$A = \left(\frac{\$100}{\$100} \times -0.43\right) \times \mathbf{100\%} \times \mathbf{100\%} \times 25.60\% \times 50\% \times 1 = -5.5\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

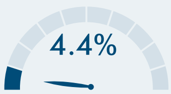
The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A).

Sources

- Federal Highway Administration (FHWA). 2017. *National Household Travel Survey–2017 Table Designer.* Travel Day PMT by TRPTRANS by HH_CBSA, Workers by WRKTRANS by HH_CBSA. Available: https://nhts.ornl.gov/. Accessed: January 2021.
- Handy, L. and S. Boarnet. 2013. *Impacts of Transit Service Strategies on Passenger Vehicle Use and Greenhouse Gas Emissions.* Available: http://www.arb.ca.gov/cc/sb375/policies/transitservice/transit_brief.pdf. Accessed: January 2021.
- Litman, T. 2020. *Transit Price Elasticities and Cross-elasticities.* Victoria Transport Policy Institute. April. Available: https://www.vtpi.org/tranelas.pdf. Accessed: January 2021.
- Taylor, B., D. Miller, H. Iseki, and C. Fink. 2008. *Nature and/or Nurture? Analyzing the Determinants of Transit Ridership Across US Urbanized Areas.* Transportation Research Part A: Policy and Practice, 43(1), 60-77. Available: https://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.367.5311&rep=rep1&type=pdf. Accessed: January 2021.

T-10. Provide End-of-Trip Bicycle Facilities

GHG Mitigation Potential



Up to 4.4% of GHG emissions from project/site employee commute VMT

Co-Benefits (icon key on pg. 34)

Climate Resilience

End-of-trip bicycle facilities could take more cars off the road, resulting in less traffic and better allowing emergency responders to access a hazard site during an extreme weather event. They could also make it easier for bicycle users to access resources in an extreme weather event.

Health and Equity Considerations

Facilities should be inclusive of all gender identities and expressions. Consider including gender-neutral, single-occupancy options to allow for additional privacy for those who want it.

Measure Description

This measure will install and maintain end-of-trip facilities for employee use. End-of-trip facilities include bike parking, bike lockers, showers, and personal lockers. The provision and maintenance of secure bike parking and related facilities encourages commuting by bicycle, thereby reducing VMT and GHG emissions.

Subsector

Trip Reduction Programs

Locational Context

Urban, suburban

Scale of Application

Project/Site

Implementation Requirements

End-of-trip facilities should be installed at a size proportional to the number of commuting bicyclists and regularly maintained.

Cost Considerations

Employer costs include capital and maintenance costs for construction and maintenance of facilities and potentially labor and materials costs for staff to monitor facilities and provide marketing to encourage use of new facilities. The beneficiaries include the program participants saving on commuting cost, the employer reducing onsite parking expenses, and the municipality reducing cars on the road, which leads to lower infrastructure and roadway maintenance costs.

Expanded Mitigation Options

Best practice is to include an onsite bicycle repair station and post signage on or near secure parking and personal lockers with information about how to reserve or obtain access to these amenities.

This measure could be paired with any combination of the other commute trip reduction strategies (Measures T-7 through T-13) for increased reductions.

GHG Reduction Formula

$$A = \frac{C \times (E - (B \times E))}{D \times F}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from employee project/site commute VMT	0.1–4.4	%	calculated
User Inputs				
	None			
Constants, Assumptions, and Available Defaults				
B	Bike mode adjustment factor	1.78 or 4.86	unitless	Buehler 2012
C	Existing bicycle trip length for all trips in region	Table T-10.1	miles	FHWA 2017a
D	Existing vehicle trip length for all trips in region	Table T-10.1	miles	FHWA 2017a
E	Existing bicycle mode share for work trips in region	Table T-10.2	%	FHWA 2017b
F	Existing vehicle mode share for work trips in region	Table T-10.2	%	FHWA 2017b

Further explanation of key variables:

- (B) – The bike mode adjustment factor should be provided by the user based on type of bike facility. A study found that commuters with showers, lockers, and bike parking at work are associated with 4.86 times greater likelihood to commute by bicycle when compared to individuals without any bicycle facilities at work. Individuals with bike parking, but no showers and lockers at the workplace, are associated with 1.78 times greater likelihood to cycle to work than those without trip-end facilities (Buehler 2012).
- (C and D) – Ideally, the user will calculate bicycle and auto trip length for a Project/Site at a scale no larger than a census tract. Potential data sources include the U.S. Census, California Household Travel Survey (preferred), or local survey efforts. If the user is not able to provide a project-specific value using one of these data sources, they have the option to input the trip lengths for bicycles and vehicles for one of the six most populated CBSAs in California, as presented in Table T-10.1 in Appendix C (FHWA 2017a). Trip lengths are likely to be longer for areas not covered by the listed CBSAs, which represent the denser areas of the state.
- (E and F) – Ideally, the user will calculate bicycle and auto mode share for work trips for a Project/Site at a scale no larger than a census tract. Potential data sources include the U.S. Census, California Household Travel Survey (preferred), or local survey efforts. If the user is not able to provide a project-specific value using one of these data sources, they have the option to input the regional average mode shares for bicycle and vehicle

work trips for one of the six most populated CBSAs in California, as presented in Table T-10.2 in Appendix C (FHWA 2017b). If the project study area is not within the listed CBSAs or the user is able to provide a project-specific value, the user should replace these regional defaults in the GHG reduction formula. For areas not covered by the listed CBSAs, which represent the denser areas of the state, bicycle mode share is likely to be lower and vehicle share higher than presented in Table T-10.2.

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The maximum GHG reduction from this measure is 4.4 percent. This maximum scenario is presented in the below example quantification.

Subsector Maximum

($\sum A_{max_{T\text{-}5 \text{ through } T\text{-}13}} \leq 45\%$) This measure is in the Trip Reduction Programs subsector. This subcategory includes Measures T-5 through T-13. The employee commute VMT reduction from the combined implementation of all measures within this subsector is capped at 45 percent.

Mutually Exclusive Measures

If this measure is selected, the user may not also take credit for either Measure T-5 or T-6. However, this measure may be implemented alongside other individual CTR measures (Measures T-7, T-8, T-9, and T-11 through T-13). The efficacy of individual programs may vary highly based on individual employers and local contexts.

Example GHG Reduction Quantification

The user reduces VMT by providing end-of-trip facilities for the project's employees, which encourages bicycle trips in place of vehicle trips. In this example, the type of bike facility provided by the project is parking with showers, bike lockers, and personal lockers (B). The project is within San Jose-Sunnyvale-Santa Clara CBSA, and the user does not have project-specific values for trip lengths and mode shares and for bicycles and vehicles. Per Tables T-10.1 and T-10.2 in Appendix C, inputs for these variables are 2.8 miles, 11.5 miles, 4.1 percent, and 86.6 percent, respectively (C, D, E, and F). GHG emissions from employee commute VMT would be reduced by 4.4 percent.

$$A = \frac{2.8 \text{ miles} \times \left(4.1\% - (4.86 \times 4.1\%)\right)}{11.5 \text{ miles} \times 86.6\%} = -4.4\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A).

Sources

- Buehler, R. 2012. *Determinants of bicycle commuting in the Washington, DC region: The role bicycle parking, cyclist showers, and free car parking at work.* Transportation Research Part D, 17, 525–531. Available: http://www.pedbikeinfo.org/cms/downloads/DeterminantsofBicycleCommuting.pdf. Accessed: January 2021.
- Federal Highway Administration (FHWA). 2017a. *National Household Travel Survey–2017 Table Designer*. Travel Day PT by TRPTRANS by HH_CBSA. Available: https://nhts.ornl.gov/. Accessed: January 2021.
- Federal Highway Administration (FHWA). 2017b. *National Household Travel Survey–2017 Table Designer.* Workers by WRKTRANS by HH_CBSA. Available: https://nhts.ornl.gov/. Accessed: January 2021.

T-11. Provide Employer-Sponsored Vanpool

Photo Credit: UCLA Transportation/Flickr, 2021

GHG Mitigation Potential

20.4%

Up to 20.4% of GHG emissions from project/site employee commute VMT

Co-Benefits (icon key on pg. 34)

Climate Resilience

Employer-sponsored vanpools could result in less traffic, potentially reducing congestion or delays on major roads during peak AM and PM traffic periods. When this reduction occurs during extreme weather events, it better allows emergency responders to access a hazard site.

Health and Equity Considerations

Consider using zero-emission or plug-in electric vehicles (PHEVs) for additional emission reduction benefits.

Measure Description

This measure will implement an employer-sponsored vanpool service. Vanpooling is a flexible form of public transportation that provides groups of 5 to 15 people with a cost-effective and convenient rideshare option for commuting. The mode shift from long-distance, single-occupied vehicles to shared vehicles reduces overall commute VMT, thereby reducing GHG emissions.

Subsector

Trip Reduction Programs

Locational Context

Urban, suburban, rural

Scale of Application

Project/Site

Implementation Requirements

Vanpool programs are more appropriate for the building occupant or tenant (i.e., employer) to implement and monitor than the building owner or developer.

Cost Considerations

Employer costs primarily include the capital costs of vehicle acquisition and the labor costs of drivers, either through incentives to current employees or the hiring of dedicated drivers. The beneficiaries include the program participants saving on commuting cost, the employer reducing onsite parking expenses, and the municipality reducing cars on the road, which leads to lower infrastructure and roadway maintenance costs.

Expanded Mitigation Options

When implementing a vanpool service, best practice is to subsidize the cost for employees that have a similar origin and destination and provide priority parking for employees that vanpool.

This measure could be paired with any combination of the other commute trip reduction strategies (Measures T-7 through T-13) for increased reductions.

GHG Reduction Formula

$$A = \frac{\left((1 - B) \times C \times F\right) + \left(B \times \frac{D}{E} \times G\right)}{\left((1 - B) \times C \times F\right) + (B \times D \times F)} - 1$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from project/site employee commute VMT	3.4–20.4	%	calculated
User Inputs				
	None			
Constants, Assumptions, and Available Defaults				
B	Percent of employees that participate in vanpool program	2.7	%	SANDAG 2019
C	Average length of one-way vehicle commute trip in region	Table T-11.1	miles per trip	FHWA 2017
D	Average length of one-way vanpool commute trip	42.0	miles per trip	SANDAG 2019
E	Average vanpool occupancy (including driver)	6.25	occupants	SANDAG 2019
F	Average emission factor of average employee vehicle	307.5	g CO_2e per mile	CARB 2020
G	Vanpool emission factor	763.4	g CO_2e per mile	CARB 2020

Further explanation of key variables:

- (B) – The percent of employees that would participate in a vanpool program is based on a survey of commuters in San Diego County (SANDAG 2019). If the project is not within San Diego County or the user is able to provide a project-specific value for within San Diego County, the user should replace the default employee participation rate in the GHG reduction formula.
- (C) – Ideally, the user will calculate auto commute trip lengths for a Project/Site at a scale no larger than a census tract. Potential data sources include the U.S. Census, California Household Travel Survey (preferred), or local survey efforts. If the user is not able to provide a project-specific value using one of these data sources, they have the option to input the regional average one-way auto commute trip length for one of the six most populated CBSAs in California, as presented in Table T-11.1 in Appendix C (FHWA 2017). Trip lengths are likely to be longer for areas not covered by the listed CBSAs, which represent the denser areas of the state.
- (D and E) – The average one-way vanpool commute trip length and occupancy are based on data from the San Diego Association of Government's regional vanpool program (SANDAG 2019). If the project is not within San Diego County or the user is

able to provide a project-specific value for within San Diego County, the user should replace these defaults in the GHG reduction formula.

- (F and G) – The average GHG emission factors for employee commute and vanpool vehicles were calculated in terms of CO_2e per mile using EMFAC2017 (v1.0.3). The model was run for a 2020 statewide average using diesel and gasoline fuel. The average of the light-duty automobile (LDA) and light duty truck (LDT1/LDT2) vehicle categories represents employee non-vanpool vehicles and the light-heavy duty truck (LHDT1) vehicle category conservatively represents a large cargo vanpool vehicle. The running emission factors for CO_2, CH_4, and N_2O (CARB 2020) were multiplied by the corresponding 100-year GWP values from the IPCC's Fourth Assessment Report (IPCC 2007). If the user can provide a project-specific value (i.e., for a future year and project location), the user should run EMFAC to replace the defaults in the GHG reduction formula.

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) For projects in San Diego County that use default CBSA data from Table T-11.1 and (B_{max}), the maximum percent reduction in GHG emissions (A) is 20.4 percent. This maximum scenario is presented in the below example quantification.

(B_{max}) The percent of employees that participate in the vanpool program is capped at 15 percent, which is based on the high end of vanpool participation survey data for several successful programs in the U.S. (SANDAG 2019).

Subsector Maximum

($\sum A_{max_{T\text{-}5 \text{ through } T\text{-}13}} \leq 45\%$) This measure is in the Trip Reduction Programs subsector. This subcategory includes Measures T-5 through T-13. The employee commute VMT reduction from the combined implementation of all measures within this subsector is capped at 45 percent.

Mutually Exclusive Measures

If this measure is selected, the user may not also take credit for either Measure T-5 or T-6. However, this measure may be implemented alongside other individual CTR measures (Measures T-7 through T-10, T-12, and T-13). The efficacy of individual programs may vary highly based on individual employers and local contexts.

Example GHG Reduction Quantification

The user reduces employee commute VMT by requiring that the employer of the project to sponsor a vanpool program. In this example, the project is in the San Diego-Carlsbad CBSA and would have an average vehicle commute trip length of 14.52 miles (C). The percent of employees that participate in the vanpool program is 15 percent (B_{max}). GHG emissions from employee commute would be reduced by 20.4 percent.

$$A = \frac{\left((1-15\%)\times 14.52\ \frac{\text{miles}}{\text{trip}}\times 307.5\ \frac{\text{g } CO_2e}{\text{miles}}\right)+\left(15\%\times\frac{42\ \frac{\text{miles}}{\text{trip}}}{6.25\ \text{occupants}}\times 763.4\ \frac{\text{g } CO_2e}{\text{miles}}\right)}{\left((1-15\%)\times 14.52\ \frac{\text{miles}}{\text{trip}}\times 307.5\ \frac{\text{g } CO_2e}{\text{miles}}\right)+\left(15\%\times 42\ \frac{\text{miles}}{\text{trip}}\times 307.5\ \frac{\text{g } CO_2e}{\text{miles}}\right)} - 1 = \text{-}20.4\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption (H) can be calculated using the GHG reduction formula except that (F) and (G) should be replaced by (I) and (J), as follows.

Fuel Use Reduction Formula

$$H = \frac{\left((1-B)\times C\times I\right)+\left(B\times\frac{D}{E}\times J\right)}{\left((1-B)\times C\times I\right)+\left(B\times D\times I\right)} - 1$$

Fuel Use Reduction Calculation Variables

ID	Variable	Value	Unit	Source
Output				
H	Percent reduction in fuel use from project/site employee commute VMT	4.7–21.4	%	calculated
User Inputs				
	None			
Constants, Assumptions, and Available Defaults				
I	Fuel efficiency of average employee vehicle	0.03639	gallon (gal) per mile	CARB 2020
J	Fuel efficiency of vanpool vehicle	0.08328	gal per mile	CARB 2020

Further explanation of key variables:

- (I and J) – The average fuel efficiencies for employee commute and vanpool vehicles were calculated using EMFAC2017 (v1.0.3). The model was run for a 2020 statewide average using diesel and gasoline fuel. The average of the LDA, LDT1, and LDT2 vehicle categories represents employee non-vanpool vehicles, and the LHDT1 vehicle category conservatively represents a large cargo vanpool vehicle. If the user can provide a project-specific value (i.e., for a future year and project location), the user should run EMFAC to replace the defaults in the fuel use reduction formula.

- Please refer to the GHG Calculation Variables table above for definitions of variables that have been previously defined.

VMT Reductions

The percent reduction in VMT can be calculated using a modified version of the GHG reduction formula, as shown below.

$$\%\ \text{VMT Reduction} = \frac{((1 - B) \times C) + \left(B \times \frac{D}{E}\right)}{C} - 1$$

Sources

- California Air Resources Board (CARB). 2020. *EMFAC2017 v1.0.3*. August. Available: https://arb.ca.gov/emfac/emissions-inventory. Accessed: January 2021.
- Federal Highway Administration (FHWA). 2017. *National Household Travel Survey–2017 Table Designer*. Travel Day VT by HH_CBSA by TRPTRANS by TRIPPURP. Available: https://nhts.ornl.gov/. Accessed: January 2021.
- Intergovernmental Panel on Climate Change (IPCC). 2007. *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp. Available: https://www.ipcc.ch/report/ar4/wg1/. Accessed: January 2021.
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T-12. Price Workplace Parking

GHG Mitigation Potential

Up to 20.0% of GHG emissions from project/site employee commute VMT

Co-Benefits (icon key on pg. 34)

Climate Resilience

Priced workplace parking could incentivize increased use of public transit and thus result in less traffic, potentially reducing congestion or delays on major roads during peak AM and PM traffic periods. When this reduction occurs during extreme weather events, it better allows emergency responders to access a hazard site.

Health and Equity Considerations

Parking pricing should include hourly and daily options so part-time staff do not need a monthly pass. If the project includes low-waged employees that have fewer transportation choices or time and resource constraints, it is instead recommended to consider implementing Measure T-13, *Implement Employee Parking Cash-Out*, or other transportation subsidy.

Measure Description

This measure will price onsite parking at workplaces. Because free employee parking is a common benefit, charging employees to park onsite increases the cost of choosing to drive to work. This is expected to reduce single-occupancy vehicle commute trips, resulting in decreased VMT, thereby reducing associated GHG emissions.

Subsector

Trip Reduction Programs

Locational Context

Urban, suburban

Scale of Application

Project/Site

Implementation Requirements

Implementation may include the following.

- Explicitly charging for employee parking.
- Implementing above-market rate pricing.
- Validating parking only for invited guests (or not providing parking validation at all).
- Not providing employee parking and transportation allowances.

In addition, this measure should include marketing and education regarding available alternatives to driving.

Cost Considerations

Parking fees would be a direct, recurring cost for employees. Employer costs include labor costs for program management and monitoring, but this may be offset by revenue generated by the program.

Expanded Mitigation Options

Best practice is to ensure that other transportation options are available, convenient, and have competitive travel times (i.e., transit service near the project site, shuttle service, or a complete active transportation network serving the site and surrounding community), and that there is not alternative free parking available nearby (such as on-street). This measure is substantially less effective in environments that do not have other modes available or where unrestricted street parking or other offsite parking is available nearby and has adequate capacity to accommodate project-related vehicle parking demand.

GHG Reduction Formula

For calculating effectiveness of pricing residential parking, see Measure T-16, *Unbundle Residential Parking Costs from Property Cost*. For calculating effectiveness of pricing parking at visitor-intensive land uses, see Measure T-24, *Implement Market Price Public Parking (On-Street)*.

$$A = \frac{B - C}{C} \times E \times D \times F$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from employee commute VMT	0–20.0	%	calculated
User Inputs				
B	Proposed parking price	[ ]	$	user input
C	Baseline parking price	[ ]	$	user input
D	Share of employees paying for parking	[ ]	%	user input
Constants, Assumptions, and Available Defaults				
E	Elasticity of parking demand with respecting to parking price	-0.4	unitless	Lehner & Peer 2019
F	Ratio of vehicle trip reduction to VMT	1	unitless	assumption

Further explanation of key variables:

- (B) – Parking price can be provided on an hourly, daily, or monthly basis. Monthly pricing is less effective than requiring daily or hourly payment since the price signal is diluted to only once a month.
- (C) – If baseline parking price is $0 (that is, if parking is typically free), set C = ¼ B, allowing for the maximum 50 percent increase in price. Alternatively, for locations that are located within 0.5 mile of transit service, set C = average transit fare to/from the location.
- (D) – Many organizations allow some employees free parking benefits. VMT reductions should be adjusted based on the share of employees that would be paying for parking.
- (E) – A meta-analysis of parking price studies found that a 0.40 percent decrease in parking demand occurs for every 1 percent increase in parking price (Lehner & Peer 2019). Price elasticity of parking demand varies by location, day of the week, and time of day.
- (F) – The adjustment factor from vehicle trips to VMT is 1. This assumes that all vehicle trips will average out to typical trip length ("assumes all trip lengths are equal"). Thus, it can be assumed that a percentage reduction in vehicle trips will equal the same percentage reduction in VMT. Subsidies or discounts targeting commute trips may have a higher factor as they are generally longer than the trip lengths for other purposes.

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The GHG reduction from priced workplace parking is capped at 20 percent. This maximum scenario is presented in the below example quantification.

($\frac{B-C}{C}_{max}$) The percent increase in parking price is capped at 50 percent.

Subsector Maximum

($\sum A_{max_{T\text{-}5 \text{ through } T\text{-}13}} \leq 45\%$) This measure is in the Trip Reduction Programs subsector. This subcategory includes Measures T-5 through T-13. The employee commute VMT reduction from the combined implementation of all measures within this subsector is capped at 45 percent.

Mutually Exclusive Measures

If this measure is selected, the user may not also take credit for Measure T-13, *Implement Employee Parking Cash-Out*. While both measures focus on providing a price signal for employees to consider other modes for their work commute, this measure actively charges all employees to park, while Measure T-13 reimburses employees who do not park. Users should select either Measure T-12 or T-13.

Example GHG Reduction Quantification

The user reduces VMT by increasing the price of a monthly parking permit. In this example, the permit fee is increased from $50 (C) to $75 (B). If 100 percent of employees are subject to parking pricing (D), the user would reduce GHG emissions from VMT by 20 percent.

$$A = \frac{\$75 - \$50}{\$50} \times -0.4 \times 100\% \times 1 = -20\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

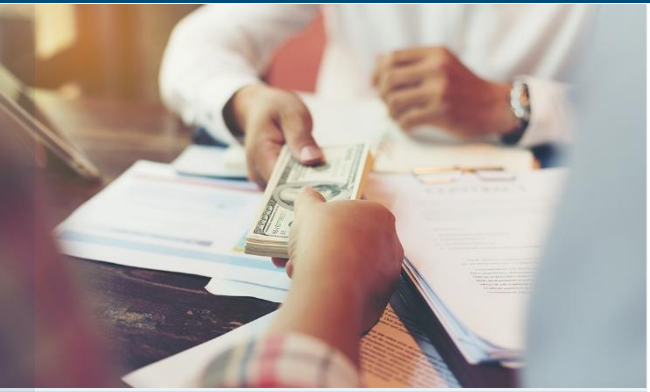
VMT Reductions

The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A).

Sources

- Lehner, S., Peer, S. 2019. *The Price Elasticity of Parking: A Meta-analysis*. Transportation Research Part A: Policy and Practice 121 2019. Available: http://sustainabletransportationsc.org/garage/pdf/parking_elasticity.pdf. Accessed: January 2021.

T-13. Implement Employee Parking Cash-Out



GHG Mitigation Potential

12%

Up to 12.0% of GHG emissions from project/site employee commute VMT

Co-Benefits (icon key on pg. 34)

Climate Resilience

Employee parking cash-out could incentivize increased use of public transit and thus result in less traffic, potentially reducing congestion or delays on major roads during peak AM and PM traffic periods. When this reduction occurs during extreme weather events, it better allows emergency responders to access a hazard site.

Health and Equity Considerations

Non-applicable

Measure Description

This measure will require project employers to offer employee parking cash-out. Cash-out is when employers provide employees with a choice of forgoing their current subsidized/free parking for a cash payment equivalent to or greater than the cost of the parking space. This encourages employees to use other modes of travel instead of single occupancy vehicles. This mode shift results in people driving less and thereby reduces VMT and GHG emissions.

Subsector

Trip Reduction Programs

Locational Context

Urban, suburban

Scale of Application

Project/Site

Implementation Requirements

To prevent spill-over parking and continued use of single occupancy vehicles, residential parking in the surrounding area must be permitted, and public on-street parking must be market rate.

Cost Considerations

Employer costs include the recurring, direct cost for payment to program participants and labor costs for program management. Employees that participate in the program would achieve cost savings through the cash-out benefit and potentially through reduced vehicle ownership and usage.

Expanded Mitigation Options

This measure could be paired with many other commute trip reduction strategies (Measures T-7 through T-11) for increased reductions.

GHG Reduction Formula

A = B × C

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from project/site commute VMT	0–12.0	%	calculated
User Inputs				
B	Percentage of employees eligible	[ ]	%	user input
Constants, Assumptions, and Available Defaults				
C	Percent reduction in commute VMT from implementation of measure	-12	%	Shoup 2005

Further explanation of key variables:

- (B) – The percentage of employees eligible refers to the employees that would be able to participate in the program. This will usually be 100 percent. Employees who might not be able to participate could include those who work nighttime hours when transit and rideshare services are not available or employees who are required to drive to work as part of their job duties. This does not refer to the percentage of employees who end up participating in the program.
- (C) – A study of eight California firms that complied with California's 1992 parking cash-out law found employee commute VMT decreased by an average of 12 percent (Shoup 2005).

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The maximum percent reduction in GHG emissions (A) is 12.0 percent. This maximum scenario is presented in the below example quantification.

Subsector Maximum

($\sum A_{max_{T\text{-}5\ through\ T\text{-}13}} \leq 45\%$) This measure is in the Trip Reduction Programs subsector. This subcategory includes Measures T-5 through T-13. The employee commute VMT reduction from the combined implementation of all measures within this subsector is capped at 45 percent.

Mutually Exclusive Measures

If this measure is selected, the user may not also take credit for Measure T-12, *Price Workplace Parking*. While both measures focus on providing a price signal for employees to consider other modes for their work commute, this measure reimburses employees who do not park, while Measure T-12 actively charges all employees to park. Users should select either Measure T-12 or T-13.

Example GHG Reduction Quantification

The user reduces project/site VMT by offering commuters the option to choose a cash payment equal to or greater than the current parking subsidy offered by their employer. In this example, all employees (i.e., 100 percent) are eligible to participate (B), which would reduce GHG emissions from employee commute VMT by 12 percent.

$A = \mathbf{100\%} \times -12\% = -12\%$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A).

Sources

- Shoup, D. 2005. *Parking Cash Out.* Planners Advisory Service, American Planning Association. Available: http://shoup.bol.ucla.edu/ParkingCashOut.pdf. Accessed: January 2021.

T-14. Provide Electric Vehicle Charging Infrastructure

GHG Mitigation Potential

11.9%

Up to 11.9% of GHG emissions from vehicles accessing the commercial or multifamily housing building

Co-Benefits (icon key on pg. 34)

Climate Resilience

Providing electric vehicle charging infrastructure increases fuel redundancy for electric vehicles even if an extreme weather event disrupts other fuel sources. Electric vehicles could also provide benefits to buildings and the grid, such as emergency backup, energy reserves, and demand response.

Health and Equity Considerations

Differential costs of PHEVs compared to conventional vehicles are decreasing over time, but at present are more expensive, which means this measure could disproportionately benefit those of greater economic means. As costs come into parity over time, this will be less of an issue. Employer, electricity provider, and state incentives for PHEV purchase could help address near-term disparities.

Measure Description

Install onsite electric vehicle chargers in an amount beyond what is required by the 2019 California Green Building Standards (CALGreen) at buildings with designated parking areas (e.g., commercial, educational, retail, multifamily). This will enable drivers of PHEVs to drive a larger share of miles in electric mode (eVMT), as opposed to gasoline-powered mode, thereby displacing GHG emissions from gasoline consumption with a lesser amount of indirect emissions from electricity. Most PHEVs owners charge their vehicles at home overnight. When making trips during the day, the vehicle will switch to gasoline mode if/when it reaches its maximum all-electric range.

Subsector

Parking or Road Pricing/Management

Locational Context

Urban, suburban, rural

Scale of Application

Project/Site

Implementation Requirements

Parking at the chargers must be limited to electric vehicles.

Cost Considerations

The primary costs associated with electric vehicle charging infrastructure include the capital costs of purchasing and installing charging stations, electricity costs from use of stations, and maintenance costs of keeping the charging stations in working order. Costs initially fall to the station owners, either municipalities or private owners, but can be passed along to station users with usage fees. Depending on station placement and charging times required for PHEVs, businesses near charging stations can derive benefits from patronage of station users.

Expanded Mitigation Options

In addition to increasing the percentage of electric miles for PHEVs, the increased availability of chargers from implementation of this measure could mitigate consumer "range anxiety" concerns and increase the adoption and use of battery electric vehicles (BEVs), but this potential effect is not included in the calculations as a conservative assumption. Expanded mitigation could include quantification of the effect of this measure on BEV use.

GHG Reduction Formula

$$A = \frac{B \times D \times (F - E) \times (G - (H \times I \times K \times L))}{-C \times J}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from vehicles accessing the office building or housing	0–11.9	%	calculated
User Inputs				
B	Number of chargers installed at site	[ ]	integer	user input
C	Total vehicles accessing the site per day	[ ]	integer	user input
Constants, Assumptions, and Available Defaults				
D	Average number of PHEVs served per day per charger installed	2	integer	CARB 2019
E	Percent of PHEV miles in electric mode without measure	46	%	CARB 2020a
F	Percent of PHEV miles in electric mode with measure	80	%	CARB 2017
G	Average emission factor of PHEV in gasoline mode	205.1	g CO_2e per mile	CARB 2020a; U.S. DOE 2021
H	Energy efficiency of PHEV in electric mode	0.327	kilowatt hours (kWh) per mile	CARB 2020b; U.S. DOE 2021
I	Carbon intensity of local electricity provider	Tables E-4.3 and E-4.4	lb CO_2e per megawatt hour (MWh)	CA Utilities 2021
J	Average emission factor of non-electric vehicles accessing the site	307.5	g CO_2e per mile	CARB 2020a
K	conversion from lb to g	454	g per lb	conversion
L	Conversion from kWh to MWh	0.001	MWh per kWh	conversion

Further explanation of key variables:

- (D) – The average number of PHEVs served per day per charger installed is 2 vehicles (CARB 2019). If the user can provide a project-specific value, they should replace the default in the GHG reduction formula.
- (E) - Based on the EMFAC2017 model (v1.0.3), 46 percent of miles traveled by PHEVs in California are eVMT, and 54 percent are in gasoline mode (CARB 2020a).

- (F) – A review of EV user surveys and analytics included in the CARB's *Advanced Clean Cars Mid-Term Report* suggest that PHEV owners can reach 80 percent eVMT with access to adequate supportive charging infrastructure (CARB 2017).
- (G) – As described for (J), the average GHG emission factor for gasoline vehicles is 307.5 grams of CO_2e per mile.
- The fuel efficiency of a PHEV in gasoline mode is calculated as 66.7 percent of the fuel consumption rate of a gasoline vehicle, based on the assumption that a gasoline hybrid vehicle has 50 percent higher fuel economy (miles per gal [mpg]) than a comparable gasoline vehicle, based on a comparison of the gasoline and hybrid Toyota Camry and Corolla models (U.S. DOE 2021). This percentage is applied to the average GHG emission factor for gasoline vehicles to determine the average emission factor for PHEVs in gasoline mode as (66.7%×307.5 g CO_2e per mile). If the user can provide a project-specific value by running EMFAC based on the future year of a project, they should replace the default in the GHG reduction formula.
- (H) – Scaled from a light-duty automobile gasoline equivalent fuel economy 30.3 mpg (CARB 2020a), an energy efficiency ratio (EER) of 2.5 (CARB 2020b), and an assumption of 33.7 kWh electricity per gallon of gasoline (U.S. DOE 2021).
- (I) – GHG intensity factors for major California electricity providers are provided in Tables E-4.3 and E-4.4 in Appendix C. If the project study area is not serviced by a listed electricity provider, or the user is able to provide a project-specific value (i.e., for the future year not referenced in Appendix C), the user should replace the default in the GHG calculation formula. If the electricity provider is not known, the user may elect to use the statewide grid average carbon intensity.
- (J) – The average GHG emission factor for non-electric vehicles accessing the site was calculated in terms of CO_2e per mile using EMFAC2017 (v1.0.3). The model was run for a 2020 statewide average of LDA, LDT1, and LDT2 vehicles using diesel and gasoline fuel. The running emission factors for CO_2, CH_4, and N_2O (CARB 2020a) were multiplied by the corresponding 100-year GWP values from the IPCC's Fourth Assessment Report (IPCC 2007). If the user can provide a project-specific value (i.e., for a future year and project location), the user should run EMFAC to replace the default in the GHG reduction formula.

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The percent reduction in GHG emissions (A) is capped at 11.9 percent, which is based on the following assumptions used to generate a maximum scenario:

- (B) – number of chargers installed = 20. CALGreen provides a non-residential voluntary Tier 2 measure that requires projects with 201 or more parking spaces to allocate 10 percent of total parking spaces for "EV Capable" parking spaces (or 20 parking spaces) (CBSC 2019). Note that EV Capable parking spaces do not actually have EV chargers installed, though they do have electrical panel capacity, a dedicated branch circuit, and a raceway to the EV parking spot to support future installation of charging stations. Therefore, using the number of EV Capable parking spaces as a proxy for EV chargers as a high-end estimate is conservative.

- (C) – total vehicles accessing the site = 200. Per the CALGreen voluntary measure, the number of total parking spaces that correspond with 20 "EV Capable" parking spaces is 201.
- (D) – PHEVs served per day per charger installed = 7. This value is the max (D_{max}). This assumes that all PHEV drivers would coordinate sharing of the limited number of chargers at the site. Value is based on data from the National Renewable Energy Laboratory (CARB 2019).
- (I) – carbon intensity of local electricity provider = 0 lb CO_2e per MWh. This assumes that the local electricity provider is powered 100 percent by renewables and thus has a carbon intensity of zero.

Subsector Maximum

($\sum A_{max_{T\text{-}14\text{ through }T\text{-}16}} \leq 35\%$) This measure is in the Parking or Road Pricing/Management subsector. This subcategory includes Measures T-14 through T-16. The VMT reduction from the combined implementation of all measures within this subsector is capped at 35 percent.

Example GHG Reduction Quantification

The user will install electric vehicle chargers at their proposed office or multifamily housing development, which will enable employees or residents with PHEVs to drive a larger share of miles in electric mode, as opposed to gasoline-powered mode, thereby displacing GHG emissions from gasoline consumption with a lesser amount of indirect emissions from indirect electricity. In this example, 20 chargers (B) will be installed at a workplace with 200 daily employee vehicles accessing the site (C). The electricity provider for the project area is the Sacramento Municipal Utility District (SMUD) and the analysis year is 2022. The carbon intensity of electricity is therefore 344 lb CO_2e per MWh (I). The GHG impact is calculated as a 3.4 percent reduction from the total emissions from vehicles accessing the site.

$$A = \frac{20 \times 2\frac{\text{PHEVs}}{\text{charger}\cdot\text{day}} \times (80\% - 46\%) \times (205.1\ \frac{\text{g } CO_2e}{\text{miles}} - (0.327\frac{\text{kWh}}{\text{mile}} \times 344\ \frac{\text{lb } CO_2e}{\text{MWh}} \times 454\frac{\text{g}}{\text{lb}} \times 0.001\frac{\text{MWh}}{\text{kWh}}))}{\text{-200 vehicles} \times 307.5\ \frac{\text{g } CO_2e}{\text{miles}}} = 3.4\%$$

Quantified Co-Benefits

While the measure will achieve fuel savings, it will also increase electricity consumption. This section defines the methods for quantifying Improved Local Air Quality and fuel savings, as well as increased electricity consumption.

Improved Local Air Quality

Local criteria pollutants will be reduced by the reduction in fossil fuel combustion. The percent reduction in criteria pollutants can be calculated using the GHG reduction formula. Electricity supplied by statewide fossil-fueled or bioenergy power plants will generate criteria pollutants. However, because these power plants are located throughout the state, electricity consumption from vehicles charging will not generate localized criteria pollutant emissions. Consequently, for the quantification of criteria pollutant emission reductions, either the electricity portion of the equation can be removed, or the electricity intensity (I) can be set to zero.

Fuel Savings (Increased Electricity)

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in criteria pollutant emissions. The percent increase in electricity use (M) from this measure can be calculated as follows.

Electricity Use Increase Formula

$$M = \frac{B \times D \times (F - E) \times J \times N \times O}{-C \times P}$$

Electricity Use Increase Calculation Variables

ID	Variable	Value	Unit	Source
Output				
M	Increase in electricity from PHEVs	[ ]	%	calculated
User Inputs				
N	Existing electricity consumption of project/site	[ ]	kWh per year	user input
O	Days per year with vehicles accessing the site	260–365	days per year	user input
P	Average annual VMT of vehicles accessing the site	[ ]	miles per day per vehicle	user input
Constants, Assumptions, and Available Defaults				
	None			

Further explanation of key variables:

- (N) – The user should take care to properly quantify building electricity using accepted methodologies (such as CalEEMod).
- (O) – If the proposed development is a workplace in which employees access the site an average of 5 days per week, the user should input 260 workdays. If the development is multifamily dwelling, the user should input 365 days.
- Please refer to the GHG Calculation Variables table above for definitions of variables that have been previously defined.

Sources

- California Air Resources Board (CARB). 2017. *Advanced Clean Cars Mid-Term Report, Appendix G: Plug-in Electric Vehicle In-Use and Charging Data Analysis*. Available: https://ww2.arb.ca.gov/resources/documents/2017-midterm-review-report. Accessed: January 2021.
- California Air Resources Board (CARB). 2019. *Final Sustainable Communities Strategy Program and Evaluation Guidelines Appendices*. November. Available: https://ww2.arb.ca.gov/sites/default/files/2019-11/Final%20SCS%20Program%20and%20Evaluation%20Guidelines%20Appendices.pdf. Accessed: January 2021.

- California Air Resources Board (CARB). 2020a. *EMFAC2017 v1.0.3.* August. Available: https://arb.ca.gov/emfac/emissions-inventory. Accessed: January 2021.
- California Air Resources Board (CARB). 2020b. *Unofficial electronic version of the Low Carbon Fuel Standard Regulation.* Available: https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf
- California Air Resources Board (CARB). 2021. OFFROAD2017–ORION. Available: https://arb.ca.gov/emfac/emissions-inventory. Database queried by Ramboll and provided electronically to ICF. March 2021.
- California Utilities. 2021. Excel database of GHG emission factors for delivered electricity, provided to the Sacramento Metropolitan Air Quality Management District and ICF. January through March 2021.
- California Building Standards Commission (CBSC). 2019. Green Building Standards Code, Title 24, Part 11. Appendix A5 – Nonresidential Voluntary Measures. Table A5.601 Nonresidential Buildings: Green Building Standards Code Proposed Performance Approach. July. Available: https://codes.iccsafe.org/content/CAGBSC2019/appendix-a5-nonresidential-voluntary-measures. Accessed: May 2021.
- Intergovernmental Panel on Climate Change (IPCC). 2007. *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp. Available: https://www.ipcc.ch/report/ar4/wg1/. Accessed: January 2021.
- U.S. Department of Energy (U.S. DOE). 2021. *Download Fuel Economy Data.* January. Available: https://www.fueleconomy.gov/feg/download.shtml. Accessed: January 2021.

T-15. Limit Residential Parking Supply

GHG Mitigation Potential

13.7%

Up to 13.7% of GHG emissions from resident vehicles accessing the site

Co-Benefits (icon key on pg. 34)

Climate Resilience

Limiting residential parking supply could incentivize increased use of public transit and thus result in less traffic, potentially reducing congestion or delays on major roads during peak AM and PM traffic periods. When this reduction occurs during extreme weather events, it better allows emergency responders to access a hazard site. Evacuation plans and plans for transport to cooling/heating/clean air centers during power outages or unhealthy air quality events, however, would need to consider needs of households without access to private vehicles.

Health and Equity Considerations

Limiting parking supply can reduce the cost of housing development and, potentially, increase housing supply and decrease housing expenses. However, this may negatively impact residents that do not have a viable alternative to personal vehicle travel.

Measure Description

This measure will reduce the total parking supply available at a residential project or site. Limiting the amount of parking available creates scarcity and adds additional time and inconvenience to trips made by private auto, thus disincentivizing driving as a mode of travel. Reducing the convenience of driving results in a shift to other modes and decreased VMT and thus a reduction in GHG emissions. Evidence of the effects of reduced parking supply is strongest for residential developments.

Subsector

Parking or Road Pricing/Management

Locational Context

Urban, suburban

Scale of Application

Project/Site

Implementation Requirements

This measure is ineffective in locations where unrestricted street parking or other offsite parking is available nearby and has adequate capacity to accommodate project-related vehicle parking demand.

Cost Considerations

Reducing residential parking supply, especially in high density residential areas, can have high-cost savings if it reduces the need for additional investment in parking infrastructure. Some of these savings may be offset by investments in alternative transport solutions, which will need to be robust to ensure that residents can effectively travel to work and all other destinations without a car.

Expanded Mitigation Options

When limiting parking supply, a best practice is to do so at sites that are located near high quality alternative modes of travel (such as a rail station, frequent bus line, or in a higher density area with multiple walkable locations nearby). Limiting parking supply may also allow for more active uses on any given lot, which may support Measures T-1 and T-2 by allowing for higher density construction.

GHG Reduction Formula

$$A = -\frac{B - C}{B} \times D \times E \times F$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from resident vehicles accessing the site	0–13.7	%	calculated
User Inputs				
B	Residential parking demand	[ ]	parking spaces	user input
C	Project residential parking supply	[ ]	parking spaces	user input
D	Percentage of project VMT generated by residents	[ ]	%	user input
Constants, Assumptions, and Available Defaults				
E	Percent of household VMT that is commute based	37	%	Caltrans 2012
F	Percent reduction in commute mode share by driving among households in areas with scarce parking	37	%	Chatman 2013

Further explanation of key variables:

- (B) – The user can calculate the parking demand in the *ITE Parking Generation Manual* based on the project building square footage or number of du. For residential projects, this demand varies based on the size of each unit, and ranges from 1.0 spaces/unit for one-bedroom apartments to 2.6 spaces/unit for single-family homes with 3+ bedrooms.
- (D) – Available research on changes in parking supply focuses on residential land uses. Therefore, reductions are applied only to the share of VMT generated by residents of a project. For most residential projects, this will be 100 percent; however, for mixed-use projects, the user will need to provide project-specific data.
- (E) – The percent of household VMT that is commute-based varies from location to location; the statewide average is 37 percent (Caltrans 2012). If the user can provide a project-specific value based on their project type and area, they should replace the default in the GHG reduction formula.
- (F) – A study found that among households with limited off-street parking (<1 space per adult), there was a 37 percent decrease in auto mode share for commute trips. The method above pro-rates this reduction based on how much the project's parking supply is reduced from demand rates calculated in the *ITE Parking Generation Manual* (ITE 2019). In addition, this reduction is applied to commute trips only due to the limitations of the research.

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The percent reduction in GHG emissions is capped at 13.7 percent. This occurs for projects that have no onsite parking (C), 100 percent of VMT arising from residential land use (D), and 37 percent of all VMT arising from commute trips (E). This maximum scenario is presented in the below example quantification.

(C>B) Parking supply is considered to be limited when demand (C) exceeds supply (B). If demand is equal to or less than supply, then implementation of this measure would not result in a GHG reduction.

Subsector Maximum

($\sum A_{max_{T\text{-}14 \text{ through } T\text{-}16}} \leq 35\%$) This measure is in the Parking or Road Pricing/Management subsector. This subcategory includes Measures T-14 through T-16. The VMT reduction from the combined implementation of all measures within this subsector is capped at 35 percent.

Example GHG Reduction Quantification

The user reduces VMT by reducing a project's parking supply. In this example, the parking demand per ITE is 100 parking spaces (B) and the project would not supply any parking spaces (C). The user would reduce GHG emissions from VMT by 13.7 percent.

$$A = -\frac{100 \text{ spaces} - 0 \text{ spaces}}{100 \text{ spaces}} \times 100\% \times 37\% \times 37\% = -13.7\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A).

Sources

- California Department of Transportation (Caltrans). 2012. *California Household Travel Survey (CHTS)*. Available: https://www.nrel.gov/transportation/secure-transportation-data/tsdc-california-travel-survey.html. Accessed: January 2021.
- Chatman, D. 2013. Does TOD need the T? On the importance of factors other than rail access. *Journal of the American Planning Association* 79(1). Available: https://trid.trb.org/view/1243004. Accessed: January 2021.
- Institute of Transportation Engineers (ITE). 2019. Parking Generation Manual. 5th Edition. February. Available: https://ecommerce.ite.org/IMIS/ItemDetail?iProductCode=PG5-ALL. Accessed: May 2021.

T-16. Unbundle Residential Parking Costs from Property Cost

GHG Mitigation Potential

15.7%

Up to 15.7% of GHG emissions from project VMT in the study area

Co-Benefits (icon key on pg. 34)

Climate Resilience

Unbundling residential parking costs from property costs could incentivize increased use of public transit and thus result in less traffic, potentially reducing congestion or delays on major roads during peak AM and PM traffic periods. When this reduction occurs during extreme weather events, it better allows emergency responders to access a hazard site.

Health and Equity Considerations

The unbundling of parking costs would help decrease housing costs for individuals who do not own personal vehicles.

Measure Description

This measure will unbundle, or separate, a residential project's parking costs from property costs, requiring those who wish to purchase parking spaces to do so at an additional cost. On the assumption that parking costs are passed through to the vehicle owners/drivers utilizing the parking spaces, this measure results in decreased vehicle ownership and, therefore, a reduction in VMT and GHG emissions. Unbundling may not be available to all residential developments, depending on funding sources.

Subsector

Parking or Road Pricing/Management

Locational Context

Urban, suburban

Scale of Application

Project/Site

Implementation Requirements

Parking costs must be passed through to the vehicle owners/drivers utilizing the parking spaces for this measure to result in decreased vehicle ownership.

Cost Considerations

Unbundling residential parking costs from property costs may decrease revenue for property owners. This loss may be partially offset by reduced costs needed to maintain parking facilities with less car occupancy and the potential for non-resident parking as a supplementary income stream. For residents, reduced fees and the ability to go without owning a car is a major cost benefit. Municipalities also benefit from a reduction of cars on the road, which can lead to lower infrastructure and roadway maintenance costs.

Expanded Mitigation Options

Pair with Measure T-19-A or T-19-B to ensure that residents who eliminate their vehicle and shift to a bicycle can safely access the area's bikeway network.

GHG Reduction Formula

$$A = \frac{B}{C} \times D \times E$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from project VMT in study area	0–15.7	%	calculated
User Inputs				
B	Annual parking cost per space	[ ]	$ per year	user input
Constants, Assumptions, and Available Defaults				
C	Average annual vehicle cost	$9,282	$ per year	AAA 2019
D	Elasticity of vehicle ownership with respect to total vehicle cost	-0.4	unitless	Litman 2020
E	Adjustment factor from vehicle ownership to VMT	1.01	unitless	FHWA 2017

Further explanation of key variables:

- (B) – For most projects, this represents a monthly parking fee multiplied by 12. For deeded parking spaces, an estimate of the additional cost to a mortgage may be used, or the total cost may be prorated over 30 years. Costs to park will vary widely based on location; however, this value should consider if other nearby offsite parking options are available at lower cost. See Table T-16.1 in Appendix C for examples of monthly parking prices for different facility types.
- (C) – The average vehicle cost per year in 2019 was $9,282, based on a car driven 15,000 miles per year. Costs include gasoline, maintenance, insurance, license and registration, loan finance charges, and depreciation but do not include parking (AAA 2019).
- (D) – A synthesis of literature reported that, on the low end, a 0.4 percent decrease in vehicle ownership occurs for every 1 percent increase in total vehicle costs (Litman 2020).
- (E) – The adjustment factor from vehicle ownership to VMT is based on the following (FHWA 2017):
  - The average Californian household with 1 vehicle drives 11,117 miles per vehicle while households with 2 vehicles drives 11,223 miles per vehicle.
  - The reduction of 1 vehicle from a 2-vehicle household leads to a 0.94 percent decrease in VMT per vehicle.
  - So, $E = 1 - \left(\frac{11{,}117 \frac{\text{miles}}{\text{vehicle}} - 11{,}223 \frac{\text{miles}}{\text{vehicle}}}{11{,}223 \frac{\text{miles}}{\text{vehicle}}} \right) = 1.01$

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The GHG reduction from unbundled parking is capped at 15.7 percent, which is based on the use of (B_{max}) in the GHG reduction formula.

(B_{max}) The annual cost of parking space is capped at $3,600, or $300 per month. At monthly costs above $300, the cost of parking represents more than a 30 percent increase in total vehicle cost. In addition, this reflects the upper maximum of observed parking prices outside of extremely dense downtown areas (such as San Francisco's SOMA neighborhood).

Subsector Maximum

($\sum A_{max_{T\text{-}14 \text{ through } T\text{-}16}} \leq 35\%$) This measure is in the Parking or Road Pricing/Management subsector. This subcategory includes Measures T-14 through T-16. The VMT reduction from the combined implementation of all measures within this subsector is capped at 35 percent.

Example GHG Reduction Quantification

The user reduces VMT by unbundling the parking costs from property costs of a project, discouraging vehicle ownership, and therefore reducing VMT. In this example, the annual parking cost per space is $1,800 (B), which would reduce GHG emissions from project study area VMT (as compared to the same project with bundled parking costs) by 7.8 percent.

$$A = \left(\frac{\$1,800}{\$9,282}\right) \times -0.4 \times 1.01 = -7.8\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A).

Sources

- AAA. 2019. *Your Driving Costs.* September. Available: https://exchange.aaa.com/wp-content/uploads/2019/09/AAA-Your-Driving-Costs-2019.pdf. Accessed: January 2021.
- Federal Highway Administration (FHWA). 2017. *National Household Travel Survey – 2017 Table Designer.* Annual VMT / Vehicle by Count of Household Vehicles in California. Available: https://nhts.ornl.gov/. Accessed: March 2021.
- Litman, T. 2020. *Parking Requirement Impacts on Housing Affordability*. June. Available: https://www.vtpi.org/park-hou.pdf. Accessed: January 2021.

T-17. Improve Street Connectivity

GHG Mitigation Potential

30%

Up to 30.0% of GHG emissions from vehicle travel in the plan/community

Co-Benefits (icon key on pg. 34)

Climate Resilience

Improving street connectivity could increase route redundancy, allowing faster and more efficient travel during extreme weather events, evacuations, or for emergency vehicles requiring access to hazard sites.

Health and Equity Considerations

Multiple active modes routing options allows vulnerable road users to choose based on perceived safety, comfort, speed, and other factors.

Measure Description

This measure accounts for the VMT reduction achieved by a project that is designed with a higher density of vehicle intersections compared to the average intersection density in the U.S. Increased vehicle intersection density is a proxy for street connectivity improvements, which help to facilitate a greater number of shorter trips and thus a reduction in GHG emissions.

Subsector

Land Use

Locational Context

Urban, suburban

Scale of Application

Plan/Community

Implementation Requirements

Projects that increase intersection density would be building a new street network in a subdivision or retrofitting an existing street network to improve connectivity (e.g., converting cul-de-sacs or dead-end streets to grid streets).

Cost Considerations

Capital and infrastructure costs for improved street connectivity may be high. Depending on the location, losses may also be incurred through the reduction of sellable land due to the increased street footprint. Benefits come mainly from the reduction of traffic on arterial streets, which reduces congestion and allows for safer use of nonmotorized transportation, such as bikes. These outcomes, in turn, can reduce car usage, which provides costs savings to commuters and municipalities.

Expanded Mitigation Options

Pair with Measure T-18, *Provide Pedestrian Network Improvement*, to best support use of the local pedestrian network.

GHG Reduction Formula

$$A = \frac{B - C}{C} \times D$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from vehicle travel in plan/community	0–30.0	%	calculated
User Inputs				
B	Intersection density in project site with measure	[ ]	intersections per sq mile	user input
Constants, Assumptions, and Available Defaults				
C	Average intersection density	36	intersections per sq mile	Fehr & Peers 2009
D	Elasticity of VMT with respect to intersection density	-0.14	unitless	Stevens 2016

Further explanation of key variables:

- (C) – The average intersection density is based on the standard suburban intersection density in the U.S. (Fehr & Peers 2009). This density is approximately equivalent to block faces of 750 to 800 feet, or cul-de-sac–style built environments, which are appropriate for suburban areas.
- (D) – A meta-regression analysis of 15 studies found that a 0.14 percent decrease in VMT occurs for every 1 percent increase in intersection density (Stevens 2016).

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The percent reduction in GHG emissions (A) is capped at 30 percent. The purpose of the 30 percent cap is to limit the influence of any single built environmental factor (such as intersection density).

Subsector Maximum

Same as (A_{max}). Measure T-17 is the only measure at the Plan/Community scale within the Land Use subsector.

Example GHG Reduction Quantification

The user reduces VMT by constructing their project with a higher intersection density than the surrounding city. In this example, the project intersection density (B) would be 72 intersections per square mile (sq mile), which would reduce GHG emissions from project VMT by 14 percent.

$$A = \frac{72\ \frac{\text{int}}{\text{sq mile}} - 36\ \frac{\text{int}}{\text{sq mile}}}{36\ \frac{\text{int}}{\text{sq mile}}} \times -0.14 = -14\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A).

Sources

- Fehr & Peers. 2009. *Proposed Trip Generation, Distribution, and Transit Mode Split Forecasts for the Bayview Waterfront Project Transportation Study*.
- Stevens, M. 2016. Does Compact Development Make People Drive Less? *Journal of the American Planning Association* 83:1(7–18), DOI: 10.1080/01944363.2016.1240044. November. Available: https://www.researchgate.net/publication/309890412_Does_Compact_Development_Make_People_Drive_Less. Accessed: January 2021.

T-18. Provide Pedestrian Network Improvement

GHG Mitigation Potential

6.4%

Up to 6.4% of GHG emissions from vehicle travel in the plan/community

Co-Benefits (icon key on pg. 34)

Climate Resilience

Improving pedestrian networks increases accessibility of outdoor spaces, which can provide health benefits and thus improve community resilience. This can also improve connectivity between residents and resources that may be needed in an extreme weather event.

Health and Equity Considerations

Ensure that the improvements also include accessibility features to allow for people of all abilities to use the network safely and conveniently. Ensure that sidewalks connect to nearby community assets, such as schools, retail, and healthcare.

Measure Description

This measure will increase the sidewalk coverage to improve pedestrian access. Providing sidewalks and an enhanced pedestrian network encourages people to walk instead of drive. This mode shift results in a reduction in VMT and GHG emissions.

Subsector

Neighborhood Design

Locational Context

Urban, suburban, rural

Scale of Application

Plan/Community

Implementation Requirements

The GHG reduction of this measure is based on the VMT reduction associated with expansion of sidewalk coverage expansion, which includes not only building of new sidewalks but also improving degraded or substandard sidewalk (e.g., damaged from street tree roots). However, pedestrian network enhancements with non-quantifiable GHG reductions are encouraged to be implemented, as discussed under *Expanded Mitigation Options*.

Cost Considerations

Depending on the improvement, capital and infrastructure costs may be high. However, improvements to the pedestrian network will increase pedestrian activity, which can increase businesses patronage and provide a local economic benefit. The local municipality may achieve cost savings through a reduction of cars on the road leading to lower infrastructure and roadway maintenance costs.

Expanded Mitigation Options

When improving sidewalks, a best practice is to ensure they are contiguous and link externally with existing and planned pedestrian facilities. Barriers to pedestrian access and interconnectivity, such as walls, landscaping buffers, slopes, and unprotected crossings should be minimized. Other best practice features could include high-visibility crosswalks, pedestrian hybrid beacons, and other pedestrian signals, mid-block crossing walks, pedestrian refuge islands, speed tables, bulb-outs (curb extensions), curb ramps, signage, pavement markings, pedestrian-only connections and districts, landscaping, and other improvements to pedestrian safety (see Measure T-35, *Provide Traffic Calming Measures*).

GHG Reduction Formula

$$A = \left(\frac{C}{B} - 1\right) \times D$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from household vehicle travel in plan/community	0–6.4	%	calculated
User Inputs				
B	Existing sidewalk length in study area	[ ]	miles	user input
C	Sidewalk length in study area with measure	[ ]	miles	user input
Constants, Assumptions, and Available Defaults				
D	Elasticity of household VMT with respect to the ratio of sidewalks-to-streets	-0.05	unitless	Frank et al. 2011

Further explanation of key variables:

- (B and C) – Sidewalk length should be measured on both sides of the street. For example, if one 0.5-mile-long street has full sidewalk coverage, the sidewalk length would be 1.0 mile. If there is only sidewalk on one side of the street, the sidewalk length would be 0.5 mile. The recommended study area is 0.6 mile around the pedestrian network improvement. This represents a 6- to 10-minute walking time.
- (D) – A study found that a 0.05 percent decrease in household vehicle travel occurs for every 1 percent increase in the sidewalk-to-street ratio (Frank et al. 2011; Handy et al. 2014).

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The percent reduction in GHG emissions (A) is capped at 3.4 percent, which is based on the following assumptions:

- 35.2 percent of vehicle trips are short trips (2 mile or less, average of 1.29 miles) and thus could easily shift to walking (FHWA 2019).
- 64.8 percent of vehicle trips are longer trips that are unlikely to shift to walking (2 miles or more, average of 10.93 miles) (FHWA 2019).
- So $A_{max} = \frac{35.2\% \times 1.29 \text{ miles}}{64.8\% \times 10.93 \text{ miles}} = 6.4\%$

Subsector Maximum

($\sum A_{max_{T\text{-}18\ through\ T\text{-}22\text{-}D}} \leq 10\%$) This measure is in the Neighborhood Design subsector. This subcategory includes Measures T-18 through T-22-D. The VMT reduction from the combined implementation of all measures within this subsector is capped at 10 percent.

Example GHG Reduction Quantification

The user reduces household VMT by improving the pedestrian network in the study area. In this example, the existing sidewalk length (B) is 9 miles, and the sidewalk length with the measure (C) would be 10 miles. With these conditions, the user would reduce GHG emissions from household VMT within the study area by 0.6 percent.

$$A = \left(\frac{10\ \text{miles}}{9\ \text{miles}} - 1\right) \times \text{-}0.05 = \text{-}0.6\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in household VMT would be the same as the percent reduction in GHG emissions (A).

Improved Public Health

Users are directed to the Integrated Transport and Health Impact Model (ITHIM) (CARB et al. 2020). The ITHIM can quantify the annual change in health outcomes associated with active transportation, including deaths, years of life lost, years of living with disability, and incidence of community and individual disease.

Sources

- California Air Resources Board (CARB), California Department of Public Health (CDPH), and Nicholas Linesch Legacy Fund. 2020. Integrated Transport and Health Impact Model. Available: https://skylab.cdph.ca.gov/HealthyMobilityOptionTool-ITHIM/#Home. Accessed: September 17, 2021.
- Federal Highway Administration (FHWA). 2019. *2017 National Household Travel Survey Popular Vehicle Trip Statistics*. Available: https://nhts.ornl.gov/vehicle-trips. Accessed: January 2021.

- Frank, L., M. Greenwald, S. Kavage, and A. Devlin. 2011. *An Assessment of Urban Form and Pedestrian and Transit Improvements as an Integrated GHG Reduction Strategy*. WSDOT Research Report WA-RD 765.1, Washington State Department of Transportation. April. Available: www.wsdot.wa.gov/research/reports/fullreports/765.1.pdf. Accessed: January 2021.
- Handy, S., S. Glan-Claudia, and M. Boarnet. 2014. *Impacts of Pedestrian Strategies on Passenger Vehicle Use and Greenhouse Gas Emissions: Policy Brief.* September. Available: https://ww2.arb.ca.gov/sites/default/files/2020-06/Impacts_of_Pedestrian_Strategies_on_Passenger_Vehicle_Use_and_Greenhouse_Gas_Emissions_Policy_Brief.pdf. Accessed: January 2021.

T-19-A. Construct or Improve Bike Facility

GHG Mitigation Potential

0.8%

Up to 0.8% of GHG emissions from vehicles parallel roadways

Co-Benefits (icon key on pg. 34)

Climate Resilience

Constructing and improving bike facilities can incentivize more bicycle use and decrease vehicle use, which have health benefits and can thus improve community resilience. This can also improve connectivity between residents and resources that may be needed in an extreme weather event.

Health and Equity Considerations

Prioritize low-income and underserved areas and communities with lower rates of vehicle ownership or fewer transit options. Make sure that the bicycle facility connects to a larger existing bikeway network that accesses destinations visited by low-income or underserved communities.

Measure Description

This measure will construct or improve a single bicycle lane facility (only Class I, II, or IV) that connects to a larger existing bikeway network. Providing bicycle infrastructure helps to improve biking conditions within an area. This encourages a mode shift on the roadway parallel to the bicycle facility from vehicles to bicycles, displacing VMT and thus reducing GHG emissions. When constructing or improving a bicycle facility, a best practice is to consider local or state bike lane width standards. A variation of this measure is provided as T-19-B, *Construct or Improve Bike Boulevard*.

Subsector

Neighborhood Design

Locational Context

Urban, suburban

Scale of Application

Plan/Community. This measure reduces VMT on the roadway segment parallel to the bicycle facility (i.e., the corridor). An adjustment factor is included in the formula to scale the VMT reduction from the corridor level to the plan/community level.

Implementation Requirements

The bicycle lane facility must be either Class I, II, or IV. Class I bike paths are physically separated from motor vehicle traffic. Class IV bikeways are protected on-street bikeways, also called cycle tracks. Class II bike lanes are striped bicycle lanes that provide exclusive use to bicycles on a roadway.

Cost Considerations

Capital and infrastructure costs for new bike facilities may be high. The local municipality may achieve cost savings through a reduction of cars on the road leading to lower infrastructure and roadway maintenance costs.

Expanded Mitigation Options

Implement alongside Measures T-22-A, T-22-B, T-22-C, and/or T-22-D to ensure that micromobility users can ride safely along bicycle lane facilities and not have to ride along pedestrian infrastructure, which is a risk to pedestrian safety.

GHG Reduction Formula

$$A = -B \times \frac{\frac{F}{I} \times (C + D) \times E \times G}{H}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from displaced vehicles on roadway parallel to bicycle facility	0–0.8	%	calculated
User Inputs				
B	Percent of plan/community VMT on parallel roadway	0–100	%	user input
C	Active transportation adjustment factor	Table T-19.1	unitless	CARB 2020
D	Credits for key destinations near project	Table T-19.2	unitless	CARB 2020
E	Growth factor adjustment for facility type	Table T-19.3	unitless	CARB 2020
Constants, Assumptions, and Available Defaults				
F	Annual days of use of new facility	Table T-19.4	days per year	NOAA 2017
G	Existing regional average one-way bicycle trip length	Table T-10.1	miles per trip	FHWA 2017
H	Existing regional average one-way vehicle trip length	Table T-10.1	miles per trip	FHWA 2017
I	Days per year	365	days per year	standard

Further explanation of key variables:

- (B) – The percent of total plan/community VMT within the roadway parallel to the bike facility should represent the expected total VMT generated by all land use in that area, including office, residences, retail, schools, and other uses. The most appropriate source for this data is from a local travel demand forecasting model. An alternate method uses VMT per worker or VMT per resident as calculated for SB 743 compliance and screening purposes multiplied by the population in the area.
- (C, D, and E) – The active transportation adjustment factor, key destination credit, and growth factor adjustment should be looked up by the user in Tables T-19.1 through T-19.3 in Appendix C. The active transport adjustment factor is based on the existing annual average daily traffic (AADT) of the facility, length of the proposed bike facility, and the city population. The key destination credit is based on the number of key destinations within 0.5-mile of the facility. The growth factor is based on the type of proposed bicycle facility.
- (F) – The annual days of use for the new facility should be looked up by users in Table T-19.4 based on the county in which the project is located. The days of use is based on the number of days per year where there is no rainfall (i.e., <=0.1 inches) (NOAA 2017).

- (G and H) – Ideally, the user will calculate bicycle and vehicle trip lengths for the corridor at a scale no larger than the surrounding census tract. Potential data sources include the U.S. Census, California Household Travel Survey (preferred), or local survey efforts. If the user is not able to provide a project-specific value using one of these data sources, they have the option to input regional average one-way bicycle and vehicle trip lengths for one of the six most populated CBSAs in California provided in Table T-10.1 in Appendix C (FHWA 2017).

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) For projects that use CBSA data from Table T-10.1 in Appendix C, the maximum percent reduction in GHG emissions (A) is 0.8 percent. This is based on a neighborhood project the size of a large corridor (B = 100%) within the CBSA of Sacramento-Roseville-Arden-Arcade that uses the highest values for (C, D, and E) in Tables T-19.1 through T-19.3 and annual use days for Sacramento County (F) in Table T-19.4. This maximum scenario is presented in the below example quantification.

(C_{max}) The active transportation adjustment factor (C) was determined for roadways with AADT ranging from 1 to 30,000 (CARB 2020). Roadways with AADT greater than 30,000 are generally not appropriate for bicycle facilities. Care should be taken by the user in interpreting the results from this equation for a project roadway with AADT greater than 30,000.

Subsector Maximum

($\sum A_{max_{T\text{-}18\ through\ T\text{-}22\text{-}D}} \leq 10\%$) This measure is in the Neighborhood Design subsector. This subcategory includes Measures T-18 through T-22-D. The VMT reduction from the combined implementation of all measures within this subsector is capped at 10 percent.

Example GHG Reduction Quantification

The user reduces VMT by constructing a bicycle facility that displaces vehicle trips with bicycle trips. In this example, the following assumptions are made to obtain inputs from Tables T-19.1 through T-19.3 in Appendix C:

- Percent of plan/community VMT on parallel roadway (B) = 100%. The project would establish a bike corridor the whole length of a central commercial thoroughfare. It is assumed this main street makes up the entire neighborhood.
- Active transportation adjustment factor (C) = 0.0207. Existing AADT on the roadway parallel to the proposed bicycle facility is 10,000, the facility length is 2.5 miles, and the project site is in a university town with a population of 200,000.
- Key destination credit (D) = 0.003. There are 10 key destinations within 0.25 mile of the project site.
- Growth factor adjustment (E) = 1.54. The bike facility would be a new Class IV bikeway.

The project is within the Sacramento-Roseville-Arden-Arcade CBSA and the user does not have project-specific values for average bicycle and vehicle trip lengths. Accordingly, the inputs of 2.9 miles and 10.9 miles, respectively (G and H), from Table T-10.1 in Appendix C are assumed. The user would displace GHG emissions from project study area VMT by 0.8 percent.

$$A = \mathbf{-100\%} \times \left(\frac{\frac{307 \text{ days}}{365 \text{ days}} \times (\mathbf{0.0207} + \mathbf{0.003}) \times \mathbf{1.54} \times 2.9 \text{ miles}}{10.9 \text{ miles}} \right) = -0.8\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A).

Improved Public Health

Users are directed to the ITHIM (CARB et al. 2020). The ITHIM can quantify the annual change in health outcomes associated with active transportation, including deaths, years of life lost, years of living with disability, and incidence of community and individual disease.

Sources

- California Air Resources Board (CARB). 2020. *Quantification Methodology for the Strategic Growth Council's Affordable Housing and Sustainable Communities Program*. September. Available: https://ww2.arb.ca.gov/sites/default/files/classic/cc/capandtrade/auctionproceeds/draft_sgc_ahsc_qm_091620.pdf. Accessed: January 2021.
- California Air Resources Board (CARB), California Department of Public Health (CDPH), and Nicholas Linesch Legacy Fund. 2020. Integrated Transport and Health Impact Model. Available: https://skylab.cdph.ca.gov/HealthyMobilityOptionTool-ITHIM/#Home. Accessed: September 17, 2021.
- Federal Highway Administration (FHWA). 2017. *National Household Travel Survey–2017 Table Designer*. Travel Day PT by TRPTRANS by HH_CBSA. Available: https://nhts.ornl.gov/. Accessed: January 2021.

- National Oceanic and Atmospheric Administration (NOAA). 2021. *Global Historical Climatology Network–Daily (GHCN-Daily), Version 3*. 2015-2019 Average of Days Per Year with Precipitation >0.1 Inches. Available: https://www.ncei.noaa.gov/access/search/data-search/daily-summaries?bbox=38.922,-120.071,38.338,-119.547&place=County:1276&dataTypes=PRCP&startDate=2015-01-01T00:00:00&endDate=2019-01-01T23:59:59. Accessed: May 2021.

T-19-B. Construct or Improve Bike Boulevard

GHG Mitigation Potential

0.2%

Up to 0.2% of GHG emissions from vehicles on roadway

Co-Benefits (icon key on pg. 34)

Climate Resilience

Constructing and improving bike boulevards can incentivize more bicycle use and decrease vehicle use, which have health benefits and can thus improve community resilience. This can also improve connectivity between residents and resources that may be needed in an extreme weather event.

Health and Equity Considerations

Prioritize low-income and underserved areas and communities with lower rates of vehicle ownership or fewer transit options. Make sure that the bicycle boulevard connects to a larger existing bikeway network that accesses destinations visited by low-income or underserved communities.

Measure Description

Construct or improve a single bicycle boulevard that connects to a larger existing bikeway network. Bicycle boulevards are a designation within Class III Bikeway that create safe, low-stress connections for people biking and walking on streets. This encourages a mode shift from vehicles to bicycles, displacing VMT and thus reducing GHG emissions. A variation of this measure is provided as T-19-A, *Construct or Improve Bike Facility*, which is for Class I, II, or IV bicycle infrastructure.

Subsector

Neighborhood Design

Locational Context

Urban, suburban

Scale of Application

Plan/Community. This measure reduces VMT on the roadway segment parallel to the bicycle facility (i.e., the corridor). An adjustment factor is included in the formula to scale the VMT reduction from the corridor level to the plan/community level.

Implementation Requirements

The following roadway conditions must be met.

- Functional classification: local and collector if there is no more than a single general-purpose travel lane in each direction.
- Design speed: <= 25 miles per hour.
- Design volume <= 5,000 average daily traffic.
- Treatments at major intersections: both directions have traffic signals (or an effective control device that prioritizes pedestrian and bicycle access such as rapid flashing beacons, pedestrian hybrid beacons, high-intensity activated crosswalks, TOUCANs), bike route signs, “sharrowed” roadway markings, and pedestrian crosswalks.

Cost Considerations

Capital and infrastructure costs for new bike boulevards may be high, though lower than implementing the same length of protected bicycle lanes (Class IV). After the bike boulevard is complete, the local municipality may achieve cost savings from reduced infrastructure and roadway maintenance costs.

Expanded Mitigation Options

Construct boulevards with forced turns for vehicles every few blocks to minimize through traffic while ensuring that speed and volume metrics are met. Implement alongside Measures T-22-A, T-22-B, T-22-C, and/or T-22-D to ensure that micromobility users can ride safely along bicycle lane facilities and not pedestrian infrastructure, which is a risk to pedestrian safety.

GHG Reduction Formula

$$A = \mathbf{B} \times \frac{D \times (F - (C \times F))}{E \times G}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from displaced vehicles on roadway with bicycle boulevard	0–0.2	%	calculated
User Inputs				
B	Percent of plan/community VMT on roadway to have bicycle boulevard	0–100	%	user input
Constants, Assumptions, and Available Defaults				
C	Bike mode adjustment factor	1.14	unitless	Schwartz 2021
D	Existing bicycle trip length for all trips in region	Table T-10.1	miles	FHWA 2017a
E	Existing vehicle trip length for all trips in region	Table T-10.1	miles	FHWA 2017a
F	Existing bicycle mode share for work trips in region	Table T-10.2	%	FHWA 2017a
G	Existing vehicle mode share for work trips in region	Table T-10.2	%	FHWA 2017a

Further explanation of key variables:

- (C) – The bike mode adjustment factor is based on a database of before/after bicycle counts for 10 projects in four U.S. cities that invested in bicycle boulevards. Bicycle ridership increased on average by 114 percent (Schwartz 2021).
- (D and E) – Ideally, the user will calculate bicycle and vehicle trip lengths for the corridor at a scale no larger than the surrounding census tract. Potential data sources include the U.S. Census, California Household Travel Survey (preferred), or local survey efforts. If the user is not able to provide a project-specific value using one of these data sources, they have the option to input regional average one-way bicycle and vehicle trip lengths for one of the six most populated CBSAs in California provided in Table T-10.1 in Appendix C (FHWA 2017a).
- (F and G) – Ideally, the user will calculate bicycle and auto mode share for work trips for a Project/Site at a scale no larger than a census tract. Potential data sources include the U.S. Census, California Household Travel Survey (preferred), or local survey efforts. If the user is not able to provide a project-specific value using one of these data sources, they have the option to input the regional average mode shares for bicycle and vehicle work trips for one of the six most populated CBSAs in California, as presented in Table T-10.2 in Appendix C (FHWA 2017b). If the project study area is not within the listed

CBSAs or the user is able to provide a project-specific value, the user should replace these regional defaults in the GHG reduction formula. For areas not covered by the listed CBSAs, which represent the denser areas of the state, bicycle mode share is likely to be lower and vehicle share higher than presented in Table T-10.2.

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) For projects that use CBSA data from Tables T-10.1 and T-10.2 in Appendix C, the maximum percent reduction in GHG emissions (A) is 0.2 percent. This is based on a neighborhood project the size of a large corridor (B = 100%) within the CBSA of San Jose-Sunnyvale-Santa Clara that uses the highest values for (C, D, and E) in Tables T-19.1 through T-19.3 and annual use days for Sacramento County (F) in Table T-19.4. This maximum scenario is presented in the below example quantification.

Subsector Maximum

($\sum A_{max_{T\text{-}18 \text{ through } T\text{-}22\text{-}D}} \leq 10\%$) This measure is in the Neighborhood Design subsector. This subcategory includes Measures T-18 through T-22-D. The VMT reduction from the combined implementation of all measures within this subsector is capped at 10 percent.

Example GHG Reduction Quantification

The user reduces VMT by providing a bicycle boulevard on the targeted roadway, which encourages bicycle trips in place of vehicle trips. In this example, it is assumed this main street makes up the entire plan area, i.e., (B) is 100 percent. The project is within San Jose-Sunnyvale-Santa Clara CBSA and the user does not have project-specific values for trip lengths and mode shares for bicycles and vehicles. Per Tables T-10.1 and T-10.2, inputs for these variables are 2.8 miles, 11.5 miles, 4.1 percent, and 86.6 percent, respectively (D, E, F, and G). GHG emissions from plan/community VMT would be reduced by 0.2 percent.

$$A = \mathbf{100\%} \times \frac{2.8 \text{ miles} \times \left(4.1\% - (1.14 \times 4.1\%)\right)}{11.5 \text{ miles} \times 86.6\%} = \text{-}0.2\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A).

Improved Public Health

Users are directed to the ITHIM (CARB et al. 2020). The ITHIM can quantify the annual change in health outcomes associated with active transportation, including deaths, years of life lost, years of living with disability, and incidence of community and individual disease.

Sources

- California Air Resources Board (CARB), California Department of Public Health (CDPH), and Nicholas Linesch Legacy Fund. 2020. Integrated Transport and Health Impact Model. Available: https://skylab.cdph.ca.gov/HealthyMobilityOptionTool-ITHIM/#Home. Accessed: September 17, 2021.
- Federal Highway Administration (FHWA). 2017a. *National Household Travel Survey–2017 Table Designer*. Travel Day PT by TRPTRANS by HH_CBSA. Available: https://nhts.ornl.gov/. Accessed: January 2021.
- Federal Highway Administration (FHWA). 2017b. *National Household Travel Survey–2017 Table Designer*. Workers by WRKTRANS by HH_CBSA. Available: https://nhts.ornl.gov/. Accessed: January 2021.
- Schwartz, S. 2021. *Planning for Stress Free Connections: Estimating VMT Reductions.* February.

T-20. Expand Bikeway Network

GHG Mitigation Potential

0.5%

Up to 0.5% of GHG emissions from vehicle travel in the plan/community

Co-Benefits (icon key on pg. 34)

Climate Resilience

Expanding bikeway networks can incentivize more bicycle use and decrease vehicle use, which have health benefits and can thus improve community resilience. This can also improve connectivity between residents and resources that may be needed in an extreme weather event.

Health and Equity Considerations

Prioritize low-income and underserved areas and communities with lower rates of vehicle ownership or fewer transit options. Make sure that destinations visited by low-income or underserved communities are served by the network.

Measure Description

This measure will increase the length of a city or community bikeway network. A bicycle network is an interconnected system of bike lanes, bike paths, bike routes, and cycle tracks. Providing bicycle infrastructure with markings and signage on appropriately sized roads with vehicle traffic traveling at safe speeds helps to improve biking conditions (e.g., safety and convenience). In addition, expanded bikeway networks can increase access to and from transit hubs, thereby expanding the "catchment area" of the transit stop or station and increasing ridership. This encourages a mode shift from vehicles to bicycles, displacing VMT and thus reducing GHG emissions. When expanding a bicycle network, a best practice is to consider bike lane width standards from local agencies, state agencies, or the National Association of City Transportation Officials' *Urban Bikeway Design Guide*.

Subsector

Neighborhood Design

Locational Context

Urban, suburban

Scale of Application

Plan/Community

Implementation Requirements

The bikeway network must consist of either Class I, II, or IV infrastructure.

Cost Considerations

Capital and infrastructure costs for expanding the bikeway network may be high. Construction of these facilities may also increase vehicle traffic, leading to more congestion and temporarily longer trip times for motorist. However, the local municipality may achieve cost savings through a reduction of cars on the road leading to lower infrastructure and roadway maintenance costs.

Expanded Mitigation Options

As networks expand, ensure safe, secure, and weather-protected bicycle parking facilities at origins and destinations. Also, implement alongside T-22-A, T-22-B, T-22-C, and/or T-22-D to ensure that micromobility options can ride safely along bicycle lane facilities and not have to ride along pedestrian infrastructure, which is a risk to pedestrian safety.

GHG Reduction Formula

$$A = -1 \times \frac{\left(\frac{C - B}{B}\right) \times D \times F \times H}{E \times G}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from employee commute vehicle travel in plan/community	0–0.5	%	calculated
User Inputs				
B	Existing bikeway miles in plan/community	[ ]	miles	user input
C	Bikeway miles in plan/community with measure	[ ]	miles	user input
Constants, Assumptions, and Available Defaults				
D	Bicycle mode share in plan/community	Table T-20.1	%	FHWA 2017
E	Vehicle mode share in plan/community	Table T-3.1	%	FHWA 2017
F	Average one-way bicycle trip length in plan/community	Table T-10.1	miles per trip	FHWA 2017
G	Average one-way vehicle trip length in plan/community	Table T-10.1	miles per trip	FHWA 2017
H	Elasticity of bike commuters with respect to bikeway miles per 10,000 population	0.25	unitless	Pucher & Buehler 2011

Further explanation of key variables:

- (B) – The existing bikeway miles in a plan/community should be calculated by measuring the distance of all Class I, II, III, and IV bikeways within the plan/community. This information can sometimes be found in a city's bicycle master plan, if a plan has been prepared and is up to date.
- (D, E, F, and G) – Ideally, the user will calculate bicycle and auto mode share and trip length for a plan/community at the city scale. Potential data sources include the California Household Travel Survey (preferred) or local survey efforts. If the user is not able to provide a project-specific value using one of these data sources, they have the option to input the mode shares and trip lengths for bicycles and vehicles for one of the six most populated CBSAs in California, as presented in Table T-3.1, T-10.2, and T-20.1 in Appendix C. Trip lengths are likely to be longer for areas not covered by the listed CBSAs, which represent the denser areas of the state. Similarly, it is likely for areas outside of the area covered by the listed CBSAs to have vehicle mode shares higher and bicycle mode shares lower than the values provided in the tables.
- (H) – A multivariate analysis of the impacts of bike lanes on cycling levels in the 100 largest U.S. cities found that a 0.25 percent increase in commute cycling occurs for every 1 percent increase in bike lane distance (Pucher & Buehler 2011).

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) For projects that use CBSA data from Tables T-3.1, T-10.2, and T-20.1 in Appendix C, the maximum percent reduction in GHG emissions (A) is 0.5 percent. This is based on a project within the CBSA of San Jose-Sunnyvale-Santa Clara that has no existing bike lane infrastructure. This maximum scenario is presented in the below example quantification.

($\frac{C-B}{B}_{max}$) The maximum percent increase in bike lane miles in the plan/community is conservatively capped at 1000 percent. If there is no existing bike lane infrastructure in the plan/community, (B) should be set to (1/11×C), resulting in a percentage change of 1000 percent.

Subsector Maximum

($\sum A_{max_{T\text{-}18\text{ through }T\text{-}22\text{-}D}} \leq 10\%$) This measure is in the Neighborhood Design subsector. This subcategory includes Measures T-18 through T-22-D. The VMT reduction from the combined implementation of all measures within this subsector is capped at 10 percent.

Example GHG Reduction Quantification

The user reduces employee commute VMT by increasing the length of a bicycle network within a plan/community, which displaces commute vehicle trips with bicycle trips. In this example, the existing bikeway length in the plan/community (B) is 0 miles and the length with the measure (C) is 11 miles. The project is within the San Jose-Sunnyvale-Santa Clara CBSA, yielding the following inputs from Tables T-3.1, T-10.2, and T-20.1 in Appendix C.

- Bicycle mode share (D) = 0.79 percent.
- Vehicle mode share (E) = 91.32 percent.
- Average one-way bicycle trip length (F) = 2.8 miles.
- Average one-way vehicle trip length (G) = 11.5 miles.

The user would displace GHG emissions from project study area employee commute VMT by 0.5 percent.

$$A = -1 \times \left(\frac{(\mathbf{1000\%}) \times 0.79\% \times 2.8 \text{ miles} \times 0.25}{91.32\% \times 11.5 \text{ miles}}\right) = -0.5\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an

adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in employee commute VMT would be the same as the percent reduction in GHG emissions (A).

Improved Public Health

Users are directed to the ITHIM (CARB et al. 2020). The ITHIM can quantify the annual change in health outcomes associated with active transportation, including deaths, years of life lost, years of living with disability, and incidence of community and individual disease.

Sources

- California Air Resources Board (CARB), California Department of Public Health (CDPH), and Nicholas Linesch Legacy Fund. 2020. Integrated Transport and Health Impact Model. Available: https://skylab.cdph.ca.gov/HealthyMobilityOptionTool-ITHIM/#Home. Accessed: September 17, 2021.
- Federal Highway Administration (FHWA). 2017. *National Household Travel Survey – 2017 Table Designer*. Travel Day PMT by TRPTRANS by HH_CBSA. Available: https://nhts.ornl.gov/. Accessed: January 2021.
- Pucher, J., and Buehler, R. 2011. *Analysis of Bicycling Trends and Policies in Large North American Cities: Lessons for New York.* March. Available: http://www.utrc2.org/sites/default/files/pubs/analysis-bike-final_0.pdf. Accessed: January 2021.

T-21-A. Implement Conventional Carshare Program

GHG Mitigation Potential

0.15%

Up to 0.15% of GHG emissions from vehicle travel in the plan/community

Co-Benefits (icon key on pg. 34)

Climate Resilience

Carshare programs can increase accessibility and provide redundancy to vehicles that can be used to evacuate or obtain resources during an extreme weather event. Carshare programs can allow residents to give up or avoid car ownership, leading to cost savings that can help build economic resilience.

Health and Equity Considerations

Provide inclusive mechanisms so people without bank accounts, credit cards, or smart phones can access the system.

Measure Description

This measure will increase carshare access in the user's community by deploying conventional carshare vehicles. Carsharing offers people convenient access to a vehicle for personal or commuting purposes. This helps encourage transportation alternatives and reduces vehicle ownership, thereby avoiding VMT and associated GHG emissions. A variation of this measure, electric carsharing, is described in Measure T-21-B, *Implement Electric Carshare Program*.

Subsector

Neighborhood Design

Locational Context

Urban, suburban

Scale of Application

Plan/Community

Implementation Requirements

The GHG mitigation potential is based, in part, on literature analyzing one-way carsharing service with a free-floating operational model. This measure should be applied with caution if using a different form of carsharing (e.g., roundtrip, peer-to-peer, fractional).

Cost Considerations

The costs incurred by the carshare program service manager (typically a municipality or carshare company) may include the capital costs of purchasing vehicles; costs of storing, maintaining, and replacing the fleet; and costs for marketing and administration. Some of these costs may be offset by income generated through program use.

Expanded Mitigation Options

When implementing a carshare program, best practice is to discount carshare membership and provide priority parking for carshare vehicles to encourage use of the service.

GHG Reduction Formula

$$A = \frac{B \times (E - D)}{C}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from vehicle travel in plan/community	0–0.15	%	calculated
User Inputs				
B	Number of vehicles deployed in plan/community	[ ]	integer	user input
C	VMT in plan/community without measure	[ ]	VMT per day	user input
Constants, Assumptions, and Available Defaults				
D	Conventional VMT avoided with measure	68.2	VMT per day per vehicle	Martin and Shaheen 2016
E	Conventional VMT added with measure	24.4	VMT per day per vehicle	Martin and Shaheen 2016

Further explanation of key variables:

- (B) – The number of cars in the carshare program is selected by the carshare provider, but its magnitude is relative to the size of the service area. A study of several carsharing programs (Martin and Shaheen 2016) documented a range of carshare fleet sizes for different North American cities: Calgary (590), San Diego (406), Seattle (640), Vancouver (920), Washington, D.C. (626).
- (C) – The total plan/community VMT should represent the expected total VMT generated by all land use in that area. The most appropriate source for this data is from a local travel demand model.
- (D) – Conventional VMT avoided per deployed carshare vehicle was derived based on a study of conventional-engine based car share programs in Calgary, Seattle, Vancouver, and Washington, D.C. It accounts for VMT avoided from carshare users who sold their personal vehicles and carshare users who decided not to purchase a personal vehicle, both directly because of the availability of carshare (Martin and Shaheen 2016).
- (E) – Conventional VMT added per deployed carshare vehicle was derived based on a study of conventional-engine based car share programs in Calgary, Seattle, Vancouver, and Washington, D.C. It accounts for the VMT of the carshare vehicles (Martin and Shaheen 2016).

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The maximum GHG reduction from this measure is 0.15 percent. This maximum scenario is presented in the below example quantification.

Subsector Maximum

($\sum A_{max_{T\text{-}18\text{ through }T\text{-}22\text{-}D}} \leq 10\%$) This measure is in the Neighborhood Design subsector. This subcategory includes Measures T-18 through T-22-D. The VMT reduction from the combined implementation of all measures within this subsector is capped at 10 percent.

Example GHG Reduction Quantification

The user reduces plan/community VMT by deploying carshare vehicles. In this example, the project would be in the city of San Diego, which in 2017 had a VMT per day of 24,101,089 miles (C) (SANDAG 2019). Assuming twice the number of vehicles used in the Car2go San Diego program (B), the GHG emissions from plan/community VMT would be reduced by 0.15 percent.

$$A = \frac{\textbf{812 vehicles} \times \left(24.4 \frac{\text{VMT}}{\text{day}\cdot\text{vehicle}} - 68.2 \frac{\text{VMT}}{\text{day}\cdot\text{vehicle}}\right)}{\textbf{24,101,089} \frac{\textbf{VMT}}{\textbf{day}}} = \text{-}0.15\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A).

Sources

- Martin, E. and S. Shaheen. 2016. *The Impacts of Car2go on Vehicle Ownership, Modal Shift, Vehicle Miles Traveled, and Greenhouse Gas Emissions: An Analysis of Five North American Cities.* July. Available: https://tsrc.berkeley.edu/publications/impacts-car2go-vehicle-ownership-modal-shift-vehicle-miles-traveled-and-greenhouse-gas. Accessed: March 2021.
- San Diego Association of Governments (SANDAG). 2019. *Mobility Management VMT Reduction Calculator Tool – Design Document.* June. Available: https://www.icommutesd.com/docs/default-source/planning/tool-design-document_final_7-17-19.pdf?sfvrsn=ec39eb3b_2. Accessed: January 2021.

T-21-B. Implement Electric Carshare Program

GHG Mitigation Potential

0.18%

Up to 0.18% of GHG emissions from vehicle travel in the plan/community

Co-Benefits (icon key on pg. 34)

Climate Resilience

Electric carshare programs can increase accessibility and provide redundancy to vehicles that can be used to evacuate or obtain resources during an extreme weather event. Electric vehicles also provide fuel redundancy by allowing an alternative fuel source if an extreme event disrupts other fuel sources; however, they may decrease resilience if they are the only option available during a power outage.

Health and Equity Considerations

Provide inclusive mechanisms so people without bank accounts, credit cards, or smart phones can access the system.

Measure Description

This measure will increase carshare access in the user's community by deploying electric carshare vehicles. Carsharing offers people convenient access to a vehicle for personal or commuting purposes. This helps encourage transportation alternatives and reduces vehicle ownership, thereby avoiding VMT and associated GHG emissions. This also encourages a mode shift from internal combustion engine vehicles to electric vehicles, displacing the emissions-intensive fossil fuel energy with less emissions-intensive electricity. Electric carshare vehicles require more staffing support compared to conventional carshare programs for shuttling electric vehicles to and from charging points. A variation of this measure, conventional carsharing, is described in Measure T-21-A, *Implement Conventional Carshare Program*.

Subsector

Neighborhood Design

Locational Context

Urban, suburban

Scale of Application

Plan/Community

Implementation Requirements

The GHG mitigation potential is based, in part, on literature analyzing one-way carsharing service with a free-floating operational model. This measure should be applied with caution if using a different form of carsharing (e.g., roundtrip, peer-to-peer, fractional).

Cost Considerations

Costs incurred by the service manager (e.g., municipality, carshare company) may include the capital costs of purchasing vehicles; costs of storing, maintaining, and replacing the fleet; and costs for marketing and administration. Some of these costs may be offset by income generated through program use. Participants' recurring costs of renting a carshare vehicle may be offset by the cost savings from access to cheaper transportation.

Expanded Mitigation Options

When implementing a carshare program, best practice is to discount carshare membership and provide priority parking for carshare vehicles to encourage use of the service.

GHG Reduction Formula

$$A = -1 \times \frac{B \times ((E \times G \times H \times I \times J) - (D \times F))}{C \times F}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from vehicle travel in plan/community	0–0.18	%	calculated
User Inputs				
B	Number of electric vehicles deployed in plan/community	[ ]	integer	user input
C	VMT in plan/community without measure	[ ]	VMT per day	user input
Constants, Assumptions, and Available Defaults				
D	Conventional VMT avoided with measure	54.8	VMT per day per EV	Martin and Shaheen 2016
E	Electric VMT added with measure	13.7	VMT per day per EV	Martin and Shaheen 2016
F	Emission factor of non-electric light duty fleet mix	307.5	g CO_2e per mile	CARB 2020a
G	Energy efficiency of carshare electric vehicle	0.327	kWh per mile	CARB 2020b; U.S. DOE 2021
H	Carbon intensity of local electricity provider	Tables E-4.3 and E-4.4	lb CO_2e per MWh	CA Utilities 2021
I	Conversion from lb to g	454	g per lb	conversion
J	Conversion from kWh to MWh	0.001	MWh per kWh	conversion

Further explanation of key variables:

- (B) – The number of cars in the carshare program is selected by the carshare provider, but its magnitude is relative to the size of the service area. A study of several carsharing programs (Martin and Shaheen 2016) documented a range of carshare fleet sizes for different North American cities: Calgary (590), San Diego (406), Seattle (640), Vancouver (920), Washington, D.C. (626).
- (C) – The total plan/community VMT should represent the expected total VMT generated by all land use in that area. The most appropriate source for this data is from a local travel demand forecasting model.
- (D) – Conventional VMT avoided per deployed carshare vehicle was derived based on a study of an electric vehicle carshare program in San Diego. It accounts for VMT avoided from carshare users who sold their personal vehicles and carshare users who decided not to purchase a personal vehicle, both directly because of the availability of carshare (Martin and Shaheen 2016).

- (E) – Electric VMT added per deployed carshare vehicle was derived based on a study of an electric vehicle carshare program in San Diego. It accounts for the VMT of the carshare vehicles and includes staff-driven VMT needed to bring the vehicles to charging points (Martin and Shaheen 2016).
- (F) – The average GHG emission factor for non-electric vehicles was calculated in terms of CO_2e per mile using EMFAC2017 (v1.0.3). The model was run for a 2020 statewide average of LDA, LDT1, and LDT2 vehicles using diesel and gasoline fuel. The running emission factors for CO_2, CH_4, and N_2O (CARB 2020a) were multiplied by the corresponding 100-year GWP values from the IPCC's Fourth Assessment Report (IPCC 2007). If the user can provide a project-specific value (i.e., for a future year and project location), the user should run EMFAC to replace the default in the GHG reduction formula.
- (G) – Scaled from light-duty automobile gasoline equivalent fuel economy (G from Measure T-14) based on energy efficiency ratio (EER) of 2.5 (CARB 2020b) and an assumption of 33.7 kWh electricity per gallon of gasoline (U.S. DOE 2021).
- (H) – GHG intensity factors for major California electricity providers are provided in Tables E-4.3 and E-4.4 in Appendix C. If the project study area is not serviced by a listed electricity provider, or the user is able to provide a project-specific value (i.e., for the future year not referenced in Appendix C), the user should replace the default in the GHG calculation formula. If the electricity provider is not known, the user may elect to use the statewide grid average carbon intensity.

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The maximum GHG reduction from this measure is 0.18 percent. This maximum scenario is presented in the below example quantification.

Subsector Maximum

($\sum A_{max_{T\text{-}18 \text{ through } T\text{-}22\text{-}D}} \leq 10\%$) This measure is in the Neighborhood Design subsector. This subcategory includes Measures T-18 through T-22-D. The VMT reduction from the combined implementation of all measures within this subsector is capped at 10 percent.

Example GHG Reduction Quantification

The user reduces plan/community VMT by deploying carshare vehicles. In this example, the project would be in the city of San Diego, which in 2017 had a VMT per day of 24,101,089 miles (C) (SANDAG 2019). Assuming twice the number of vehicles used in the Car2go San Diego program (B), and a commitment by the carshare service provider to purchase zero-carbon electricity for all carshare charging stations (H), the GHG emissions from plan/community VMT would be reduced by 0.18 percent.

A =

$$-1 \times \frac{812 \times \left(\left(13.7\,\frac{\text{eVMT}}{\text{day}\cdot\text{vehicle}} \times 0.327\,\frac{\text{kWh}}{\text{mile}} \times 0\,\frac{\text{lb } CO_2e}{\text{MWh}} \times 454\,\frac{\text{g}}{\text{lb}} \times 0.001\,\frac{\text{MWh}}{\text{kWh}}\right) - \left(54.8\,\frac{\text{cVMT}}{\text{day}\cdot\text{vehicle}} \times 307.5\,\frac{\text{g } CO_2e}{\text{mile}}\right)\right)}{24{,}101{,}089\,\frac{\text{VMT}}{\text{day}} \times 307.5\,\frac{\text{g } CO_2e}{\text{mile}}} = -0.18\%$$

Quantified Co-Benefits

Improved Local Air Quality

Local criteria pollutants will be reduced by the reduction in vehicle fuel consumption. Electricity supplied by statewide fossil-fueled or bioenergy power plants will generate criteria pollutants. However, because these power plants are located throughout the state, electricity consumption from electric vehicles will not generate localized criteria pollutant emissions. Accordingly, the percent reduction in NO_X, CO, NO_2, SO_2, and PM (K) is calculated using a simplified version of the GHG reduction formula, as follows:

$$K = -1 \times \frac{B \times -D}{C}$$

Reductions in ROG emissions can be calculated by multiplying the percent reduction in other criteria pollutant emissions (K) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Fuel Savings (Increased Electricity)

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in criteria pollutant emissions (K). The percent increase in electricity use (L) from this measure can be calculated using a variation of the GHG reduction formula, as follows.

Electricity Use Increase Formula

$$L = \frac{B \times E \times G \times N}{M}$$

Electricity Use Increase Calculation Variables

ID	Variable	Value	Unit	Source
Output				
L	Increase in electricity from electric vehicles	[ ]	%	calculated
User Inputs				
M	Existing electricity consumption of plan/community	[ ]	kWh per year	user input
Constants, Assumptions, and Available Defaults				
N	Days per year carshare program operational	365	days per year	assumed

Further explanation of key variables:

- (M) – The user should take care to properly quantify building electricity using accepted methodologies (such as CalEEMod).
- Please refer to the GHG Calculation Variables table above for definitions of variables that have been previously defined.

VMT Reductions

The percent reduction in VMT (O) is calculated using a simplified version of the GHG reduction formula that excludes the variables related to emission factors, as follows.

$$O = -1 \times \frac{B \times (E - D)}{C}$$

Sources

- California Air Resources Board (CARB). 2020a. *EMFAC2017 v1.0.3*. August. Available: https://arb.ca.gov/emfac/emissions-inventory. Accessed: January 2021.
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T-22-A. Implement Pedal (Non-Electric) Bikeshare Program

GHG Mitigation Potential

0.02%

Up to 0.02% of GHG emissions from vehicle travel in the plan/community

Co-Benefits (icon key on pg. 34)

Climate Resilience

Bikeshare programs can incentivize more bicycle use and decrease vehicle use, which have health benefits and can thus improve community resilience. This can also improve connectivity between residents and resources that may be needed in an extreme weather event.

Health and Equity Considerations

Provide inclusive mechanisms so people without bank accounts, credit cards, or smart phones can access the system.

Measure Description

This measure will establish a bikeshare program. Bikeshare programs provide users with on-demand access to bikes for short-term rentals. This encourages a mode shift from vehicles to bicycles, displacing VMT and thus reducing GHG emissions. Variations of this measure are described in Measure T-22-B, *Implement Electric Bikeshare Program*, Measure T-22-C, *Implement Scootershare Program,* and Measure T-22-D, *Transition Conventional to Electric Bikeshare*.

Subsector

Neighborhood Design

Locational Context

Urban, suburban

Scale of Application

Plan/Community

Implementation Requirements

The GHG mitigation potential is based, in part, on literature analyzing docked (i.e., station-based) bikeshare programs. This measure should be applied with caution if using dockless (free-floating) bikeshare.

Cost Considerations

The costs incurred by the service manager (e.g., municipality or bikeshare company) may include the capital costs for purchasing a bicycle fleet; installing accessible and secure docking stations; storing, maintaining, and replacing the fleet; and marketing and administration. Some of these costs may be offset by income generated through program use. Program participants will benefit from the cost savings from access to cheaper transportation alternatives (compared to private vehicles, private bicycles, or use of ride-hailing services). The local municipality may achieve cost savings through a reduction of cars on the road leading to lower infrastructure and roadway maintenance costs.

Expanded Mitigation Options

Best practice is to discount bikeshare membership and dedicate bikeshare parking to encourage use of the service. Also consider including space on the vehicle to store personal items while traveling, such as a basket.

GHG Reduction Formula

This measure methodology does not account for the direct GHG emissions from vehicle travel of program employees picking up and dropping off bikes.

$$A = -1 \times \frac{(C - B) \times D \times E \times F}{G \times H}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from vehicle travel in plan/community	0–0.02	%	calculated
User Inputs				
B	Percent of residences in plan/community with access to bikeshare system without measure	0–100	%	user input
C	Percent of residences in plan/community with access to bikeshare system with measure	0–100	%	user input
Constants, Assumptions, and Available Defaults				
D	Daily bikeshare trips per person	0.021	trips per day per person	MTC 2017
E	Vehicle to bikeshare substitution rate	19.6	%	McQueen et al. 2020
F	Bikeshare average one-way trip length	1.4	miles per trip	Lazarus et al. 2019
G	Daily vehicle trips per person	2.7	trips per day per person	FHWA 2018
H	Regional average one-way vehicle trip length	Table T-10.1	miles per trip	FHWA 2017

Further explanation of key variables:

- (B and C) – Access to bikesharing is measured as the percent of residences in the plan/community within 0.25 mile of a bikeshare station. For dockless bikes, assume that all residences within 0.25 mile of the designated dockless service area would have access.
- (D) – An analysis of bike share service areas in the San Francisco Bay Area estimated that in locations with access to bikesharing, there were between 21 and 25 bikeshare trips per day per 1,000 residents (MTC 2017). To be conservative, the low end of this range is cited.
- (E) – A literature review of several academic and government reports found that the average car trip substitution rate by bikeshare trips was 19.6 percent. This included bikeshare programs in Washington D.C., Minneapolis, and Montreal (McQueen et al. 2020).

- (F) – A case study on average trip lengths for pedal and electric bikeshare programs in San Francisco reported a one-way pedal bikeshare trip of 1.4 miles (Lazarus et al. 2019).
- (G) – A summary report of the 2017 National Household Travel Survey data found that the average person in the U.S. takes 2.7 vehicle trips per day (FHWA 2018).
- (H) – Ideally, the user will calculate auto trip length for a plan/community at a scale no larger than a census tract. Potential data sources include the U.S. Census, California Household Travel Survey (preferred), or local survey efforts. If the user is not able to provide a plan-specific value using one of these data sources, they have the option to input the existing regional average one-way auto trip length for one of the six most populated CBSAs in California, as presented in Table T-10.1 in Appendix C (FHWA 2017). Trip lengths are likely to be longer for areas not covered by the listed CBSAs, which represent the denser areas of the state.

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) For projects that use default CBSA data from Table T-10.1, the maximum percent reduction in GHG emissions (A) is 0.02 percent. This maximum scenario is presented in the below example quantification.

Subsector Maximum

($\sum A_{max_{T\text{-}18 \text{ through } T\text{-}22\text{-}D}} \leq 10\%$) This measure is in the Neighborhood Design subsector. This subcategory includes Measures T-18 through T-22-D. The VMT reduction from the combined implementation of all measures within this subsector is capped at 10 percent.

Example GHG Reduction Quantification

The user reduces plan/community VMT by deploying bikesharing throughout the area. In this example, the project is in the Los Angeles-Long Beach-Anaheim CBSA, and the one-way vehicle trip length would be 9.72 miles (H). Assuming 100 percent of residents in the plan/community would have bikeshare access (C) where there was no existing access (B), the user would reduce GHG emissions from plan/community VMT by 0.02 percent.

$$A = -1 \times \frac{(\mathbf{100\% - 0\%}) \times 0.021 \dfrac{\text{trips}}{\text{day·person}} \times 19.6\% \times 1.4 \dfrac{\text{miles}}{\text{trip}}}{2.7 \dfrac{\text{trips}}{\text{day·person}} \times 9.72 \dfrac{\text{miles}}{\text{trip}}} = -0.02\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an

adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A).

Sources

- Federal Highway Administration (FHWA). 2017. *National Household Travel Survey–2017 Table Designer*. Travel Day PT by TRPTRANS by HH_CBSA. Available: https://nhts.ornl.gov/. Accessed: January 2021.
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T-22-B. Implement Electric Bikeshare Program

GHG Mitigation Potential

0.06%

Up to 0.06% of GHG emissions vehicle travel in the plan/community

Co-Benefits (icon key on pg. 34)

Climate Resilience

Bikeshare programs can incentivize more bicycle use and decrease vehicle use, which have health benefits and can thus improve community resilience. This can also improve connectivity between residents and resources that may be needed in an extreme weather event. However, they may decrease resilience if they are the only option available during a power outage.

Health and Equity Considerations

Provide inclusive mechanisms so people without bank accounts, credit cards, or smart phones can access the system.

Measure Description

This measure will establish an electric bikeshare program. Electric bikeshare programs provide users with on-demand access to electric pedal assist bikes for short-term rentals. This encourages a mode shift from vehicles to electric bicycles, displacing VMT and reducing GHG emissions. Variations of this measure are described in Measure T-22-A, *Implement Pedal (Non-Electric) Bikeshare Program*, Measure T-22-C, *Implement Scootershare Program,* and Measure T-22-D, *Transition Conventional to Electric Bikeshare*.

Subsector

Neighborhood Design

Locational Context

Urban, suburban

Scale of Application

Plan/Community

Implementation Requirements

The GHG mitigation potential is based, in part, on literature analyzing docked (i.e., station-based) bikeshare programs. This measure should be applied with caution if using dockless (free-floating) bikeshare.

Cost Considerations

The costs incurred by the service manager (e.g., municipality or bikeshare company) may include the capital costs for purchasing a bicycle fleet; installing accessible and secure charging stations; storing, maintaining, and replacing the fleet; and marketing and administration. Some of these costs may be offset by income generated through program use. Program participants will benefit from the cost savings from access to cheaper transportation alternatives (compared to private vehicles, private bicycles, or use of ride-hailing services). The local municipality may achieve cost savings through a reduction of cars on the road leading to lower infrastructure and roadway maintenance costs.

Expanded Mitigation Options

Best practice is to discount electric bikeshare membership and dedicate electric bikeshare parking to encourage use of the service. Consider also including space on the vehicle to store personal items while traveling, such as a basket.

GHG Reduction Formula

The quantification methodology does not account for indirect GHG emissions from electricity used to charge the bicycles or direct GHG emissions from vehicle travel of program employees picking up and dropping off bikes.

$$A = -1 \times \frac{(C - B) \times D \times E \times F}{G \times H}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from vehicle travel in plan/community	0–0.06	%	calculated
User Inputs				
B	Percent of residences in plan/community with access to electric bikeshare system without measure	0–100	%	user input
C	Percent of residences in plan/community with access to electric bikeshare system with measure	0–100	%	user input
Constants, Assumptions, and Available Defaults				
D	Daily electric bikeshare trips per person	0.021	trips per day per person	MTC 2017
E	Vehicle to electric bikeshare substitution rate	35	percent	Fitch et al. 2021
F	Electric bikeshare average one-way trip length	2.1	miles per trip	Fitch et al. 2021
G	Daily vehicle trips per person	2.7	trips per day per person	FHWA 2018
H	Regional average one-way vehicle trip length	Table T-10.1	miles per trip	FHWA 2017

Further explanation of key variables:

- (B and C) – Access to electric bikesharing is measured as the percent of residences in the plan/community within 0.25-mile of an electric bikeshare station. For dockless bikes, assume that all residences within 0.25 mile of the designated dockless service area would have access.
- (D) – An analysis of bike share service areas in the San Francisco Bay Area estimated that in locations with access to bikesharing, there were between 21 and 25 bikeshare trips per day per 1,000 residents (MTC 2017). To be conservative, the low end of this range is cited. Conventional bikeshare trip rate data was used due to lack of specific data for electric bikeshare.
- (E) – A study of dockless electric bike share in Sacramento found that the substitution rate of vehicles trips by electric bikeshare trips was 35 percent (Fitch et al. 2021).

- (F) – A study of dockless electric bike share in Sacramento found that the average one-way bikeshare trip was 2.1 miles (Fitch et al. 2021).
- (G) – A summary report of the 2017 National Household Travel Survey data found that the average person in the U.S. takes 2.7 vehicle trips per day (FHWA 2018).
- (H) – Ideally, the user will calculate auto trip length for a plan/community at a scale no larger than a census tract. Potential data sources include the U.S. Census, California Household Travel Survey (preferred), or local survey efforts. If the user is not able to provide a plan-specific value using one of these data sources, they have the option to input the existing regional average one-way auto trip length for one of the six most populated CBSAs in California, as presented in Table T-10.1 in Appendix C (FHWA 2017). Trip lengths are likely to be longer for areas not covered by the listed CBSAs, which represent the denser areas of the state.

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) For projects that use default CBSA data from Table T-10.1, the maximum percent reduction in GHG emissions (A) is 0.06 percent. This maximum scenario is presented in the below example quantification.

Subsector Maximum

($\sum A_{max_{T\text{-}18\text{ through }T\text{-}22\text{-}D}} \leq 10\%$) This measure is in the Neighborhood Design subsector. This subcategory includes Measures T-18 through T-22-D. The VMT reduction from the combined implementation of all measures within this subsector is capped at 10 percent.

Example GHG Reduction Quantification

The user reduces plan/community VMT by deploying electric bikesharing throughout the area. In this example, the project is in the Los Angeles-Long Beach-Anaheim CBSA, and the one-way vehicle trip length would be 9.72 miles (H). Assuming 100 percent of residents in the plan/community would have bikeshare access (C) where there was no existing access (B), the user would reduce GHG emissions from plan/community VMT by 0.06 percent.

$$A = -1 \times \frac{(\mathbf{100\% - 0\%}) \times 0.021\ \frac{\text{trips}}{\text{day}\cdot\text{person}} \times 35\% \times 2.1\ \frac{\text{miles}}{\text{trip}}}{2.7\ \frac{\text{trips}}{\text{day}\cdot\text{person}} \times 9.72\ \frac{\text{miles}}{\text{trip}}} = -0.06\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an

adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A). This quantification methodology does not account for the increase in electricity used to charge the vehicles or the fuel consumption from vehicle travel of program employees picking up and dropping off bikes.

VMT Reductions

The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A). This quantification methodology does not account for the miles traveled from vehicle travel of program employees picking up and dropping off bikes.

Sources

- Federal Highway Administration (FHWA). 2017. *National Household Travel Survey–2017 Table Designer*. Travel Day PT by TRPTRANS by HH_CBSA. Available: https://nhts.ornl.gov/. Accessed: January 2021.
- Federal Highway Administration (FHWA). 2018. *Summary of Travel Trends 2017–National Household Travel Survey*. July. Available: https://www.fhwa.dot.gov/policyinformation/documents/2017_nhts_summary_travel_trends.pdf. Accessed: January 2021.
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- Metropolitan Transportation Commission (MTC). 2017. *Plan Bay Area 2040 Final Supplemental Report–Travel Modeling Report*. July. Available: http://2040.planbayarea.org/files/2020-02/Travel_Modeling_PBA2040_Supplemental%20Report_7-2017.pdf. Accessed: January 2021.

T-22-C. Implement Scootershare Program

GHG Mitigation Potential

0.07%

Up to 0.07% of GHG emissions from vehicle travel in the plan/community

Co-Benefits (icon key on pg. 34)

Climate Resilience

Scootershare programs can incentivize more scooter use and decrease vehicle use, which have health benefits and can thus improve community resilience. This can also improve connectivity between residents and resources that may be needed in an extreme weather event.

Health and Equity Considerations

Provide inclusive mechanisms so people without bank accounts, credit cards, or smart phones can access the system.

Measure Description

This measure will establish a scootershare program. Scootershare programs provide users with on-demand access to electric scooters for short-term rentals. This encourages a mode shift from vehicles to scooters, displacing VMT and thus reducing GHG emissions. Variations of this measure are described in Measure T-22-A, *Implement Pedal (Non-Electric) Bikeshare Program*, and Measure T-22-B, *Implement Electric Bikeshare Program,* and Measure T-22-D, *Transition Conventional to Electric Bikeshare*.

Subsector

Neighborhood Design

Locational Context

Urban, suburban

Scale of Application

Plan/Community

Implementation Requirements

The GHG mitigation potential is based, in part, on literature analyzing docked (i.e., station-based) bikeshare programs. This measure should be applied with caution given the likely higher popularity of scootershare compared to bikeshare.

Cost Considerations

The costs incurred by the service manager (e.g., municipality or scootershare company) may include the capital costs for purchasing a scooter fleet; installing accessible and secure docking stations; storing, maintaining, and replacing the fleet; and marketing and administration. Some of these costs may be offset by income generated through program use. Program participants will benefit from cost savings from access to cheaper transportation alternatives (compared to private vehicles, private scooters, or use of ride-hailing services). The local municipality may achieve cost savings through a reduction of cars on the road leading to lower infrastructure and roadway maintenance costs.

Expanded Mitigation Options

Best practice is to discount scootershare membership and dedicate scootershare parking to encourage use of the service. Consider also including space on the vehicle to store personal items while traveling, such as a basket.

GHG Reduction Formula

This measure methodology does not account for the indirect GHG emissions from electricity used to charge the scooters or direct GHG emissions from vehicle travel of program employees picking up and dropping off scooters.

$$A = -1 \times \frac{(C - B) \times D \times E \times F}{G \times H}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from vehicle travel in plan/community	0–0.07	%	calculated
User Inputs				
B	Percent of residences in plan/community with access to scootershare system without measure	0–100	%	user input
C	Percent of residences in plan/community with access to scootershare system with measure	0–100	%	user input
Constants, Assumptions, and Available Defaults				
D	Daily scootershare trips per person	0.021	trips per day per person	MTC 2017
E	Vehicle to scootershare substitution rate	38.5	%	McQueen et al. 2020
F	Scootershare average one-way trip length	2.14	miles per trip	PBOT 2021
G	Daily vehicle trips per person	2.7	trips per day per person	FHWA 2018
H	Regional average one-way vehicle trip length	Table T-10.1	miles per trip	FHWA 2017

Further explanation of key variables:

- (B and C) – Access to scootersharing is measured as the percent of residences in the plan/community within 0.25-mile of a scootershare station. For dockless scooters, assume that all residences within 0.25-mile of the designated dockless service area would have access.
- (D) – An analysis of bike share service areas in the San Francisco Bay Area estimated that in locations with access to bikesharing, there were between 21 and 25 bikeshare trips per day per 1,000 residents (MTC 2017). To be conservative, the low end of this range is cited. Conventional bikeshare trip rate data was used due to lack of specific data for scootershare.
- (E) – A literature review of several academic and government reports found that the average car trip substitution rate by scootershare trips was 38.5 percent. This included scootershare programs in Santa Monica, Minneapolis, San Francisco, and Portland (McQueen et al. 2020).

- (F) – In Oregon, Portland's scootershare pilot data dashboard reports that the average trip length of scootershare trips is 2.14 miles (PBOT 2021).
- (G) – A summary report of the 2017 National Household Travel Survey data found that the average person in the U.S. takes 2.7 vehicle trips per day (FHWA 2018).
- (H) – Ideally, the user will calculate auto trip length for a plan/community at a scale no larger than a census tract. Potential data sources include the U.S. Census, California Household Travel Survey (preferred), or local survey efforts. If the user is not able to provide a plan-specific value using one of these data sources, they have the option to input the existing regional average one-way auto trip length for one of the six most populated CBSAs in California, as presented in Table T-10.1 in Appendix C (FHWA 2017). Trip lengths are likely to be longer for areas not covered by the listed CBSAs, which represent the denser areas of the state.

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) For projects that use default CBSA data from Table T-10.1, the maximum percent reduction in GHG emissions (A) is 0.07 percent. This maximum scenario is presented in the below example quantification.

Subsector Maximum

($\sum A_{max_{T\text{-}18 \text{ through } T\text{-}22\text{-}D}} \leq 10\%$) This measure is in the Neighborhood Design subsector. This subcategory includes Measures T-18 through T-22-D. The VMT reduction from the combined implementation of all measures within this subsector is capped at 10 percent.

Example GHG Reduction Quantification

The user reduces plan/community VMT by deploying scootershare throughout the area. In this example, the project is in the Los Angeles-Long Beach-Anaheim CBSA, and the one-way vehicle trip length would be 9.72 miles (H). Assuming 100 percent of residents in the plan/community would have scootershare access (C) where there was no existing access (B), the user would reduce GHG emissions from plan/community VMT by 0.07 percent.

$$A = -1 \times \frac{(\mathbf{100\% - 0\%}) \times 0.021 \ \frac{\text{trips}}{\text{day}\cdot\text{person}} \times 38.5\% \times 2.14 \ \frac{\text{miles}}{\text{trip}}}{2.7 \ \frac{\text{trips}}{\text{day}\cdot\text{person}} \times 9.72 \ \frac{\text{miles}}{\text{trip}}} = -0.07\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an

adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A). This quantification methodology does not account for the increase in electricity used to charge the scooters or the fuel consumption from vehicle travel of program employees picking up and dropping off scooters.

VMT Reductions

The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A). This quantification methodology does not account for the miles traveled from vehicle travel of program employees picking up and dropping off scooters.

Sources

- Federal Highway Administration (FHWA). 2017. *National Household Travel Survey–2017 Table Designer*. Travel Day PT by TRPTRANS by HH_CBSA. Available: https://nhts.ornl.gov/. Accessed: January 2021.
- Federal Highway Administration (FHWA). 2018. *Summary of Travel Trends 2017–National Household Travel Survey*. July. Available: https://www.fhwa.dot.gov/policyinformation/documents/2017_nhts_summary_travel_trends.pdf. Accessed: January 2021.
- Metropolitan Transportation Commission (MTC). 2017. *Plan Bay Area 2040 Final Supplemental Report–Travel Modeling Report*. July. Available: http://2040.planbayarea.org/files/2020-02/Travel_Modeling_PBA2040_Supplemental%20Report_7-2017.pdf. Accessed: January 2021.
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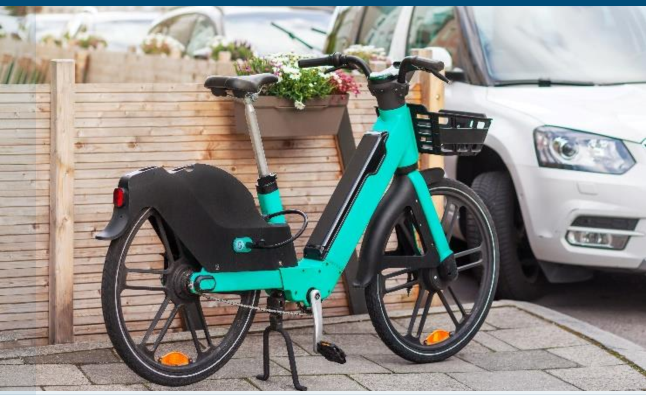
T-22-D. Transition Conventional to Electric Bikeshare



GHG Mitigation Potential

.059%

Up to 0.059% of GHG emissions from transitioning an existing traditional bikeshare system to electric bikes.

Co-Benefits (icon key on pg. 34)

Climate Resilience

Bikeshare programs can incentivize more bicycle use and decrease vehicle use, which have health benefits and can thus improve community resilience. This can also improve connectivity between residents and resources that may be needed in an extreme weather event. However, they may decrease resilience if they are the only option available during a power outage.

Health and Equity Considerations

Commuters who switch from passenger vehicle use to electric bicycle use initiate regular physical activity, reducing their health risk. Electric bicycles are more affordable than owning a car and can improve access to healthcare and other health-promoting goods and services. Program implementers should provide inclusive mechanisms so people without bank accounts, credit cards, or smart phones can access the system.

Measure Description

This measure accounts for the VMT reduction achieved by transitioning an existing traditional bikeshare program to an electric bikeshare program. Research in California has found that electric bikeshare programs lead to increased ridership and accessibility over traditional bikes. This makes sense because, with an electric bike, it is easier to climb hills and is more enjoyable and faster for riders to get where they are going, leading to increased utility. Variations of this measure are described in Measure T-22-A, *Implement Pedal (Non-Electric) Bikeshare Program*, Measure T-22-B, *Implement Electric Bikeshare Program*, and Measure T-22-C, *Implement Scootershare Program*.

Subsector

Neighborhood Design

Locational Context

Urban, suburban

Scale of Application

Plan/Community

Implementation Requirements

The GHG mitigation potential is based, in part, on literature analyzing docked (i.e., station-based) bikeshare programs. This measure should be applied with caution if using dockless (free-floating) bikeshare.

Cost Considerations

The costs incurred by the service manager (e.g., municipality or bikeshare company) may include the capital costs for purchasing an electric bicycle fleet; installing accessible and secure charging stations; storing, maintaining, and replacing the fleet; and marketing and administration. Some of these costs may be offset by income generated through program use. Program participants will benefit from the cost savings from access to cheaper transportation alternatives (compared to private vehicles, private bicycles, or use of ride-hailing services). The local municipality may achieve cost savings through a reduction of cars on the road leading to lower infrastructure and roadway maintenance costs.

Expanded Mitigation Options

Best practice is to discount electric bikeshare membership and dedicate electric bikeshare parking to encourage use of the service. Consider also including space on the vehicle to store personal items while traveling, such as a basket.

GHG Reduction Formula

The quantification methodology does not account for indirect GHG emissions from electricity used to charge the bicycles or direct GHG emissions from vehicle travel of program employees picking up and dropping off bikes.

$$A=\frac{-B\times C\times D\times\left((E\times F)-(G\times H)\right)}{I\times J}$$

GHG Calculation Variables

ID	Parameter	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from vehicle travel in plan/community	0-0.059	%	calculated
User Inputs				
B	Percent of residences in plan/community with access to traditional bikeshare system	0–100	%	user input
C	Percent of bikeshare bikes transitioned to electric bikeshare	0–100	%	user input
Constants, Assumptions, and Available Defaults				
D	Daily bikeshare trips per person	0.021	trips per day per person	MTC 2021
E	Vehicle to electric bikeshare substitution rate	35	%	Fitch et al. 2021
F	Electric bikeshare average one-way trip length	2.1	miles per trip	Fitch et al. 2021
G	Vehicle to conventional bikeshare substitution rate	19.6	%	McQueen et al. 2020
H	Conventional bikeshare average one-way trip length	1.4	miles per trip	Lazarus et al. 2019
I	Daily vehicle trips per person	1.7	trips per day per person	FHWA 2023
J	Regional average one-way vehicle trip length	Table T-10.1	miles per trip	FHWA 2017

Further explanation of key variables:

- (B) – Access to bike sharing is measured as the percentage of residences in the plan/community within 0.25 mile of a bikeshare station. For dockless bikes, users can assume that all residences within 0.25 mile of the designated dockless service area would have access.
- (C) – This is the percentage of bikes within the existing system that are switched from conventional bikeshare bikes to electric bicycles. For example, if a system with 100

conventional bikes retires 50 bikes and replaces them with 50 e-bikes, then this would represent a 50 percent transition. This calculation assumes that a bikeshare transition is not combined with a bikeshare expansion. If it is, the new areas can be estimated using Measure T-22-A, *Implement Pedal (Non-Electric) Bikeshare Program*, Measure T-22-B, *Implement Electric Bikeshare*.

- (D) – An analysis of bikeshare service areas in the San Francisco Bay Area estimated that in locations with access to bikesharing, there were between 21 and 25 bikeshare trips per day per 1,000 residents (MTC 2021). To be conservative, the low end of this range is cited.
- (E) – A study of dockless electric bikeshare in Sacramento found that the substitution rate of vehicles trips by electric bikeshare trips was 35 percent (Fitch et al. 2021).
- (F) – A study of dockless electric bikeshare in Sacramento found that the average one-way bikeshare trip was 2.1 miles (Fitch et al. 2021).
- (G) – A literature review of several academic and government reports found that the average car trip substitution rate by bikeshare trips was 19.6 percent. This included bikeshare programs in Washington D.C., Minneapolis, and Montreal (McQueen et al. 2020).
- (H) – A case study on average trip lengths for pedal and electric bikeshare programs in San Francisco reported a one-way pedal bikeshare trip of 1.4 miles (Lazarus et al. 2019).
- (I) – A summary report of the 2022 National Household Travel Survey (data found that the average person in the United States takes 1.7 vehicle trips per day (FHWA 2023).
- (J) – Ideally, the user will calculate auto trip length for a plan/community at a scale that is appropriate to the geographical area of the electrification efforts. Potential data sources include the metropolitan planning organization travel model, NHTS California Supplement (preferred), or local survey efforts. If the user is not able to provide a plan-specific value using one of these data sources, they have the option to input the existing regional average one-way auto trip length for one of the six most populated core-based statistical areas (CBSA) in California, as presented in Table T-10.1 (FHWA 2017). Trip lengths are likely to be longer for areas not covered by the listed CBSAs, which represent the denser areas of the state.

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) For projects that use default CBSA data from Table T-10.1, the maximum percent reduction in GHG emissions (A) is 0.059 percent. This maximum scenario is presented in the below example quantification.

Subsector Maximum

($\sum A_{max_{T\text{-}18\ through\ T\text{-}22\text{-}D}} \leq 10\%$) This measure is in the Neighborhood Design subsector. This subcategory includes Measures T-18 through T-22-D. The VMT reduction from the combined implementation of all measures within this subsector is capped at 10 percent.

Example GHG Reduction Quantification

The user is transitioning from a large conventional bikeshare system to an electric bikeshare system. For this example, the project is in the Los Angeles-Long Beach-Anaheim CBSA, and the one-way vehicle trip length would be 9.72 miles (J). If we assume that 100 percent of the residents in the plan/community have bikeshare access (B) and that the fleet is fully transitioning (C), the user would reduce GHG emissions from the plan/community VMT by 0.059 percent.

$$A = \frac{\mathbf{-100\% \times 100\%} \times 0.021 \frac{\text{trips}}{\text{day person}} \times \left(35\% \times 2.1 \frac{\text{miles}}{\text{trip}} - 19.6\% \times 1.4 \frac{\text{miles}}{\text{trip}}\right)}{1.7 \frac{\text{trips}}{\text{day person}} \times 9.72 \frac{\text{miles}}{\text{trip}}} = -0.059\%$$

Quantified Co-Benefits

Improved Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NOx, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A). This quantification methodology does not account for the increase in electricity used to charge the vehicles or the fuel consumption from vehicle travel of program employees picking up and dropping off bikes.

VMT Reductions

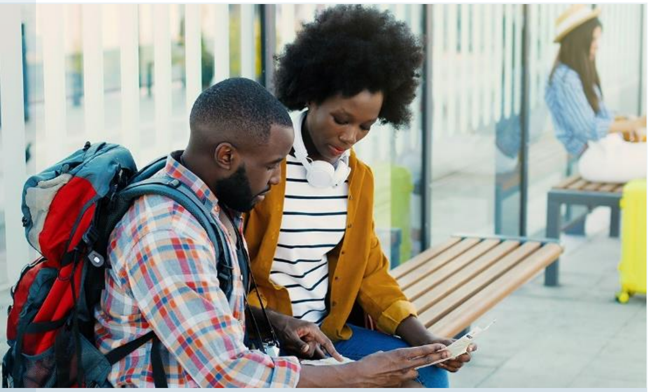
The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A). This quantification methodology does not account for the miles traveled from vehicle travel of program employees picking up and dropping off bikes.

Sources

- Federal Highway Administration (FHWA). 2017. National Household Travel Survey–2017 Table Designer. Travel Day PT by TRPTRANS by HH_CBSA. Available: https://nhts.ornl.gov/. Accessed: December 2023.
- Federal Highway Administration (FHWA). 2023. 2022 National Household Travel Survey. Available: https://nhts.ornl.gov/. Accessed: January 2024.
- Fitch, D., H. Mohiuddin, and S. Handy. 2021. Examining the Effects of the Sacramento Dockless E-Bike Share on Bicycling and Driving. MDPI: Sustainability. January. Available: https://www.mdpi.com/2071-1050/13/1/368. Accessed: December 2023.
- Lazarus, J., J. Pourquier, F. Feng, H. Hammel, and S. Shaheen. 2019. Bikesharing Evolution and Expansion: Understanding How Docked and Dockless Models Complement and Compete – A Case Study of San Francisco. Paper No. 19-02761. Annual Meeting of the Transportation Research Board: Washington, DC. Available: https://trid.trb.org/view/1572878. Accessed: January 2021.

- McQueen, M., G. Abou-Zeid, J. MacArthur, and K. Clifton. 2020. Transportation Transformation: Is Micromobility Making a Macro Impact on Sustainability? Journal of Planning Literature. November. Available: https://doi.org/10.1177/0885412220972696. Accessed: March 2021.
- Metropolitan Transportation Commission (MTC). 2021. Technical Methodology to Estimate Greenhouse Gas Emissions for Plan Bay Area 2050. Available: https://www.planbayarea.org/sites/default/files/documents/Technical-Methodology-Memo-to-CARB_final.pdf. Accessed: December 2023.

T-23. Provide Community-Based Travel Planning



GHG Mitigation Potential

2.3%

Up to 2.3% of GHG emissions from vehicle travel in the plan/community

Co-Benefits (icon key on pg. 34)

Climate Resilience

CBTP can decrease vehicle use and thus improve air quality, resulting in health impacts that may increase the resilience of communities near freeways and roads. This can also increase the adaptive capacity of communities by informing them of travel alternatives if certain modes become disrupted due to extreme events.

Health and Equity Considerations

Outreach materials may need to be in multiple languages to address diverse linguistic communities.

Measure Description

This measure will target residences in the plan/community with community-based travel planning (CBTP). CBTP is a residential-based approach to outreach that provides households with customized information, incentives, and support to encourage the use of transportation alternatives in place of single occupancy vehicles, thereby reducing household VMT and associated GHG emissions.

Subsector

Trip Reduction Programs

Locational Context

Urban, suburban

Scale of Application

Plan/Community

Implementation Requirements

CBTP involves teams of trained travel advisors visiting all households within a targeted geographic area, having tailored conversations about residents' travel needs, and educating residents about the various transportation options available to them. Due to the personalized outreach method, communities are typically targeted in phases.

Cost Considerations

The main cost consideration for CBTP is labor costs for program managers and resident outreach staff plus material costs for development of educational material. The beneficiaries are the commuters who may be able to reduce vehicle usage or ownership. The local municipality may achieve cost savings through a reduction of cars on the road leading to lower infrastructure and roadway maintenance costs.

Expanded Mitigation Options

Pair with any of the Measures from T-17 through T-22-D to ensure that residents that are targeted by CBTP who want to use alternative transportation have the infrastructure and technology to do so.

GHG Reduction Formula

$$A = \frac{C}{B} \times D \times -E \times F$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from household vehicle travel in plan/community	0–2.3	%	calculated
User Inputs				
B	Residences in plan/community	[ ]	residences	user input
C	Residences in plan/community targeted with CBTP	[ ]	residences	user input
Constants, Assumptions, and Available Defaults				
D	Percent of targeted residences that participate	19	%	MTC 2021
E	Percent vehicle trip reduction by participating residences	12	%	MTC 2021
F	Adjustment factor from vehicle trips to VMT	1	unitless	assumed

Further explanation of key variables:

- (D) – Results from program evaluations of CBTP in several counties in Washington and Oregon across multiple years indicate that an average of 19 percent of residences targeted will participate (MTC 2021).
- (E) – Results from program evaluations of CBTP in several counties in Washington and Oregon across multiple years indicate that a 12 percent vehicle trip reduction will occur among participating residences (MTC 2021).
- (F) – The adjustment factor from vehicle trips to VMT is 1. This assumes that all vehicle trips will average out to typical trip length ("assumes all trip lengths are equal"). Thus, it can be assumed that a percentage reduction in vehicle trips will equal the same percentage reduction in VMT.

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The maximum percent reduction in GHG emissions (A) is 2.3 percent. This maximum scenario is presented in the below example quantification.

Subsector Maximum

Same as (A_{max}). Measure T-23 is the only measure at the Plan/Community scale within the Trip Reduction Programs subsector.

Example GHG Reduction Quantification

The user reduces household VMT by having residences in the plan/community participate in CBTP. In this example, all of the residences in a city of 5,000 are targeted (B and C), which would reduce GHG emissions from citywide household VMT by 2.3 percent.

$$A = \left(\frac{5{,}000\ \text{residences}}{5{,}000\ \text{residences}}\right) \times 19\% \times -12\% \times 1 = -2.3\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in household VMT would be the same as the percent reduction in GHG emissions (A).

Sources

- Metropolitan Transportation Commission (MTC). October 2021. *Plan Bay Area 2050, Forecasting and Modeling Report*. Available: https://www.planbayarea.org/sites/default/files/documents/Plan_Bay_Area_2050_Forecasting_Modeling_Report_October_2021.pdf. Accessed: November 2021.

T-24. Implement Market Price Public Parking (On-Street)

GHG Mitigation Potential

30%

Up to 30.0% of GHG emissions from vehicle travel in the plan/community

Co-Benefits (icon key on pg. 34)

Climate Resilience

Implementing market price public parking could incentivize increased use of public transit and thus result in less traffic, potentially reducing congestion or delays on major roads during peak AM and PM traffic periods. In addition, this reduces illegal loading/standing in bus stops and travel lanes. When these reductions occur during extreme weather events, they better allow emergency responders to access a hazard site.

Health and Equity Considerations

Pricing on-street parking at market rates reduces illegal loading/standing in bus stops and travel lanes, improving transit times.

Measure Description

This measure will price all on-street parking in a given community, with a focus on parking near central business districts, employment centers, and retail centers. Increasing the cost of parking increases the total cost of driving to a location, incentivizing shifts to other modes and thus decreasing total VMT to and from the priced areas. This VMT reduction results in a corresponding reduction in GHG emissions.

Subsector

Parking or Road Pricing/Management

Locational Context

Urban, suburban

Scale of Application

Plan/Community

Implementation Requirements

When pricing on-street parking, best practice is to allow for dynamic adjustment of prices to ensure approximately 85 percent occupancy, which helps prevent induced VMT due to circling behaviors as individuals search for a vacant parking space. In addition, this method should primarily be implemented in areas with available alternatives to driving, such as transit availability within 0.5. mile or areas of high residential density nearby (allowing for increased walking/biking). If the measure is implemented in a small area, residential parking permit programs should be considered to prevent parking intrusion on nearby streets in residential areas without priced parking.

Cost Considerations

Municipalities may incur costs from installing the meter network, which may require meters at individual spaces or at more central terminals. There would also be staffing costs to monitor the metered spaces and collect payments. Residents also incur a cost by having to pay for on-street parking. A portion of costs to the municipality may be offset through revenue collected by the parking system.

Expanded Mitigation Options

Pricing on-street parking also helps support individual projects with priced onsite parking by removing potential alternative parking locations.

GHG Reduction Formula

$$A = \frac{B}{C} \times \frac{D - E}{E} \times F \times G \times H$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from vehicle travel in plan/community	0–30.0	%	calculated
User Inputs				
B	VMT in priced area without measure	[ ]	VMT per day	user input
C	VMT in plan/community without measure	[ ]	VMT per day	user input
D	Proposed parking price	1.00–5.00	$ per hour	user input
E	Initial parking price	0.00–5.00	$ per hour	user input
F	Default percentage of trips parking on street	5–75	%	user input
Constants, Assumptions, and Available Defaults				
G	Elasticity of parking demand with respect to price	-0.4	unitless	Pierce and Shoup 2013
H	Ratio of VMT to vehicle trips	1	unitless	assumption

Further explanation of key variables:

- (B and C) – Total daily VMT in both the priced area and the plan/community area should represent the expected total VMT generated by all land use in that area, including office, residences, retail, schools, and other uses. The most appropriate source for this data is from a local travel demand forecasting model. An alternate method uses VMT per worker or VMT per resident as calculated for SB 743 compliance and screening purposes multiplied by the population in the area.
  - These variables for VMT by area are used to ensure that the percent GHG reduction from the priced area is at the same geographic scale as the vehicle travel in the plan/community. If the area priced is a business district and the analysis is limited to the business district, then the VMT would be equal (B=C).
- (D) – The proposed parking price can be presented in cost per minute, hour, or day, provided that the same units are used for variable (E)
- (E) – Because this is used to calculate the percent change in parking price, if parking is free under existing conditions, (E) should be set to (1/2×D), resulting in a percentage change of 100 percent. In areas where metered parking is common, E may instead by set to equal the average metered parking price in nearby areas or districts.
- (F) – On-street parking represents only a portion of the total available parking supply. An estimate will typically range from 5 percent (in locations with offsite parking garages available) to 75 percent (in locations where most parcels have little to no onsite parking for visitors). The user should provide a project-specific value within this range, by surveying the total on-street vs. off-street parking spaces within ¼ mile of the study area.

- (G) – An evaluation of the SFPark program in San Francisco found that a 0.4 percent decrease in parking demand occurs for every 1 percent increase in parking price (Pierce and Shoup 2013). Price elasticity of parking demand varies by location, day of the week, and time of day.
- (H) – The adjustment factor from vehicle trips to VMT is 1. This assumes that all vehicle trips will average out to typical trip length ("assumes all trip lengths are equal"). Thus, it can be assumed that a percentage reduction in vehicle trips will equal the same percentage reduction in VMT.

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The total reduction in VMT due to on-street parking pricing is capped at 30 percent, which is based on the following assumptions:

- $\left(\frac{D-E}{E}=100\%\right)$ – Parking prices double (i.e., increase by 100 percent) or parking pricing is introduced in previously free areas.
- (F) – 75 percent of all vehicle trips utilize on-street parking. Note that only within a small-scale commercial district is 75 percent of parking likely to occur on street.

This maximum scenario is presented in the below example quantification.

Subsector Maximum

Same as (A_{max}). Measure T-24 is the only measure at the Plan/Community scale within the Parking or Road Pricing/Management subsector.

Example GHG Reduction Quantification

The user reduces VMT by increasing hourly on-street parking costs. In this example, the hourly parking cost increases from $1.00 (E) to $2.00 (D) in a business district. The business district daily VMT is 1,000,000 (B), and the scale of implementation is the business district (B=C). If around 75 percent of the district's parking supply is on street (F), the user would reduce GHG emissions from VMT by 30 percent.

$$A = \frac{1{,}000{,}000\,\frac{VMT}{day}}{1{,}000{,}000\,\frac{VMT}{day}} \times \frac{\$2.00 - \$1.00}{\$1.00} \times 75\% \times -0.4 \times 1 = -30\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an

adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A).

Sources

- Pierce, G., and D. Shoup. 2013. Getting the Prices Right: An Evaluation of Pricing Parking by Demand in San Francisco. *Journal of the American Planning Association* 79(1)67–81. May. Available: https://www.tandfonline.com/doi/pdf/10.1080/01944363.2013.787307?needAccess=true. Accessed: January 2021.

T-25. Extend Transit Network Coverage or Hours

GHG Mitigation Potential

4.6%

Up to 4.6% of GHG emissions from vehicle travel in the plan/community

Co-Benefits (icon key on pg. 34)

Climate Resilience

Increasing transit network coverage or hours improves the reliability of the transportation network and allows redundancy to exist even if an extreme event disrupts part of the system. They could also incentivize more people to use transit, resulting in less traffic and better allowing emergency responders to access a hazard site during an extreme weather event.

Health and Equity Considerations

This measure increases access to social, educational, and employment opportunities. Expansion of transit networks need to ensure equitable access by all communities to the transit system.

Measure Description

This measure will expand the local transit network by either adding or modifying existing transit service or extending the operation hours to enhance the service near the project site. Starting services earlier in the morning and/or extending services to late-night hours can accommodate the commuting times of alternative-shift workers. This will encourage the use of transit and therefore reduce VMT and associated GHG emissions.

Subsector

Transit

Locational Context

Urban, suburban

Scale of Application

Plan/Community

Implementation Requirements

There are two primary means of expanding the transit network: by increasing the frequency of service, thereby reducing average wait times and increasing convenience, or by extending service to cover new areas and times.

Cost Considerations

Infrastructure costs for extending the physical network coverage of a transit system can be significant. Costs to expand track-dependent transit, such as light rail and passenger rail, are high and can require resource- and time-intensive advanced planning. Costs to expand vehicle-dependent transit, such as busses, are likewise high but may be limited to procurement of additional vehicles. Any expansion of transit, including just service hours, would increase staffing and potentially maintenance costs. A portion of these costs may be offset by increased transit usage and associated income. Commuters who may more easily be able to travel without a car may also observe cost savings from reduce vehicle usage or ownership.

Expanded Mitigation Options

This measure is focused on providing additional transit network coverage, with no changes to transit frequency. This measure can be paired with Measure T-26, *Increase Transit Service Frequency*, which is focused on increasing transit service frequency, for increased reductions.

GHG Reduction Formula

$$A = -1 \times \frac{C - B}{B} \times D \times E \times F \times G$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from plan/community VMT	0–4.6	%	calculated
User Inputs				
B	Total transit service miles or service hours in plan/community before expansion	[ ]	miles	user input
C	Total transit service miles or service hours in plan/community after expansion	[ ]	miles	user input
D	Transit mode share in plan/community	Table T-3.1	%	user input
Constants, Assumptions, and Available Defaults				
E	Elasticity of transit demand with respect to service miles or service hours	0.7	unitless	Handy et al. 2013
F	Statewide mode shift factor	57.8	%	FHWA 2017
G	Ratio of vehicle trip reduction to VMT	1	unitless	assumption

Further explanation of key variables:

- (A) – This formula does not reflect any increase in transit vehicle travel and emissions, which can at least partially offset the reduction in GHG emissions from passenger vehicle travel. Inclusion of this component in the percent GHG reduction formula would require inputs that would not be available to most users.
- (B and C) – Transit service miles are defined as the total service mileage. Service hours represent the hours of operation. Either metric can be used in the GHG reduction formula so long as both B and C use the same metric.
- (D) – The transit mode share for the six most populated CBSAs in California are provided in Table T-3.1 in Appendix C (FHWA 2017). If the project study area is not within the listed CBSAs or the user is able to provide a project-specific value, the user should replace these regional defaults in the GHG reduction formula. It is likely for areas outside of the area covered by the listed CBSAs to have transit mode shares lower than the values provided in the table. Ideally, the user will calculate existing transit mode share for work trips or all trips at a scale no larger than a census tract. Potential data sources include the U.S. Census, California Household Travel Survey (preferred), or local survey efforts. Care should be taken to not present the reported commute mode share as retrieved from the ACS, unless the land use is office or employment based and the ACS tables are based on work location (rather than home location).
- (E) – A policy brief summarizing the results of transit service strategies concluded that a 0.7 percent increase in transit ridership occurs for every 1 percent increase in service miles or hours (Handy et al. 2013).

- (F) – Mode shift factor is an adjustment to reflect the reduction in vehicle trips associated with a reduction in person trips, since some vehicles carry more than one person. It is calculated as (1/average vehicle occupancy).
- (G) – The adjustment factor from vehicle trips to VMT is 1. This assumes that all vehicle trips will average out to typical trip length ("assumes all trip lengths are equal"). Thus, it can be assumed that a percentage reduction in vehicle trips will equal the same percentage reduction in VMT.

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The GHG reduction from expanding the transit network is capped at 4.6 percent, which is based on the following assumptions:

- $\left(\frac{C-B}{B} \leq 100\%\right)$ – The transit network increase is capped at a doubling in size, or 100 percent (twice as many revenue miles are provided, for a 100 percent increase).
- (D) – The CBSA is San Francisco-Oakland-Hayward, which has a default transit mode share for all trips of 11.38 percent.

This maximum scenario is presented in the below example quantification.

Subsector Maximum

($\sum A_{max_{T\text{-}25 \text{ through } T\text{-}29,\ T\text{-}46}} \leq 15\%$) This measure is in the Transit subsector. This subcategory includes Measures T-25 through T-29 and T-46. The VMT reduction from the combined implementation of all measures within this subsector is capped at 15 percent.

Example GHG Reduction Quantification

The user reduces VMT by extending an existing transit route or lengthening the service hours. In this example, the project in a neighborhood of the San Francisco-Oakland-Hayward CBSA and would increase transit coverage in the area from 20 miles (B) to 40 miles (C). If the existing transit mode share in the study area is 11.38 percent (D), the user would reduce GHG emissions from VMT by 4.6 percent.

$$A = -1 \times \frac{(40 \text{ miles} - 20 \text{ miles})}{20 \text{ miles}} \times 11.38\% \times 0.7 \times 57.8\% \times 1 = -4.6\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in VMT would be the same as the percent reduction in GHG emissions (A).

Sources

- Federal Highway Administration (FHWA). 2017. *National Household Travel Survey–2017 Table Designer*. Average Vehicle Occupancy by HHSTFIPS. Available: https://nhts.ornl.gov/. Accessed: January 2021.
- Handy, S., K. Lovejoy, M. Boarnet, and S. Spears. 2013. *Impacts of Transit Service Strategies on Passenger Vehicle Use and Greenhouse Gas Emissions*. October. Available: https://ww2.arb.ca.gov/sites/default/files/2020-06/Impacts_of_Transit_Service_Strategies_on_Passenger_Vehicle_Use_and_Greenhouse_Gas_Emissions_Policy_Brief.pdf. Accessed: January 2021.

T-26. Increase Transit Service Frequency

GHG Mitigation Potential

11.3%

Up to 11.3% of GHG emissions from vehicle travel in the plan/community

Co-Benefits (icon key on pg. 34)

Climate Resilience

Increasing transit service frequency improves the reliability of the transportation network and allows redundancy to exist even if an extreme event disrupts part of the system. It could also incentivize more people to use transit, resulting in less traffic and better allow emergency responders to access a hazard site during an extreme weather event.

Health and Equity Considerations

This measure increases access to social, educational, and employment opportunities. Expansion of transit service needs to ensure equitable access by all communities to the transit system.

Measure Description

This measure will increase transit frequency on one or more transit lines serving the plan/community. Increased transit frequency reduces waiting and overall travel times, which improves the user experience and increases the attractiveness of transit service. This results in a mode shift from single occupancy vehicles to transit, which reduces VMT and associated GHG emissions.

Subsector

Transit

Locational Context

Urban, suburban

Scale of Application

Plan/Community

Implementation Requirements

See measure description.

Cost Considerations

Increasing transit service frequency may require capital investment to purchase additional vehicles. Staff and maintenance costs may also increase. A portion of these costs may be offset by increased transit usage and associated income. Commuters who may more easily be able to travel without a car may also observe cost savings from reduce vehicle usage or ownership.

Expanded Mitigation Options

This measure is focused on providing increased transit frequency, with no changes to transit network coverage. This measure can be paired with Measure T-25, *Extend Transit Network Coverage or Hours*, which is focused on increasing transit network coverage, for increased reductions.

GHG Reduction Formula

$$A = -C \times \frac{B \times E \times D \times G}{F}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from vehicle travel in plan/community	0–11.3	%	calculated
User Inputs				
B	Percent increase in transit frequency	0–300	%	user input
C	Level of implementation	0–100	%	user input
Constants, Assumptions, and Available Defaults				
D	Elasticity of transit ridership with respect to frequency of service	0.5	unitless	Handy et al. 2013
E	Transit mode share in plan/community	Table T-3.1	%	FHWA 2017a
F	Vehicle mode share in plan/community	Table T-3.1	%	FHWA 2017a
G	Statewide mode shift factor	57.8	%	FHWA 2017b

Further explanation of key variables:

- (A) – This formula does not reflect any increase in transit vehicle travel and emissions, which can at least partially offset the reduction in GHG emissions from passenger vehicle travel. Inclusion of this component in the percent GHG reduction formula would require inputs that would not be available to most users. Users can calculate the absolute changes in passenger vehicle and bus VMT and emissions using the process described under *Co-Benefits*.
- (B) – Frequency is measured as the number of arrivals over a given time (e.g., buses per hour). Frequency is the inverse of transit headway, defined as the time between transit vehicle arrivals on a given route. This variable can be calculated as [transit frequency with measure minus existing transit frequency] divided by existing transit frequency.
- (C) – The level of implementation refers to the number of transit routes receiving the frequency improvement as a fraction of the total transit routes in the plan/community.
- (D) – A policy brief summarizing the results of transit service strategies concluded that a 0.5 percent increase in transit ridership occurs for every 1 percent increase in frequency (Handy et al. 2013).
- (E and F) – Ideally, the user will calculate transit and auto mode shares for a plan/community at the city scale (or larger). Potential data sources include the California Household Travel Survey (preferred) or local survey efforts. If the user is not able to provide a project-specific value using one of these data sources, they have the option to input the mode shares for transit and vehicles for one of the six most populated CBSAs in California, as presented in Table T-3.1 in Appendix C. It is likely for areas outside of

the area covered by the listed CBSAs to have vehicle mode shares higher and transit mode shares lower than the values provided in the table.

- (G) – Mode shift factor is an adjustment to reflect the reduction in vehicle trips associated with a reduction in person trips, since some vehicles carry more than one person. It is calculated as (1/average vehicle occupancy).

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) For projects that use default CBSA data from Table T-3.1 and (B_{max}), the maximum percent reduction in GHG emissions (A) is 11.3 percent. This maximum scenario is presented in the below example quantification.

(B_{max}) The percent change in transit frequency is capped at 300 percent (SANDAG 2019).

Subsector Maximum

($\sum A_{max_{T\text{-}25 \text{ through } T\text{-}29, T\text{-}46}} \leq 15\%$) This measure is in the Transit subsector. This subcategory includes Measures T-25 through T-29 and T-46. The VMT reduction from the combined implementation of all measures within this subsector is capped at 15 percent.

Mutually Exclusive Measures

If the user selects Measure T-28, *Provide Bus Rapid Transit*, and converts all transit routes in the plan/community to BRT, then the user cannot also take credit for this measure, Measure T-27, *Implement Transit-Supportive Roadway Treatments*, or Measure T-46, *Provide Transit Shelters*. This is because Measure T-28 accounts for the VMT reduction associated with increased transit frequency and decreased transit travel time as well as the additional BRT-specific bonus. To combine the GHG reductions from Measure T-28 with Measure T-27, Measure T-26, and/or Measure T-46 would be considered double counting. However, where BRT is proposed on less than all of the existing bus routes in the plan/community area, this measure, Measure T-27, and/or Measure T-46 could be applied to the remaining bus routes, and the measure reductions could be combined with Measure T-28 to determine the emissions reduction at the larger plan/community scale.

Example GHG Reduction Quantification

The user reduces plan/community GHGs by increasing transit frequency, thereby encouraging a mode shift from vehicles to transit and reducing VMT. In this example, the project is in the San Francisco-Oakland-Hayward CBSA where the transit and vehicle mode shares would be 11.38 percent and 86.96 percent, respectively (E and F). Assuming the maximum increase in transit frequency of 300 percent (B) and implementation for all transit routes (100 percent) in the plan/community (C), the user would reduce plan/community GHG emissions from VMT by 11.3 percent.

$$A = -100\% \times \frac{300\% \times 11.38\% \times 0.5 \times 57.8\%}{86.96\%} = -11.3\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

VMT Reductions

The decrease in passenger vehicle miles (H) and increase in bus miles (L) by the measure can be calculated as follows.

Passenger Vehicle VMT Reduction Formula

The percent reduction in passenger VMT would be the same as the percent reduction in GHG emissions (A). The absolute reduction in passenger VMT can be calculated using the following formula.

$$H = I \times E \times J \times B \times D \times G \times K$$

Passenger Vehicle VMT Reduction Calculation Variables

ID	Variable	Value	Unit	Source
Output				
H	Reduction in passenger vehicle miles in plan/community	[ ]	miles per year	calculated
User Inputs				
I	Total daily person trips in corridor(s)	[ ]	trips per day	user input
J	Vehicle trip length	[ ]	miles per trip	user input
Constants, Assumptions, and Available Defaults				
K	Days per year transit available	365	days per year	assumed

Further explanation of key variables:

- (I) – The total daily person trips in the corridor(s) represents the total daily trips by all modes between the bus route origin area and the bus route destination area. This may be obtained through travel demand modeling. If the strategy involves frequency improvements for more than one transit route, then the total person trips should reflect the sum of all the routes being improved.
- (J) – If the strategy involves frequency improvements for more than one transit route, then the trip length should reflect the average of all the routes being improved.
- Please refer to the GHG Calculation Variables table above for definitions of variables that have been previously defined.

Bus VMT Increase Formula

The absolute increase in bus VMT can be calculated using the formula below. As noted above, the formula for the percent GHG reduction (A) does not reflect any increase in bus VMT and bus emissions. Users that wish to capture these impacts should calculate absolute changes.

$$L = P \times (M_2 - M_1) \times N \times O \times K$$

Bus VMT Increase Calculation Variables

ID	Variable	Value	Unit	Source
Output				
L	Increase in annual bus miles in plan/community	[ ]	miles per year	calculated
User Inputs				
M_1	Bus frequency without measure	[ ]	transit vehicle roundtrips per hour	user input
M_2	Bus frequency with measure	[ ]	transit vehicle roundtrips per hour	user input
N	Bus hours of operation	0–24	hours per day	user input
O	Bus route one-way length	[ ]	miles per route	user input
Constants, Assumptions, and Available Defaults				
P	One-way trips in a roundtrip	2	one-way trips per roundtrip	conversion

Further explanation of key variables:

- (L) – If the strategy involves frequency improvements for more than one transit route, then the increase in bus miles should be calculated separately for each route.
- Please refer to the GHG Calculation Variables table above for definitions of variables that have been previously defined.

Energy and Fuel Savings

The decrease in passenger vehicle fuel consumption and increase in bus fuel consumption by the measure can be calculated as follows.

Passenger Vehicle Fuel Use Reduction Formula

Multiply the reduction in passenger vehicle miles (H) above by the fuel efficiency of the vehicle type (see Table T-30.2 in Appendix C) to output the change in fuel consumption.

Bus Fuel Use Increase Formula

The absolute increase in bus fuel consumption (Q) can be calculated using the formula below.

$$Q = L \times R$$

Bus Fuel Use Increase Calculation Variables

ID	Variable	Value	Unit	Source
Output				
Q	Increase in annual bus fuel consumption in plan/community	[ ]	gal per year	calculated
User Inputs				
	None			
Constants, Assumptions, and Available Defaults				
R	Fuel economy of a transit bus, by fuel type	Table T-26.1	gal or kilowatt hour per mile	CARB 2020; U.S. DOE 2021

Further explanation of key variables:

- (R) – The average fuel economy for gasoline, diesel, and natural gas transit buses was calculated using EMFAC2017 (v1.0.3). The model was run for a 2020 statewide average of UBUS vehicles, disaggregated by fuel type (CARB 2020). The efficiency of electric buses was calculated based on the gasoline equivalent value (U.S. DOE 2021). The user should reference Table T-26.1 for the fuel economy of the appropriate fuel type for their location's transit system. If the user can provide a project-specific value (i.e., for a future year and project location), the user should run EMFAC to replace the default in the fuel use increase formula.
- Please refer to the Bus VMT Increase Calculation Variables table above for definitions of variables that have been previously defined.

Sources

- California Air Resources Board (CARB). 2020. *EMFAC2017 v1.0.3*. August. Available: https://arb.ca.gov/emfac/emissions-inventory. Accessed: January 2021.
- Federal Highway Administration (FHWA). 2017a. *National Household Travel Survey–2017 Table Designer*. Travel Day PMT by TRPTRANS by HH_CBSA. Available: https://nhts.ornl.gov/. Accessed: January 2021.
- Federal Highway Administration (FHWA). 2017b. *National Household Travel Survey–2017 Table Designer*. Average Vehicle Occupancy by HHSTFIPS. Available: https://nhts.ornl.gov/. Accessed: January 2021.
- Handy, S., K. Lovejoy, M. Boarnet, S. Spears. 2013. *Impacts of Transit Service Strategies on Passenger Vehicle Use and Greenhouse Gas Emissions*. October. Available: https://ww2.arb.ca.gov/sites/default/files/2020-06/Impacts_of_Transit_Service_Strategies_on_Passenger_Vehicle_Use_and_Greenhouse_Gas_Emissions_Policy_Brief.pdf. Accessed: January 2021.
- San Diego Association of Governments (SANDAG). 2019. *Mobility Management VMT Reduction Calculator Tool–Design Document*. June. Available: https://www.icommutesd.com/docs/default-source/planning/tool-design-document_final_7-17-19.pdf?sfvrsn=ec39eb3b_2. Accessed: January 2021.
- U.S. Department of Energy (U.S. DOE). 2021. *Fuel Economy Datasets for All Model Years (1984-2021)*. January. Available: https://www.fueleconomy.gov. Accessed: January 2021.

T-27. Implement Transit-Supportive Roadway Treatments

GHG Mitigation Potential

0.6%

Up to 0.6% of GHG emissions from vehicle travel in the plan/community

Co-Benefits (icon key on pg. 34)

Climate Resilience

Implementing transit-supportive roadway treatments improves the reliability of the transportation network and allows redundancy to exist even if an extreme event disrupts part of the system. It could also incentivize more people to use transit, resulting in less traffic and better allowing emergency responders to access a hazard site during an extreme weather event. Furthermore, emergency responders can use queue jumps and dedicated bus lanes when needed.

Health and Equity Considerations

Transit facilities can have conflicts with cyclists. Consider appropriate treatments to minimize conflicts. Improved transit investments should be equitably distributed prioritizing areas with transit deficiencies in underserved communities.

Measure Description

This measure will implement transit-supportive treatments on the transit routes serving the plan/community. Transit-supportive treatments incorporate a mix of roadway infrastructure improvements and/or traffic signal modifications to improve transit travel times and reliability. This results in a mode shift from single occupancy vehicles to transit, which reduces VMT and the associated GHG emissions.

Subsector

Transit

Locational Context

Urban, suburban

Scale of Application

Plan/Community

Implementation Requirements

Treatments can include transit signal priority, bus-only signal phases, queue jumps, curb extensions to speed passenger loading, and dedicated bus lanes.

Cost Considerations

Costs and savings of transit-supportive roadway treatments vary depending on the strategy pursued, ranging from low-cost route optimization changes to high-cost infrastructure projects (e.g., bus-only lanes). Reducing route cycle time without significantly increasing the number of transit vehicles can result in net cost savings for the transit system. Dedicated transit infrastructure will improve transit reliability and increase ridership. This supplements existing transit income streams for municipalities. Increased ridership similarly reduces vehicle use, which has cost benefits for both commuters and municipalities.

Expanded Mitigation Options

This measure could be paired with other Transit subsector strategies (Measures T-25, T-29, and T-46) for increased reductions.

GHG Reduction Formula

$$A = -1 \times \frac{B \times C \times D \times E \times G}{F}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from vehicle travel in plan/community	0–0.6	%	calculated
User Inputs				
B	Percent of plan/community transit routes that receive treatments	0–100	%	user input
Constants, Assumptions, and Available Defaults				
C	Percent change in transit travel time due to treatments	-10	%	TRB 2007
D	Elasticity of transit ridership with respect to transit travel time	-0.4	unitless	TRB 2007
E	Transit mode share in plan/community	Table T-3.1	%	FHWA 2017a
F	Vehicle mode share in plan/community	Table T-3.1	%	FHWA 2017a
G	Statewide mode shift factor	57.8	%	FHWA 2017b

Further explanation of key variables:

- (C) – A literature review of studies from the U.S. and United Kingdom indicates that the travel time savings associated with one type of transit-supportive roadway treatment—transit signal prioritization—typically ranged from 8 to 12 percent (TRB 2007). To account for the likelihood that a user would implement multiple transit-supportive treatments, the midpoint of this range is used for the measure formula. Use of the midpoint is still conservative given the additional travel time savings associated with other transit-supportive treatments. If the user can provide a project-specific value based on the suite of their treatments, then the user should replace this default in the GHG reduction formula.
- (E and F) – Ideally, the user will calculate transit and auto mode shares for a plan/community at the city scale (or larger). Potential data sources include the California Household Travel Survey (preferred) or local survey efforts. If the user is not able to provide a project-specific value using one of these data sources, they have the option to input the mode shares for transit and vehicles for one of the six most populated CBSAs in California, as presented in Table T-3.1 in Appendix C. It is likely for areas outside of the area covered by the listed CBSAs to have vehicle mode shares higher and transit mode shares lower than the values provided in the table.

- (G) – Mode shift factor is an adjustment to reflect the reduction in vehicle trips associated with a reduction in person trips as some vehicles carry more than one person. It is calculated as (1/average vehicle occupancy) (FHWA 2017b).

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) For projects that use default CBSA data from Table T-3.1 and (C_{max}), the maximum percent reduction in GHG emissions (A) is 0.6 percent. This maximum scenario is presented in the below example quantification.

(C_{max}) The percent reduction in transit travel time is capped at 20 percent, which is based on the values reported in a literature review of studies from the U.S. and United Kingdom (TRB 2007).

Subsector Maximum

($\sum A_{max_{T\text{-}25 \text{ through } T\text{-}29,\ T\text{-}46}} \leq 15\%$) This measure is in the Transit subsector. This subcategory includes Measures T-25 through T-29 and T-46. The VMT reduction from the combined implementation of all measures within this subsector is capped at 15 percent.

Mutually Exclusive Measures

If the user selects Measure T-28, *Provide Bus Rapid Transit*, and converts all transit routes in the plan/community to BRT, then the user cannot also take credit for this measure, Measure T-26, *Increase Transit Service Frequency*, or Measure T-46, *Provide Transit Shelters*. This is because Measure T-28 accounts for the VMT reduction associated with increased transit frequency and decreased transit travel time as well as the additional BRT-specific bonus. To combine the GHG reductions from Measure T-28 with Measure T-27, Measure T-26, and/or Measure T-46 would be considered double counting. However, where BRT is proposed on less than all of the existing bus routes in the plan/community area, this measure, Measure T-26, and/or Measure T-46 could be applied to the remaining bus routes, and the measure reductions could be combined with Measure T-28 to determine the emissions reduction at the larger plan/community scale.

Example GHG Reduction Quantification

The user reduces plan/community GHGs by implementing transit-supportive roadway treatments that decrease transit travel time, thereby encouraging a mode shift from vehicles to transit and reducing VMT. In this example, the project is in San Francisco-Oakland-Hayward CBSA where the transit and vehicle mode shares would be 11.38 percent and 86.96 percent, respectively (E and G). Assuming the maximum decrease in transit travel time of 20 percent (C_{max}) and implementation for all transit routes (100 percent) in the plan/community (B), the user would reduce plan/community GHG emissions from VMT by 0.6 percent.

$$A = -1 \times \frac{100\% \times -20\% \times -0.4 \times 11.38\% \times 57.8\%}{86.96\%} = -0.6\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in passenger vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in passenger VMT would be the same as the percent reduction in GHG emissions (A).

Sources

- Federal Highway Administration (FHWA). 2017a. *National Household Travel Survey–2017 Table Designer*. Travel Day PMT by TRPTRANS by HH_CBSA. Available: https://nhts.ornl.gov/. Accessed: January 2021.
- Federal Highway Administration (FHWA). 2017b. *National Household Travel Survey–2017 Table Designer*. Average Vehicle Occupancy by HHSTFIPS. Available: https://nhts.ornl.gov/. Accessed: January 2021.
- Transportation Research Board (TRB). 2007. *Transit Cooperative Research Program Report 118: Bus Rapid Transit Practitioner's Guide*. Available: https://nacto.org/docs/usdg/tcrp118brt_practitioners_kittleson.pdf. Accessed: January 2021.

T-28. Provide Bus Rapid Transit

Photo Credit: LA Metro, 2021

GHG Mitigation Potential

13.8%

Up to 13.8% of GHG emissions from vehicle travel in the plan/community

Co-Benefits (icon key on pg. 34)

Climate Resilience

Providing BRT can incentivize more people to use transit, resulting in less traffic and better allowing emergency responders to access a hazard site during an extreme weather event. Furthermore, emergency responders can use queue jumps and dedicated BRT lanes when needed.

Health and Equity Considerations

Transit facilities can have conflicts with cyclists. Consider appropriate BRT components to minimize conflicts. Improved transit investments should be equitably distributed, prioritizing areas with transit deficiencies in underserved communities.

Measure Description

This measure will convert an existing bus route to a bus rapid transit (BRT) system. BRT includes the following additional components, compared to traditional bus service: exclusive right-of-way (e.g., busways, queue jumping lanes) at congested intersections, increased limited-stop service (e.g., express service), intelligent transportation technology (e.g., transit signal priority, automatic vehicle location systems), advanced technology vehicles (e.g., articulated buses, low-floor buses), enhanced station design, efficient fare-payment smart cards or smartphone apps, branding of the system, and use of vehicle guidance systems. BRT can increase the transit mode share in a community due to improved travel times, service frequencies, and the unique components of the BRT system. This mode shift reduces VMT and the associated GHG emissions.

Subsector

Transit

Locational Context

Urban, suburban

Scale of Application

Plan/Community

Implementation Requirements

The measure quantification methodology accounts for the increase in ridership from (1) improved travel times from transit signal prioritization, (2) increased service frequency, and (3) the unique ridership increase associated with a full-featured BRT service operating on a fully segregated running way with specialized (or stylized) vehicles, attractive stations, and efficient fare collection practices. To take credit for the estimated emissions reduction, the user should implement, at minimum, these components.

Cost Considerations

Providing BRT will require capital investment to purchase specialized vehicles, develop passenger information systems, and construct stations and busways. Total costs vary depending on the suite of BRT components pursued. Grade-separated busways are more expensive than at-grade busways and mixed flow lanes. Dedicated transit infrastructure will improve transit reliability and increase ridership. This supplements existing transit income streams for municipalities. Increased ridership similarly reduces vehicle use, which has cost benefits for both commuters and municipalities.

Expanded Mitigation Options

This measure could be paired with Measure T-25, *Extend Transit Network Coverage or Hours,* and Measure T-29, *Reduce Transit Fares,* for increased reductions.

GHG Reduction Formula

$$A = -C \times \frac{D \times F \times \left((B \times I) + (H \times J) + G\right)}{E}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from vehicle travel in plan/community	0–13.8	%	calculated
User Inputs				
B	Percent increase in transit frequency due to BRT	0–300	%	user input
C	Level of implementation	0–100	%	user input
Constants, Assumptions, and Available Defaults				
D	Transit mode share in plan/community	Table T-3.1	%	FHWA 2017a
E	Vehicle mode share in plan/community	Table T-3.1	%	FHWA 2017a
F	Statewide mode shift factor	57.8	%	FHWA 2017b
G	Percent change in transit ridership due to BRT	25	%	TRB 2007
H	Percent change in transit travel time due to BRT	-10 to -20	%	TRB 2007
I	Elasticity of transit ridership with respect to frequency of service	0.5	unitless	Handy et al. 2013
J	Elasticity of transit ridership with respect to transit travel time	-0.4	unitless	TRB 2007

Further explanation of key variables:

- (A) – This formula does not reflect any increase in transit vehicle travel and emissions, which can at least partially offset the reduction in GHG emissions from passenger vehicle travel.[14] Inclusion of this component in the percent GHG reduction formula would require inputs that would not be available to most users. Users can calculate the absolute changes in passenger vehicle and bus VMT and emissions using the process described under *Co-Benefits*.
- (B) – Frequency is measured as the number of arrivals over a given time (e.g., buses per hour). Frequency is the inverse of transit headway, defined as the time between transit vehicle arrivals on a given route. This variable can be calculated as [transit frequency with measure minus existing transit frequency] divided by existing transit frequency.

[14] As discussed in Chapter 2, *Integrated and Resilient Planning*, the ICT regulation requires all public transit agencies to gradually transition to 100 percent zero-emission bus fleets by 2040. Accordingly, combustion emissions from transit operation will decline as vehicle fleets move to achieve the state's zero-emission bus goals.

- (C) – The level of implementation refers to the number of transit routes receiving the frequency improvement as a fraction of the total transit routes in the plan/community.
- (D and E) – Ideally, the user will calculate transit and auto mode shares for a plan/community at the city scale (or larger). Potential data sources include the California Household Travel Survey (preferred) or local survey efforts. If the user is not able to provide a project-specific value using one of these data sources, the user has the option to input the mode shares for transit and vehicles for one of the six most populated CBSAs in California, as presented in Table T-3.1 in Appendix C. It is likely for areas outside of the area covered by the listed CBSAs to have vehicle mode shares higher and transit mode shares lower than the values provided in the table.
- (F) – Mode shift factor is an adjustment to reflect the reduction in vehicle trips associated with a reduction in person trips, since some vehicles carry more than one person. It is calculated as (1/average vehicle occupancy).
- (G) – A BRT practitioner's guide summarizing the results of numerous BRT case studies concluded that, on top of the ridership gains from improved travel times and increased service frequency, an additional 25 percent increase in ridership would occur from a full-featured BRT service operating on a fully segregated running way with specialized (or stylized) vehicles, attractive stations, and efficient fare collection practices.
- (H) – A literature review of studies from the United States and United Kingdom indicates that the travel time savings associated with one type of BRT component—transit signal prioritization—typically average 10 percent (TRB 2007). If the user can provide a project-specific value based on the suite of BRT components, then the user should replace this default in the GHG reduction formula. Note that, as described below, (H) should not exceed 20 percent.
- (I) – A policy brief summarizing the results of transit service strategies concluded that a 0.5 percent increase in transit ridership occurs for every 1 percent increase in frequency (Handy et al. 2013).
- (J) – A BRT practitioner's guide summarizing the results of numerous BRT case studies concluded that a -0.4 percent decrease in transit ridership occurs for every 1 percent increase in transit travel time (TRB 2007).

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) For projects that use default CBSA data from Table T-3.1 and (B_{max}), the maximum percent reduction in GHG emissions (A) is 13.8 percent. This maximum scenario is presented in the below example quantification.

(B_{max}) The percent change in transit frequency is capped at 300 percent (SANDAG 2019).

(H_{max}) The percent reduction in transit travel time is capped at 20 percent, which is based on the values reported in a literature review of studies from the United States and United Kingdom (TRB 2007).

Subsector Maximum

($\sum A_{max_{T\text{-}25\text{ through }T\text{-}29,\ T\text{-}46}} \leq 15\%$) This measure is in the Transit subsector. This subcategory includes Measures T-25 through T-29 and T-46. The VMT reduction from the combined implementation of all the non–mutually-exclusive measures within this subsector is capped at 15 percent.

Mutually Exclusive Measures

If the user selects this measure and converts all transit routes in the plan/community to BRT (B), then the user cannot also take credit for Measure T-26, *Increase Transit Service Frequency*, Measure T-27, *Implement Transit-Supportive Roadway Treatments,* or Measure T-46, *Provide Transit Shelters*. This is because Measure T-28 accounts for the VMT reduction associated with increased transit frequency and decreased transit travel time as well as the additional BRT-specific bonus. To combine the GHG reductions from Measure T-28 with Measure T-27, Measure T-26, and/or Measure T-46 would be considered double counting. However, where BRT is proposed on less than all of the existing bus routes in the plan/community area, Measure T-26, Measure T-27, and/or Measure T-46 could be applied to the remaining bus routes, and the measure reductions could be combined to determine the emissions reduction at the larger plan/community scale.

Example GHG Reduction Quantification

The user reduces plan/community GHGs by implementing a full-featured BRT system, thereby encouraging a mode shift from vehicles to transit and reducing VMT. In this example, the project is in the San Francisco–Oakland–Hayward CBSA where transit and vehicle mode shares would be 11.38 percent and 86.96 percent, respectively (D and E). Assuming the maximum increase in transit frequency of 300 percent (B_{max}), the maximum decrease in transit travel time of 20 percent (H_{max}), and implementation for all transit routes (100 percent) in the plan/community (B), the user would reduce plan/community GHG emissions from VMT by 13.8 percent.

$$A = -100\% \times \frac{11.38\% \times 57.8\% \times ((300\% \times 0.5) + (-20\% \times -0.4) + 25\%)}{86.96\%} = -13.8\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

VMT Reductions

The decrease in passenger vehicle miles (K) and increase in BRT miles (O) by the measure can be calculated as follows.

Passenger Vehicle VMT Reduction Formula

The percent reduction in passenger VMT would be the same as the percent reduction in GHG emissions (A). The absolute reduction in passenger VMT can be calculated using the following formula.

$$K = -\left(D \times L \times M \times N \times \left((B \times I) + (H \times J) + G\right)\right)$$

Passenger Vehicle VMT Reduction Calculation Variables

ID	Variable	Value	Unit	Source
Output				
K	Reduction in passenger vehicle miles in plan/community	[ ]	miles per year	calculated
User Inputs				
L	Total daily person trips in corridor(s)	[ ]	trips per day	user input
M	Vehicle trip length	[ ]	miles per trip	user input
Constants, Assumptions, and Available Defaults				
N	Days per year BRT available	365	days per year	assumed

Further explanation of key variables:

- (L) – The total daily person trips in the corridor(s) represents the total daily trips by all modes between the BRT origin area and the BRT destination area. This may be obtained through travel demand modeling. If the strategy involves BRT for more than one route, then the total person trips should reflect the sum of all the routes being improved.
- (M) – If the strategy involves BRT for more than one transit route, then the trip length should reflect the average of all the routes being converted.
- Please refer to the GHG Calculation Variables table above for definitions of variables that have been previously defined.

BRT VMT Increase Formula

The absolute increase in BRT VMT can be calculated using the formula below. As noted above, the formula for the percent GHG reduction (A) does not reflect any increase in BRT VMT or BRT emissions. Users that wish to capture these impacts should calculate absolute changes.

$$O = S \times (P_2 - P_1) \times Q \times R \times N$$

BRT VMT Increase Calculation Variables

ID	Variable	Value	Unit	Source
Output				
O	Increase in annual BRT miles in plan/community	[ ]	miles per year	calculated
User Inputs				
P_1	Bus frequency without measure	[ ]	transit vehicle roundtrips per hour	user input
P_2	BRT frequency with measure	[ ]	transit vehicle roundtrips per hour	user input
Q	BRT hours of operation	0–24	hours per day	user input
R	BRT route one-way length	[ ]	miles per route	user input
Constants, Assumptions, and Available Defaults				
S	One-way trips in a roundtrip	2	One-way trips per roundtrip	conversion

Further explanation of key variables:

- (O) – If the strategy involves frequency improvements for more than one transit route, then the increase in BRT miles should be calculated separately for each route.
- Please refer to the Passenger Vehicle VMT Reduction Calculation Variables table above for definitions of variables that have been previously defined.

Energy and Fuel Savings

The decrease in passenger vehicle fuel consumption and increase in BRT fuel consumption by the measure can be calculated as follows.

Passenger Vehicle Fuel Use Reduction Formula

Multiply the reduction in passenger vehicle miles (K) above by the fuel efficiency of the vehicle type (see Table T-30.2 in Appendix C) to output the change in fuel consumption.

BRT Fuel Use Increase Formula

The absolute increase in BRT fuel consumption (T) can be calculated using the formula below.

$$T = O \times U$$

BRT Fuel Use Increase Calculation Variables

ID	Variable	Value	Unit	Source
Output				
T	Increase in annual BRT fuel consumption in plan/community	[ ]	gal per year	calculated
User Inputs				
	None			
Constants, Assumptions, and Available Defaults				
U	Fuel economy of BRT, by fuel type	Table T-26.1	gal or kilowatt hour per mile	CARB 2020; U.S. DOE 2021

Further explanation of key variables:

- (U) – The average fuel economy for gasoline, diesel, and natural gas transit buses was calculated using EMFAC2017 (v1.0.3). The model was run for a 2020 statewide average of UBUS vehicles, disaggregated by fuel type (CARB 2020). The efficiency of electric buses was calculated based on the gasoline equivalent value (U.S. DOE 2021). The user should reference Table T-26.1 for the fuel economy of the appropriate fuel type for their location's transit system. If the user can provide a project-specific value (i.e., for a future year and project location), the user should run EMFAC to replace the default in the fuel use increase formula. Also, if the BRT vehicles are fueled by hydrogen, the user will need to calculate the increase in hydrogen fuel consumption using project-specific values, as hydrogen is currently not included as a fuel type in EMFAC.
- Please refer to the BRT VMT Increase Calculation Variables table above for definitions of variables that have been previously defined.

Sources

- California Air Resources Board (CARB). 2020. *EMFAC2017 v1.0.3*. August. Available: https://arb.ca.gov/emfac/emissions-inventory. Accessed: January 2021.
- Federal Highway Administration (FHWA). 2017a. *National Household Travel Survey–2017 Table Designer*. Travel Day PMT by TRPTRANS by HH_CBSA. Available: https://nhts.ornl.gov/. Accessed: January 2021.
- Federal Highway Administration (FHWA). 2017b. *National Household Travel Survey–2017 Table Designer*. Average Vehicle Occupancy by HHSTFIPS. Available: https://nhts.ornl.gov/. Accessed: January 2021.
- Handy, S., K. Lovejoy, M. Boarnet, and S. Spears. 2013. *Impacts of Transit Service Strategies on Passenger Vehicle Use and Greenhouse Gas Emissions*. October. Available: https://ww2.arb.ca.gov/sites/default/files/2020-06/Impacts_of_Transit_Service_Strategies_on_Passenger_Vehicle_Use_and_Greenhouse_Gas_Emissions_Policy_Brief.pdf. Accessed: January 2021.
- San Diego Association of Governments (SANDAG). 2019. *Mobility Management VMT Reduction Calculator Tool–Design Document*. June. Available: https://www.icommutesd.com/docs/default-source/planning/tool-design-document_final_7-17-19.pdf?sfvrsn=ec39eb3b_2. Accessed: January 2021.
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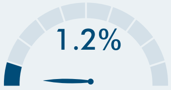
- U.S. Department of Energy (U.S. DOE). 2021. *Fuel Economy Datasets for All Model Years (1984-2021)*. January. Available: https://www.fueleconomy.gov. Accessed: January 2021.

T-29. Reduce Transit Fares

GHG Mitigation Potential



Up to 1.2% of GHG emissions from vehicle travel in the plan/community

Co-Benefits (icon key on pg. 34)

Climate Resilience

Reducing transit fares increases the capacity of low-income populations to use transit to evacuate or access resources during extreme weather events. Reduced fares could also incentivize more people to use transit, resulting in less traffic and better allowing emergency responders to access sites. This also reduces transit system disruptions due to extreme weather events. Lower transportation costs would also increase community resilience by freeing up resources for other purposes, such as increased cooling costs.

Health and Equity Considerations

Transit fare reduction programs should first prioritize routes with higher-volume potential in underserved communities and those most reliant on transit for travel (e.g., students, persons with disabilities, seniors).

Measure Description

This measure will reduce transit fares on the transit lines serving the plan/community. A reduction in transit fares creates incentives to shift travel to transit from single-occupancy vehicles and other traveling modes, which reduces VMT and associated GHG emissions.

This measure differs from Measure T-8, *Implement Subsidized or Discounted Transit Program*, which can be offered through employer-based benefits programs in which the employer fully or partially pays the employee's cost of transit.

Subsector

Transit

Locational Context

Urban, suburban

Scale of Application

Plan/Community

Implementation Requirements

Transit fare reductions can be implemented systemwide or in specific fare-free or reduced-fare zones.

Cost Considerations

Reducing transit fares will lower the per capita income of the transit service. This may be outweighed by increased ridership, and savings on infrastructure costs due to reduced car usage. Reduced fares can be targeted to specific populations or groups, depending on need. Individuals receiving the reduced fare will obtain a cost savings.

Expanded Mitigation Options

This measure could be paired with other Transit subsector strategies (Measure T-25, *Extend Transit Network Coverage or Hours,* and Measure T-26, *Increase Transit Service Frequency*) for increased reductions.

GHG Reduction Formula

$$A = \frac{B \times C \times D \times E \times G}{F}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from vehicle travel in plan/community	0–1.2	%	calculated
User Inputs				
B	Percent reduction in transit fare with measure	0–50	%	user input
C	Percent of plan/community transit routes that receive reduced fares	0–100	%	user input
Constants, Assumptions, and Available Defaults				
D	Elasticity of transit ridership with respect to transit fare	-0.3	unitless	Handy et al. 2013
E	Transit mode share in plan/community	Table T-3.1	%	FHWA 2017a
F	Vehicle mode share in plan/community	Table T-3.1	%	FHWA 2017a
G	Statewide mode shift factor	57.8	%	FHWA 2017a

Further explanation of key variables:

- (B) – The user can calculate the percent reduction in transit fare based on the percent difference between the existing fare price and the proposed fare price.
- (C) – The level of implementation refers to the fraction of transit routes that on which fare reductions are implemented. Typically, fare reductions are made system-wide, so this variable would be 100.
- (D) – A policy brief summarizing the results of transit service studies reported that a 0.3 to 1.0 percent increase in transit ridership occurs for every 1.0 percent decrease in transit fares (Handy et al. 2013). To be conservative, the low end of this range is cited.
- (E and F) – Ideally, the user will calculate transit and auto mode shares for a plan/community at the city scale (or larger). Potential data sources include the California Household Travel Survey (preferred) or local survey efforts. If the user is not able to provide a project-specific value using one of these data sources, they have the option to input the mode shares for transit and vehicles for one of the six most populated CBSAs in California, as presented in Table T-3.1 in Appendix C. It is likely for areas outside of the area covered by the listed CBSAs to have vehicle mode shares higher and transit mode shares lower than the values provided in the table.
- (G) – Mode shift factor is an adjustment to reflect the reduction in vehicle trips associated with a reduction in person trips as some vehicles carry more than one person. It is calculated as (1/average vehicle occupancy) (FHWA 2017b).

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) For projects that use default CBSA data from Table T-3.1 and (B_{max}), the maximum percent reduction in GHG emissions (A) is 1.2 percent.

(B_{max}) The percent reduction in transit fare is capped at 50 percent (SANDAG 2019).

Subsector Maximum

($\sum A_{max_{T\text{-}25\text{ through }T\text{-}29,\ T\text{-}46}} \leq 15\%$) This measure is in the Transit subsector. This subcategory includes Measures T-25 through T-29 and T-46. The VMT reduction from the combined implementation of all measures within this subsector is capped at 15 percent.

Example GHG Reduction Quantification

The user reduces plan/community GHGs by reducing the costs associated with using transit, thereby encouraging a mode shift from single occupancy vehicles to transit and reducing VMT. In this example, the project is in the San Jose-Sunnyvale-Santa Clara CBSA, where the transit and vehicle mode shares would be 6.69 percent and 91.32 percent, respectively (E and F). Assuming the maximum decrease in transit fares of 50 percent (B) and implementation for all transit routes (100 percent) in the plan/community (C), the user would reduce plan/community GHG emissions from VMT by 0.6 percent.

$$A = \frac{\mathbf{50\%} \times \mathbf{100\%} \times -0.3 \times 6.69\% \times 57.8\%}{91.32\%} = -0.6\%$$

Quantified Co-Benefits

Improved Local Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* above for further discussion.

Energy and Fuel Savings

The percent reduction in passenger VMT would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in passenger vehicle fuel consumption would be the same as the percent reduction in GHG emissions (A).

Sources

- Federal Highway Administration (FHWA). 2017a. *National Household Travel Survey–2017 Table Designer*. Travel Day PMT by TRPTRANS by HH_CBSA. Available: https://nhts.ornl.gov/. Accessed: January 2021.
- Federal Highway Administration (FHWA). 2017b. *National Household Travel Survey–2017 Table Designer*. Average Vehicle Occupancy by HHSTFIPS. Available: https://nhts.ornl.gov/. Accessed: January 2021.
- Handy, S., K. Lovejoy, M. Boarnet, and S. Spears. 2013. *Impacts of Transit Service Strategies on Passenger Vehicle Use and Greenhouse Gas Emissions*. October. Available: https://ww2.arb.ca.gov/sites/default/files/2020-06/Impacts_of_Transit_Service_Strategies_on_Passenger_Vehicle_Use_and_Greenhouse_Gas_Emissions_Policy_Brief.pdf. Accessed: January 2021.
- San Diego Association of Governments (SANDAG). 2019. *Mobility Management VMT Reduction Calculator Tool–Design Document*. June. Available: https://www.icommutesd.com/docs/default-source/planning/tool-design-document_final_7-17-19.pdf?sfvrsn=ec39eb3b_2. Accessed: January 2021.

T-30. Use Cleaner-Fuel Vehicles

GHG Mitigation Potential

100%

Up to 100% of GHG emissions from on-road vehicles

Co-Benefits (icon key on pg. 34)

(icon key on pg. 34)

Climate Resilience

Using cleaner-fuel vehicles increases transportation resilience by providing a wider range of available vehicles if other fuels (like gasoline) become unavailable.

Health and Equity Considerations

While most cleaner fuels reduce both GHG and criteria air pollutants, a few may increase criteria pollutant emissions. The most prominent example of this is biodiesel, which generally results in higher NO_x emissions, but lower PM emissions compared to diesel.

Measure Description

This measure requires use of cleaner-fuel vehicles in lieu of similar vehicles powered by gasoline or diesel fuel. Cleaner-fuel vehicles addressed in this measure include electric vehicles, natural gas and propane vehicles, and vehicles powered by biofuels such as composite diesel (blend of renewable diesel, biodiesel, and conventional fossil diesel), ethanol, and renewable natural gas.

The full GHG emissions impact of cleaner fuels depends on the emissions from the vehicle's tailpipe as well as the emissions associated with production of the fuel (sometimes termed "upstream" emissions). For example, tailpipe GHG emissions from renewable natural gas are identical to tailpipe GHG emissions from conventional natural gas; the GHG benefits of renewable natural gas come from the fact that it is produced from biomass. Similarly, BEVs have zero tailpipe emissions, but properly accounting for their GHG impacts requires quantifying the emissions associated with the electricity generation needed to charge the vehicle's batteries.

Subsector

Clean Vehicles and Fuels

Locational Context

Non-applicable

Scale of Application

Project/Site or Plan/Community

Implementation Requirements

See measure description.

Cost Considerations

Capital costs to purchase cleaner fuel vehicles are high. Fueling infrastructure may be required, which will add to the upfront cost of transitioning to cleaner fuel vehicles. Fuel costs and savings compared to gasoline and diesel will vary depending on the type of fuel and market conditions. It is feasible to expect reduced fuel costs from cleaner fuels with an increased market and overall fuel cost savings over the life of the vehicle fleet.

Expanded Mitigation Options

If using electric vehicles, pair with Measure T-14 to ensure that electric vehicles have sufficient access to charging infrastructure.

GHG Reduction Formula

California has a well-defined process for quantifying the GHG emissions impacts of cleaner-fuel vehicles by virtue of the state's Low Carbon Fuel Standard (LCFS) program. An emissions calculation that considers both vehicle tailpipe and upstream fuel production emissions is sometimes referred to as a "well-to-wheels" analysis (A3 below). An emissions calculation that considers only vehicle tailpipe emissions is referred to as a "tank-to-wheels" analysis (A1 and A2 below).

The convention for project analysis under CEQA typically employs a hybrid approach. For natural gas, propane, and biofuels vehicles, the CEQA analysis quantifies only tailpipe emissions and does not seek to capture differences in emission associated with fuel production. However, for electric vehicles, CEQA analyses typically account for emissions associated with electricity generation (A1 and A2 below).

$$A1 = B \times \frac{(D \times E \times F \times G) - C}{C}$$

$$A2 = B \times \frac{(D \times E \times F \times G \times H) + \left(C \times \frac{1}{I} \times (1 - H)\right) - C}{C}$$

$$A3 = B \times \frac{J - K}{K}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A1	Percent reduction in GHG emissions from on-road vehicle emissions for BEVs	0–100	%	calculated
A2	Percent reduction in GHG emissions from on-road vehicle emissions for PHEVs	0–64	%	calculated
A3	Percent reduction in well-to-wheels GHG emissions from cleaner fuels or vehicle technologies	0–100	%	calculated
User Inputs				
B	Percent of vehicle fleet being converted to cleaner fuels	1–100	%	user input
C	Emission factor for existing (conventional fuel) vehicle	[ ]	g CO_2e per mile	CARB 2020a
Constants, Assumptions, and Available Defaults				
D	BEV efficiency	Table T-30.1	kWh per mile	see note

ID	Variable	Value	Unit	Source
E	Carbon intensity of local electricity provider	Tables E-4.3 and E-4.4	lb CO_2e per MWh	CA Utilities 2021
F	Conversion from lb to gram	454	g per lb	conversion
G	Conversion from kWh to MWh	0.001	MWh per kWh	conversion
H	Percent of PHEV miles in electric mode	46	%	CARB 2020a
I	Ratio of average hybrid vehicle mpg to comparable gasoline vehicle mpg	1.5	unitless	see below
J	Well-to-wheels emission factor for cleaner vehicle/fuel	Table T-30.2	g CO_2e per mile	CARB 2020a, 2020b, 2020c; U.S. DOE 2021
K	Well-to-wheels emission factor for existing (conventional fuel) vehicle	Table T-30.2	g CO_2e per mile	CARB 2020a, 2020b, 2020c; U.S. DOE 2021

Further explanation of key variables:

- (A1 or A2) – Use of these equations is appropriate for a typical CEQA project analysis, which considers tailpipe GHG emissions and, for electric vehicles, electricity generation emissions.
- (A3) – Use of this equation is appropriate for a user interested in a well-to-wheels analysis for all fuel types. The user should determine the appropriate emission factors for the conventional fuel and cleaner fuel.
- (C) – The user should run EMFAC to output GHG emission factors (CO_2, CH_4, and N_2O) for the existing (conventional fuel) vehicles. The EMFAC run should be based on project-specific values for the region, project year, season, vehicle category, model year, speed, and fuel type (gasoline, diesel, or a weighted average).[15] To determine the CO_2e emission factor of the conventional fuel vehicle, the emission factors for CO_2, CH_4, and N_2O from EMFAC should be multiplied by the corresponding 100-year GWP values (1, 25, and 298, respectively) from the IPCC's Fourth Assessment Report (IPCC 2007) and then summed.
- (E) – GHG intensity factors for major California electricity providers are provided in Tables E-4.3 and E-4.4. If the project study area is not serviced by a listed electricity provider, or the user is able to provide a project-specific value (i.e., for a future year not referenced in Tables E-4.3 and E-4.4), the user should use that specific value in the GHG calculation formula. If the electricity provider is not known, users may elect to use the statewide grid average carbon intensity.
- (H) – Based on the EMFAC2017 model (v1.0.3), 46 percent of miles traveled by PHEVs in California are in electric mode (eVMT), with 54 percent in gasoline mode (CARB 2020a).

[15] There are many different combinations of input variables a user could specify in EMFAC to result in a unique emission factor output. This report does not attempt to consolidate a standardized group of emission factor output into a database table for the user to refer to. It is recommended the user run EMFAC to obtain project-specific results.

- (I) – Assumes that a PHEV operating in gasoline mode is similar to a gasoline hybrid (non-plug-in) vehicle. A typical gasoline hybrid vehicle has 50 percent higher fuel economy (mpg) than a comparable gasoline vehicle, based on a comparison of the gasoline and hybrid Toyota Camry and Corolla models (U.S. DOE 2021).
- (J and K) – The average California values for fuel efficiency, energy density, and carbon intensity of typical vehicle and fuel types are provided in Table T-30.2 (CARB 2020a, 2020b, 2020c; U.S. DOE 2021). Table T-30.2 also provides the well-to-wheels emission factor, which can be calculated based on the product of the fuel efficiency, energy density, and carbon intensity. If the user can provide a project-specific value, then the user should replace in the GHG calculation formula one or more of these values that produces the emission factor.
- (D) – BEV energy efficiency varies by vehicle type. The average California values are provided in Table T-30.1 in Appendix C. If the user can provide a project-specific value, they should replace the default in the GHG reduction formula. BEV energy efficiency can be calculated as:

$$\text{BEV efficiency (kWh per mile)} = \frac{L}{M \times N}$$

Where,

- (L) – Gasoline to electricity conversion. Users can assume 33.7 kWh per gallon of gasoline, which is a standard conversion factor used by U.S. EPA and U.S DOE (U.S. EPA 2021).
- (M) – Fuel economy (mpg) of a comparable gasoline vehicle. Users can obtain this from Table T-30.2.
- (N) –EER for an electric vehicle. Users can assume 3.4, which is the EER established by CARB for electric vehicles as stated in the LCFS regulation. (CARB 2020b).

GHG Calculation Caps or Maximums

Measure Maximum

($A1_{max}$) The GHG reduction from the use of BEVs is capped at 100 percent, which assumes that 100 percent of the fleet would be converted (B) and that the local electricity provider is powered 100 percent by renewables and thus has a carbon intensity of zero (E).

($A2_{max}$) The GHG reduction from the use of PHEVs is capped at 64 percent, which assumes that 100 percent of the fleet would be converted (B) and that the local electricity provider is powered 100 percent by renewables and thus has a carbon intensity of zero (E).

($A3_{max}$) For a well-to-wheels analysis, the GHG reduction from the use of electric vehicles is capped at 100 percent, which assumes that the local electricity provider is powered 100 percent by renewables and thus has a carbon intensity of zero (L). Note that the maximum percent reduction for all other cleaner vehicles and fuels presented in Table T-30.2 will not reach this maximum.

Subsector Maximum

Same as (A_{max}). Measure T-30 is the only measure at the Plan/Community scale within the Clean Vehicles and Fuels subsector.

Example GHG Reduction Quantification

The user reduces vehicle emissions by avoiding the use of conventional fuels in place of cleaner fuels or vehicle technologies. In this example, a municipality that sources their electricity from an electricity provider powered 100 percent by renewables (E) is converting half of their fleet of gasoline light duty automobiles to BEVs (B). The user has run EMFAC for their county, vehicle category, and project year, and determined the fleet emission factor to be 400 g CO_2e (C). The user would reduce GHG emissions from the existing fleet by 50 percent.

$$A1 = \mathbf{50\%} \times \frac{(0.33\,\frac{\text{kWh}}{\text{mi}} \times 0\,\frac{\text{lb CO}_2\text{e}}{\text{MWh}} \times 454\,\frac{\text{g}}{\text{lb}} \times 0.001\,\frac{\text{MWh}}{\text{kWh}}) - \mathbf{400\,\frac{g\ CO_2e}{mi}}}{\mathbf{400\,\frac{g\ CO_2e}{mi}}} = \text{-50\%}$$

Quantified Co-Benefits

Improved Local Air Quality

(O1) – The use of BEVS in lieu of conventional vehicles would decrease local criteria pollutants. The percent reduction is equal to (B). Electricity supplied by statewide fossil-fueled or bioenergy power plants will generate criteria pollutants. However, because these power plants are located throughout the state or outside the state, electricity consumption from vehicles charging typically will not generate localized criteria pollutant emissions on the project site or roadways traveled by the electric vehicles.

(O2) – The percent reduction in local criteria pollutants from use of PHEVs in lieu of conventional vehicles (A2) is equal to ($B \times A2_{max}$). See ($A2_{max}$) above, which assumes (E) is set to zero to nullify eVMT activity and vehicle fleet conversion (B_{max}) is set to 100 percent. ($A2_{max}$) is multiplied by the actual conversion of the vehicle fleet (B) to adjust the percent reduction calculated from ($A2_{max}$). Electricity supplied by statewide fossil-fueled or bioenergy power plants will generate criteria pollutants. However, because these power plants are located throughout the state or outside the state, electricity consumption from vehicles charging typically will not generate localized criteria pollutant emissions.

(O3) – For a well-to-wheels analysis, the fuels produced by facilities within and outside of California will generate criteria pollutants. Because these facilities are dispersed, offsite of the project/site or plan/community, fuel production typically will not generate localized criteria pollutant emissions. Therefore, only the tank-to-wheels (i.e., tailpipe) portion of the vehicle criteria pollutant emissions should be quantified. For BEVs and PHEVs, this can be done using the methodologies described above (O1 and O2, respectively). For vehicles fueled by diesel, biodiesel, renewable diesel, and natural gas, the criteria pollutant emission factor can be outputted by EMFAC (see C). The criteria pollutant reductions from use of gasoline hybrid or flex fuel vehicles cannot be readily quantified within EMFAC as these fuel types are not inputs the user can specify.

Fuel Savings (Increased Electricity)

(P1 and Q1) – The use of BEVs in lieu of conventional vehicles would decrease vehicle fuel consumption and increase electricity use. The percent reduction in fuel use (P1) is equal to (B). The absolute increase in electricity use can be calculated using the below formula (Q1).

(P2 and Q2) – The use of PHEVs in lieu of conventional vehicles would decrease vehicle fuel consumption and increase electricity use. The percent reduction in fuel use (P2) is equal to $(B \times A2_{max})$. The absolute increase in electricity use (Q2) is equal to $(H \times Q1)$.

(P3 and Q3) – For gasoline, gasoline hybrid, flex fuel, diesel, biodiesel, renewable diesel, and natural gas, the percent reduction in fuel use of the existing (conventional fuel) vehicle is equal to (B). The absolute increase in the cleaner fuel/vehicle energy can be calculated using the below formula (P3).

BEV Electricity Use Increase Formula

$$Q1 = \mathbf{B} \times \mathbf{D} \times \mathbf{R}$$

Electricity Use Increase Calculation Variables

ID	Variable	Value	Unit	Source
Output				
Q1	Increase in electricity from electric vehicles	[ ]	kWh per year	calculated
User Inputs				
R	Average annual VMT of all vehicles in fleet	[ ]	miles per year	user input
Constants, Assumptions, and Available Defaults				
	None			

Further explanation of key variables:

- Please refer to the GHG Calculation Variables table above for definitions of variables that have been previously defined.

Cleaner Vehicle Energy Use Increase Formula

$$P3 = \mathbf{B} \times \mathbf{R} \times \frac{S}{T}$$

Cleaner Vehicle Energy Use Increase Variables

ID	Variable	Value	Unit	Source
Output				
P3	Increase in vehicle fuel use in fleet	[ ]	megajoules (MJ)	calculated
User Inputs				
	None			
Constants, Assumptions, and Available Defaults				
S	Energy density for cleaner fuel/vehicle	Table T-30.2	MJ per gal	CARB 2019, 2020a, 2020b, 2020c; U.S. DOE 2021
T	Fuel efficiency for cleaner fuel/vehicle	Table T-30.2	mpg	

Further explanation of key variables:

- (S and T) – The average California values for fuel efficiency and energy density of typical vehicle and fuel types are provided in Table T-30.2 (CARB 2019, 2020a, 2020b, 2020c; U.S. DOE 2021). If the user can provide a project-specific value, then the user should replace in the fuel use reduction formula one or more of these values that produces the energy consumption value (MJ).
- Please refer to the GHG Calculation Variables table above for definitions of variables that have been previously defined.

Sources

- California Air Resources Board (CARB). 2019. *LCFS Pathway Certified Carbon Intensities.* Available: https://ww2.arb.ca.gov/resources/documents/lcfs-pathway-certified-carbon-intensities. Accessed: January 2021.
- California Air Resources Board (CARB). 2020a. *EMFAC2017 v1.0.3*. August. Available: https://arb.ca.gov/emfac/emissions-inventory. Accessed: January 2021.
- California Air Resources Board (CARB). 2020b. *Unofficial electronic version of the Low Carbon Fuel Standard Regulation.* Available: https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf. Accessed: January 2021.
- California Air Resources Board (CARB). 2020c. *California Climate Investments Quantification Methodology Emission Factor Database and Documentation.* August. Available: https://ww2.arb.ca.gov/resources/documents/cci-quantification-benefits-and-reporting-materials. Accessed: January 2021.
- Intergovernmental Panel on Climate Change (IPCC). 2007. *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp. Available: https://www.ipcc.ch/report/ar4/wg1/. Accessed: January 2021.
- U.S. Department of Energy (U.S. DOE). 2021. *Fuel Economy Datasets for All Model Years (1984-2021)*. January. Available: https://www.fueleconomy.gov. Accessed: January 2021.
- U.S. Environmental Protection Agency (U.S. EPA). 2021. *Green Vehicle Guide*. Available: https://www3.epa.gov/otaq/gvg/learn-more-technology.htm.

T-40. Establish a School Bus Program

GHG Mitigation Potential

57%

Up to 57% of GHG emissions from school commute vehicle travel

Co-Benefits (icon key on pg. 34)

Climate Resilience

Establishing a school bus program can take more cars off the road, resulting in less traffic and better allowing emergency responders to access a hazard site during an extreme weather event.

Health and Equity Considerations

Shifting children's trips to school from private car trips to bus, bicycling or walking trips promotes consistent physical activity. Prioritize service for students who live further away from schools with limited access to sustainable modes of transportation.

Measure Description

This measure requires establishing or expanding a school bus program. Busing provides a practical way to transport students to school while also offering reductions in GHG emissions when there is high enough ridership. When districts establish busing programs, they directly replace automobile trips to take students to and from school.

Subsector

School Programs

Locational Context

Urban, suburban

Scale of Application

Project/Site

Implementation Requirements

See measure description.

Cost Considerations

Establishing or expanding a school bus program requires capital investment to purchase school buses or operating expenses associated with using contracted transportation service, along with increased staffing to direct the program. Total costs vary depending on the type and capacity of buses, as well as on the routes and frequency of service. Electric school buses can cost more initially but offer long-term cost benefits through lower maintenance costs and fuel efficiency. Familes of students who may more easily be able to travel without a car may also observe cost savings from reduced vehicle usage or ownership.

Expanded Mitigation Options

Use electric buses to achieve greater emissions reductions compared to conventional diesel buses with the same number of passengers. Because diesel school buses have much higher emissions per mile than a typical light-duty vehicle and take a much longer route than a direct drive to school, they need to transport a high number of students to make up for the bus emissions. The circumstances change, however, with the introduction of electric buses; even a small capacity electric bus of five students leads to emission reductions relative to the average passenger vehicle.

GHG Reduction Formula

$$A = -\frac{B \times C \times D \times \left(\frac{H}{E} - \frac{G \times I}{F}\right)}{\frac{H}{E}}$$

GHG Calculation Variables

ID	Parameter	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from vehicle travel among students	0–57	%	calculated
User Inputs				
B	Percent of students across the school who begin riding the bus as a result of the program	0–100	%	user input
C	Percent of students served by bus system (regardless of whether they ride)	0–100	%	user input
Constants, Assumptions, and Available Defaults				
D	Percent of new bus riders who drove or were driven beforehand	79	%	FHWA 2023
E	Average student occupancy of cars driving to school	1.58	students/car	FHWA 2023
F	Average student occupancy of school buses	Table T-40.1	students/bus	Wang 2019
G	Adjustment for ratio of bus touring distance to driving distance	3.42	unitless	FHWA 2023; Duran 2013
H	Light-duty emission factor	Table T-30.2	grams CO_2e/mile	CARB 2019, 2020a, 2020b, 2020c; U.S. DOE 2021
I	School bus emission factor	Table T-40.2	grams CO_2e/mile	CARB 2021

Further explanation of key variables:

- (B) – This is the percentage of students at the school who can ride the bus and who begin riding the bus after the implementation of the program. For a new program, this is equal to the percentage of all students who ride. For a program change, this is equal to the difference in percentage of students who ride before and after program implementation.
- (C) – This is the percentage of students for whom the bus program provides service. If one neighborhood is served, then this is the percentage of students at the school who live in that neighborhood.

- (D) – If a district is conducting surveys as part of their California's Safe Routes to Schools (SR2S) or bus program expansion, it is recommended to include a question that assesses what fraction of new riders were driving before bus service was introduced. This eliminates any over counting from riders who biked, walked or took some other form of transit prior to the service's introduction.
- (E) – This constant is from NHTS and represents the average occupancy of school trips taken by car in the Pacific division. NHTS does not consider the driver an occupant if they are dropping someone off; however, students driving themselves to school are included in this occupancy value.
- (F) – This constant represents an estimate of the average occupancy of school buses based on research from Wang 2019.
- (G) – This constant was derived from NHTS data and school bus drive cycle data from Duran 2013. The average school trip taken in a private vehicle is 9.3 miles long in the Pacific Census division, while the average school bus tour is 31.7 miles. Thus, the ratio of bus touring distance to driving distance is 3.42.
- (H) – These light duty emissions factors are used throughout the Handbook and represent the emissions of cars taking students to school. The emission factors for light-duty autos or light-duty trucks is most appropriate.
- (I) – The school bus emission factor is taken from the most recent version of EMFAC and is used to determine the new emissions from the school buses added in this program. If a different type of vehicle is used for the program (such as a van or other light-duty vehicle), users should select the appropriate emission factor for that vehicle type as found in Table T-30.2 in Appendix C.

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The percent reduction in GHG emissions (A) is capped at 57 percent. The benefits are unlikely to be this high; this level assumes that buses have an occupancy of 17.3 students, all buses are electric, and all students ride the bus.

Subsector Maximum

($\sum A_{max_{T\text{-}40\ \&\ T\text{-}56}} \leq 57\%$) This measure is in the School Programs subsector. This subcategory includes Measures T-40 and T-56 at the Project/Site scale of application. The school trip VMT reduction from the combined implementation of all measures within this subsector is capped at 57 percent. The reduction percentage for this measure is applicable to the School Programs subsector, which includes school commute trips. If users would like to apply the reduction percentage to community-wide emissions, the reductions can be converted to community-scale reductions by multiplying the reduction percentage by 1.64 percent (FHWA 2023).

Example GHG Reduction Quantification

A school district in the San Diego area starts a new busing program that serves all students but only 50 percent (B) of eligible students ride. The buses run on compressed natural gas, and the average parent drives their child to school in an SUV. This would lead to a reduction in GHG emissions from school-based trips of 5.8 percent.

$$A = -\frac{\mathbf{50\%} \times \mathbf{100\%} \times 79\% \times \left(\frac{416.9 \frac{g}{mi}}{1.58 \frac{riders}{veh}} - \frac{3.42 \times 981 \frac{g}{mi}}{14.9 \frac{riders}{veh}} \right)}{\frac{417\ g/mi}{1.58 \frac{riders}{veh}}} = -5.8\%$$

Quantified Co-Benefits

Improved Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NOx, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption achieved by the measure would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in VMT achieved by the measure would be the same as the percent reduction in GHG emissions (A).

Sources

- California Air Resources Board (CARB). 2019. *LCFS Pathway Certified Carbon Intensities*. Available: https://ww2.arb.ca.gov/resources/documents/lcfs-pathway-certified-carbon-intensities. Accessed: January 2021.
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T-46. Provide Transit Shelters

GHG Mitigation Potential

.32%

Up to 0.32% of GHG emissions associated with plan/community VMT

Co-Benefits (icon key on pg. 34)

Climate Resilience

Transit shelters protect passengers from extreme weather, such as high temperatures and heavy precipitation. Providing transit shelters can also incentivize more people to use transit, resulting in less traffic and better allowing emergency responders to access a hazard site during an extreme weather event.

Health and Equity Considerations

Transit shelters can increase shade and provide heat mitigation for waiting passengers. Transit shelters also provide rest areas for people with disabilities and pregnant passengers. Increased access to safe, efficient, comfortable, and well-maintained public transit promotes physical activity and results in reduced health risk.

Measure Description

For this measure, a local government or transit agency provides amenities that make it safer and more comfortable to wait for the bus. The two interventions that have proven to lead to changes in rider perceptions are adding bus shelters and adding real-time arrival information. Research into transit ridership shows that adding these amenities decreases both the real and the perceived wait time for riders, which impacts riders' willingness to ride.

Subsector

Transit

Locational Context

Urban, suburban

Scale of Application

Plan/Community

Implementation Requirements

This measure requires that bus shelters also have benches because the combined effect of shelters and benches was measured in the studies cited.

Cost Considerations

Providing amenities requires capital investment to construct bus shelters and improve passenger communication systems to relay arrival information. Staff and maintenance costs may also increase. A portion of these costs may be offset by increased transit ridership and associated income. Increased ridership also reduces vehicle use, which has cost benefits for both commuters and municipalities.

Expanded Mitigation Options

When adding bus shelters, providing lighting is recommended as it increases rider perceptions of safety at night.

GHG Reduction Formula

$A1 = B \times \frac{C}{D} \times E \times \frac{F}{G} \times (H - I1) \times J$ (for bus shelters only)

$A2 = B \times \frac{C}{D} \times E \times \frac{F}{G} \times (H - I2) \times J$ (for bus shelters and real-time arrival information)

GHG Calculation Variables

ID	Parameter	Value	Unit	Source
Output				
A1, A2	Percent reduction in GHG emissions from vehicle travel in plan/community	0–0.32	%	calculated
User Inputs				
B	Number of transit stops with new bus shelters and benches	[ ]	unitless	user input
C	Average number of boardings per day at each transit station with added amenities	[ ]	boardings/day	user input
D	Average number of boardings per day across the transit agency	[ ]	boardings/day	user input
E	Transit mode share in the core-based statistical area	Table T-3.1	%	FHWA 2017
Constants, Assumptions, and Available Defaults				
F	Percent of transit users who would otherwise drive	83.3	%	FHWA 2017
G	Average auto occupancy	1.45	riders/vehicle	FHWA 2023
H	Percent of total travel time spent waiting (transit trips)	24.9	%	FHWA 2023
I1	Percent of perceived total travel time spent waiting (transit trips with shelters)	20.3	%	Fan 2016
I2	Percent of total travel time spent waiting (transit trips with shelters and real-time arrival information [RTI])	15.8	%	Watkins 2011
J	Wait time elasticity	-0.54	unitless	Taylor et al. 2009

Further explanation of key variables:

- (B) – This input is the number of bus stops that get equipped with new amenities (either shelters or shelters and real-time information).
- (C) – This input is the average number of boardings per day at the bus stop before the new amenities are added.

- (D) – This input is the average number of boardings per day across the entire transit agency.
- (E) – This is the transit mode share in the city where the bus amenities are being added. It is recommended that users use local data from the California extension of the NHTS or the U.S. Census for where the project(s) is located. The user can also use the values for CBSAs in the case where the projects are spread out across multiple cities.
- (F) – This constant is based on the percentage of trips taken by car from NHTS, weighted by transit ridership and number of cars available in the household to account for the fact that some riders do not have a choice to take transit and would ride regardless of the wait time. This value from FHWA 2018 represents pre-COVID-19 pandemic conditions but is the most recent value from FHWA.
- (G) – This is the average car occupancy for trips taken as of the latest version of the NHTS in 2022. This value accounts for the effects of the COVID-19 pandemic.
- (H) – This value represents the percentage of the total transit trip travel time that is composed of waiting and is derived from average wait times and travel times in the NHTS in the Pacific region.
- (I1, I2) – This represents the percentage of the total transit trip travel time that is composed of waiting after the addition of transit amenities. This is derived from the average wait times and travel times in the NHTS and the perceived wait time changes found in Fan 2016 and Watkins 2011.
- (J) – This elasticity is sourced from a study (Taylor et al. 2009) that uses data from LA Metro to estimate the effect of wait time and travel time on ridership across the system.

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The percent reduction in GHG emissions (A) is capped at 0.32 percent. This assumes that the CBSA is San Francisco-Oakland-Hayward, which has a default transit mode share for all trips of 11.38 percent.

Subsector Maximum

($\sum A_{max_{T\text{-}25 \text{ through } T\text{-}29,\ T\text{-}46}} \leq 15\%$) This measure is in the Transit subsector. This subcategory includes Measures T-25 through T-29 and T-46. The VMT reduction from the combined implementation of all measures within this subsector is capped at 15 percent.

Example GHG Reduction Quantification

The user reduces VMT by constructing twelve transit shelters in Oakland with real time information for a bus system that has an average of 15,000 boardings per day (D) and

$$A = 12 \times \frac{300}{15{,}000} \times 11.38\% \times \frac{83.3\%}{1.45} \times (24.9\% - 15.8\%) \times -0.54 = -0.077\%$$

300 boardings per day at each of the stops (C) before the project. This leads to a reduction in transportation related GHG emissions of 0.077 percent.

Quantified Co-Benefits

Improved Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NOx, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption achieved by the measure would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in VMT achieved by the measure would be the same as the percent reduction in GHG emissions (A).

Sources

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T-55. Infill Development

GHG Mitigation Potential

30%

Up to 30% of GHG emissions from project/site residential VMT

Co-Benefits (icon key on pg. 34)

Climate Resilience

Infill development increases density, which can put people closer to resources they may need to access during an extreme weather event. Infill development can also shorten commutes, decreasing the amount of time people are on the road and exposed to hazards, such as extreme heat or flooding. Screening and management of climate risks should still be considered, especially if infill occurs in a hazardous area, to preserve the benefits of density without introducing new risks.

Health and Equity Considerations

Living in compact areas with greater accessibility provides residents with health benefits, such as better access to health-promoting goods and services and more opportunities to be physically active.

Measure Description

This measure accounts for the VMT reduction achieved by infill housing development programs that allow residents to live closer to downtown areas where there is greater access to jobs and activities. Residents living at infill development projects typically do not need to travel as far to access essential destinations. This leads to lower VMT and associated GHG emissions compared to similar projects located farther from a downtown area. An example implementation of this measure is Sacramento Area Council of Government's Green Means Go program (SACOG 2021a, 2021b).

Subsector

Land Use

Locational Context

Urban, suburban

Scale of Application

Project/Site

Implementation Requirements

To ensure that the development would only proceed with implementation of this measure, the applicable projects would have to be commercial or industrial lots that are rezoned as high-density residential or mixed-use. GHG reductions from this measure cannot be credited unless the project site is currently a commercial or industrial lot that is being rezoned into either high-density residential or mixed-use.

Cost Considerations

Depending on the location, siting housing projects in infill locations can increase housing and development costs. However, the costs of providing public services, such as health care, education, policing, and transit, are generally lower in more dense areas where things are in closer proximity. Infrastructure for water and electricity also operates more efficiently when the service and transmission area is reduced. Local governments may provide approval streamlining benefits or financial incentives for infill residential projects.

Expanded Mitigation Options

Pair with Measure T-2, *Increase Job Density*, to promote further densification and yield increased co-benefits from a highly walkable and bikeable area, including VMT reductions, improved public health, and social equity.

GHG Reduction Formula

$$A = \frac{-B+C}{C} \times D$$

GHG Calculation Variables

ID	Parameter	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from project VMT in study area	0–30.0	%	calculated
User Inputs				
B	Distance to downtown for proposed project	[ ]	miles	user input
C	Distance to downtown of conventional development	[ ]	miles	user input
Constants, Assumptions, and Available Defaults				
D	Elasticity of VMT with respect to distance to downtown	-0.22	unitless	Ewing et al. 2010; Stevens 2016

Further explanation of key variables:

- (B) – For polycentric metros such as the San Francisco-Oakland-Berkeley metropolitan statistical area (MSA), the downtown area used to measure the distance needs to represent the closest of the relevant polycentric cities. For example, for a development in San Leandro, downtown Oakland would be the relevant downtown.
- (C) – This variable needs to be estimated for each region or metropolitan planning organization (MPO) where the measure will be applied because it differs greatly based on geographic context. Using geographic information system tools, this distance can be measured using the Census Centers of Population data for each block group to estimate the average distance to the appropriate downtown within a region weighted by population. For example, applying this technique to the San Francisco-Oakland-Berkeley MSA for the dual centroids of Oakland and San Francisco yields a population-weighted average distance of 21.6 kilometers, or 13.4 miles.
- (D) – An analysis of three studies in which disaggregate travel data were used found that a 0.22 percent decrease in VMT occurs for every 1 percent decrease in distance to downtown (Ewing et al. 2010).

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The percent reduction in GHG emissions (A) is capped at 30 percent. The purpose for the 30 percent cap is to limit the influence of any single built environmental factor (such as density). Projects that implement multiple land use strategies (e.g., density, design, diversity) will show more of a reduction than relying on improvements from a single built environment factor.

Subsector Maximum

($\sum A_{max_{T\text{-}1\ through\ T\text{-}4,\ T\text{-}55}} \leq 65\%$) This measure is in the Land Use subsector. This subcategory includes Measures T-1 through T-4 and T-55. The VMT reduction from the combined implementation of all measures within this subsector is capped at 65 percent. This measure could not be used in conjunction with Measures T-1, *Increase Residential Density*, or T-3, *Transit-Oriented Development*, due to correlation between distance to downtown and the other measures.

Example GHG Reduction Quantification

The user reduces VMT by rezoning areas near the downtown area to allow for a new mixed-use development. Areas that were undeveloped but already zoned as mixed-use can still achieve reductions, but such reductions can only be attributed to the developer and not to an MPO or city. This requirement ensures the benefits are not counted for projects that could have happened without the rezoning process. In this example, the projects would be located 5 miles from downtown (B) in a metro area where the population-weighted average distance to downtown is 25 miles (C). This would reduce GHG emissions from the project's VMT by 17.6 percent.

$$A = \frac{\text{-5 mi} + \text{25 mi}}{\text{25 mi}} \times \text{-0.22} = \text{-17.6\%}$$

Quantified Co-Benefits

Successful implementation of this measure could achieve improved air quality, energy and fuel savings, VMT reductions, enhanced pedestrian or traffic safety, improved public health and enhanced energy security. This section defines the methods for quantifying improved air quality, energy and fuel savings, and VMT reductions.

Improved Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NO_X, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption achieved by the measure would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in VMT achieved by the measure would be the same as the percent reduction in GHG emissions (A).

Sources

- Ewing, R., and R. Cervero. 2010. Travel and the Built Environment: A Meta-Analysis. Journal of the American Planning Association 76(3):265–294. Available: https://doi.org/10.1080/01944361003766766. Accessed: December 2023.
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T-56. Active Modes of Transportation for Youth

GHG Mitigation Potential

22.2%

Up to 22.2% of GHG emissions from school commute vehicle travel

Co-Benefits (icon key on pg. 34)

Climate Resilience

Planning that promotes more active modes of transportation for youth allows children to travel to a safe place more easily during emergencies. This measure could also take more cars off the road, resulting in less traffic and better allowing emergency responders to access a hazardous site during an extreme weather event. Furthermore, increasing youth active transportation modes can have health benefits, improving community resilience.

Health and Equity Considerations

Shifting children's trips to school from private car trips to bus, bicycling, or walking trips promotes consistent physical activity in children. Prioritize underserved areas with lower rates of vehicle ownership or fewer transit options.

Measure Description

This measure accounts for reductions in VMT achieved by projects that provide infrastructure to support any form of active transport among youth. Trips to school and extracurricular activities represent most of the everyday travel taken by youth. Thus, ensuring that children can use active transportation whenever possible can serve to reduce VMT and allow them to get the necessary exercise to live healthy lives.

Safe Routes to Schools (SR2S) provides federal funding for new sidewalks, bike lanes, off-street pathways, and street crossings to help children use active modes of transportation to get to school, bringing health benefits to children, in addition to reductions in VMT from mode-shifts away from private vehicle trips. This is a blanket measure that can cover projects related to all forms of active transport among youth. Methods for this measure were influenced by methodology from CARB (CARB 2023).

Subsector

School Programs

Locational Context

Urban, suburban

Scale of Application

Project/Site

Implementation Requirements

Specific projects that are implemented need not be funded by SR2S or be located at a school; however, one advantage of the program is the requirement for student travel surveys, which provide critical before and after project data, to quantify the effects of the program.

Cost Considerations

Depending on the improvement, capital and infrastructure costs may be high. Eligible projects may be able to utilize federal funding through California's SR2S program. In addition, the local municipality may achieve cost savings through a reduction of cars on the road leading to lower infrastructure and roadway maintenance costs.

Expanded Mitigation Options

When paired with Measure T-40, *Establish a School Bus Program*, students who live beyond walking or biking distance from their school will have an option for lower-emissions transportation to get to school.

GHG Reduction Formula

$$A = C \times F \times \frac{B - D}{G \times E \times (1 - C) + C \times D \times F}$$

GHG Calculation Variables

ID	Parameter	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from vehicle travel among students within walking/biking distance	0–22.2	%	calculated
User Inputs				
B	Known or estimated percent of students within 2 miles who are driven to school after project implementation	0–100	%	Use survey data – see tools from SR2S
Constants, Assumptions, and Available Defaults				
C	Percent of students living within 2 miles of the school	62	%	SR2S Partnership 2013
D	Percent of students within 2 miles who are driven to school before measure implementation	51	%	SR2S Partnership 2013
E	Percent of students more than 2 miles who are driven to school	66	%	FHWA 2023
F	Average driving distance for students who could walk or bike to school	2	miles	Assumption
G	Average driving distance for students who cannot walk or bike to school (> 2 miles)	8.66	miles	FHWA 2023

Further explanation of key variables:

- (B) – This is the percentage of students who could walk or bike to school who are driven to school after the project implementation. An informed estimate could be used if calculating reductions for a future project; however, survey data after the fact will provide the most accurate result.
- (C) – It is estimated in SR2S Partnership's 2013 report that 62 percent of students live within 2 miles of their school. The assumption that students are not willing to bike or walk longer than 2 miles is a simplification that makes it easier to exclude students who could not have benefited from infrastructure or programming that encourages walking and biking to school. If survey data are available, users should select a value that is representative of the school, school district, or youth center where the project is being implemented.
- (D) – This represents the percentage of students who live within 2 miles from school but are driven to school nonetheless. This value is from the statewide average, but a local-specific value should be used if that is available for the school or school district.

- (E) – This represents the percentage of students outside of the 2-mile radius who are driven to school. This value is derived from 2022 NHTS data, but a local value should be used instead if it is available.
- (F) – This value represents the average driving distance for students who could walk or bike to school. This is based on the earlier assertion that students would not be willing to travel more than 2 miles by bike or on foot to school. If survey data are available, users should select a value that is representative of the school, school district, or youth center where the project is being implemented.
- (G) – Using 2022 NHTS data, it is estimated that the average driving distance for students who cannot walk or bike to school is 8.66 miles. If more local data is available for the school area, use that value instead.

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The percent reduction in GHG emissions (A) is capped at 22.2 percent. The benefits are unlikely to be this high because this level assumes that all students who could walk or bike to school start doing so.

Subsector Maximum

($\sum A_{max_{T\text{-}40\ \&\ T\text{-}56}} \leq 57\%$) This measure is in the School Programs subsector. This subcategory includes Measures T-40 and T-56 at the Project/Site scale of application. The school trip VMT reduction from the combined implementation of all measures within this subsector is capped at 57 percent. The reduction percentage for this measure is applicable to the School Programs subsector, which includes school commute trips. If users would like to apply the reduction percentage to community-wide emissions, the reductions can be converted to community-scale reductions by multiplying the reduction percentage by 1.64 percent (FHWA 2023).

Example GHG Reduction Quantification

A school installs a new raised pedestrian crossing in combination with an outreach program that brings children to school as part of a walking school bus. After this program is implemented, the percentage of students within 2 miles of school who are driven to school drops to 20 percent (B). This would lead to a reduction in GHG emissions from school trips of 13.5 percent.

$$A = 62\% \times 2\text{ mi} \times \frac{\mathbf{20\%} - 51\%}{8.66\text{ mi} \times 66\%\ (1-62\%) + 62\% \times 51\% \times 2\text{ mi}} = -13.5\%$$

Quantified Co-Benefits

Improved Air Quality

The percent reduction in GHG emissions (A) would be the same as the percent reduction in NOx, CO, NO_2, SO_2, and PM. Reductions in ROG emissions can be calculated by multiplying the percent reduction in GHG emissions (A) by an adjustment factor of 87 percent. See *Adjusting VMT Reductions to Emission Reductions* for further discussion.

Energy and Fuel Savings

The percent reduction in vehicle fuel consumption achieved by the measure would be the same as the percent reduction in GHG emissions (A).

VMT Reductions

The percent reduction in VMT achieved by the measure would be the same as the percent reduction in GHG emissions (A).

Sources

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Energy

The GHG emissions from energy use come from power generation that provides the energy used to operate a building or source. Power is typically generated by either a remote, central electricity generating plant, onsite generation by fuel combustion, or onsite solar, wind, or other renewable power. Because the emissions from central electricity generation are not emitted where the electricity is being used, these types of emissions are referred to as *indirect* emissions. As such, measures that reduce electricity consumption result in reductions of criteria pollutants where the electricity is generated (i.e., power plants). Electricity-reducing measures are, therefore, not considered to result in local air quality co-benefits at the project site, although they could contribute to regional air quality improvements.

Because the emissions from onsite fuel combustion are emitted where the fuel is being consumed, these types of emissions are referred to as *direct* emission. Measures that reduce residential natural gas use (e.g., from cooktops and for space and water heating) reduce onsite fuel combustion and improve local air quality. Direct use of onsite solar or wind power generated electricity does not result in emissions.

Energy sector emissions can be reduced through energy efficiency improvements, renewable energy generation, building electrification, and CH_4 recovery and reuse at industrial facilities (landfills and wastewater treatment plants). These types of measures are discussed below. This section also provides guidance for combining emission reductions from energy measures and accounting for statewide legislation that may reduce future emissions reductions achieved by energy measures. The measure factsheets and quantification methods for individual measures follow. Use the graphic on the following page to click on an individual measure to navigate directly to the measure's factsheet.

Measures to Improve Efficiency

Energy sector emissions can be reduced by lowering the amount of electricity and natural gas required for building operations. This can be achieved by designing a more energy-efficient building structure and/or installing energy-efficient appliances.[14] Emissions reductions from energy efficiency improvements are quantified based on the amount of expected energy savings that would be achieved over existing energy codes and regulations. Existing consumption values are determined using California-specific energy end use databases, such as the California Commercial End-Use Survey and Residential Appliance Saturation Study (RASS), and other literature sources (e.g., ENERGY STAR program). Quantified measures that target energy efficiency improvements described in this section include Measures E-1 through E-9 and E-26.

[14] This Handbook does not account for potential "rebound effects" of energy efficiency measures. *Rebound effect* is the phenomenon that an increase in energy efficiency may lead to fewer energy savings because energy use will increase due to consumer and market responses. While rebound effects have been documented in literature, they are difficult to precisely and reliably quantify.

Energy

ENERGY EFFICIENCY IMPROVEMENTS

- E-1. Buildings Exceed 2019 Title 24 Building Envelope Energy Efficiency Standards
- E-2. Require Energy Efficient Appliances
- E-3-A. Require Energy Efficient Residential Boilers
- E-3-B. Require Energy Efficient Commercial Packaged Boilers
- E-4. Install Cool Roofs and/or Cool Walls in Residential Development
- E-5. Install Green Roofs in Place of Dark Roofs
- E-6. Encourage Residential Participation in Existing Demand Response Program(s)
- E-7. Require Higher Efficacy Public Street and Area Lighting
- E-8. Replace Incandescent Traffic Lights with LED Traffic Lights
- E-9. Utilize a Combined Heat and Power System
- E-21. Install Cool Pavement

RENEWABLE ENERGY GENERATION

- E-10-A. Establish Onsite Renewable Energy Systems—Generic
- E-10-B. Establish Onsite Renewable Energy Systems—Solar Power
- E-10-C. Establish Onsite Renewable Energy Systems—Wind Power
- E-11. Procure Electricity from Lower Carbon Intensity Power Supply
- E-26. Biomass Energy

BUILDING DECARBONIZATION

- E-12. Install Alternative Type of Water Heater in Place of Gas Storage Tank Heater in Residences
- E-13. Install Electric Ranges in Place of Gas Ranges
- E-14. Limit Wood Burning Devices and Natural Gas/Propane Fireplaces in Residential Development
- E-15. Require All-Electric Development
- E-16. Require Zero Net Energy Buildings
- E-17. Require Renewable-Surplus Buildings

METHANE RECOVERY

- E-18. Establish Methane Recovery in Landfills
- E-19. Establish Methane Recovery in Wastewater Treatment Plants

Measures to Increase Renewable Energy Generation

Different modes of electricity generation have different GHG emission intensities. Fossil fuel-based generation emits GHGs from fuel combustion, with the emissions quantity depending on the quantity and type of fuel used. Renewable energy generation, on the other hand, typically has significantly fewer emissions, and most types of renewable sources—such as solar photovoltaic (PV) systems—have zero associated GHG emissions. Renewable energy generation reduces emissions by avoiding an equivalent amount of grid energy. To calculate this, the amount of energy generated by the renewable system(s) must be quantified and then multiplied by the electricity provider-specific emission factor for the type of energy (e.g., electricity, natural gas) being replaced.[15] An exception to typical renewable energy sources is biomass or biofuels, which result in comparable direct emissions as fossil fuels when combusted; however, these fuels have lower upstream emissions than fossil fuels and result in GHG reductions when considering the entire lifecycle of the energy source. Thus, the methodology used to quantify emission reductions from the biomass measure (Measure E-21) is based on a lifecycle approach that accounts for upstream emissions associated with various fuel types. Consequently, users are cautioned in how these reductions are compared to operational emissions inventories, which may not include lifecycle emissions.

Quantified measures that target renewable energy generation described in this section include Measures E-10-A through E-11 and E-21.

Measures for Building Decarbonization

Building decarbonization, also termed *beneficial electrification* or *building electrification*, involves shifting from fossil fuels (e.g., natural gas) to electricity as the power source for heating, cooking, and appliances. In a fully electrified building, gas-powered water heaters, gas-powered ovens and cooktops, gas-powered clothes washers and dryers, and space heating that normally uses natural gas, propane, or heating oil are all replaced by electric alternatives, which are usually 2 to 3 times more efficient than traditional appliances. Displacing emissions-intensive fossil fuel energy with less emissions-intensive electricity results in a net emission reduction. Further, the emission reduction increases if the electricity for these end uses is generated by solar, wind, or other sources of zero-carbon electricity. These zero-carbon sources can be provided on a project site or integrated into the local electricity providers' renewable energy mix. In future years, building decarbonization measures will become increasingly effective at reducing GHG emissions because electricity provided by retail sellers of electricity will be procured from increasing amounts of renewable energy sources.

Emissions reductions achieved through building electrification are quantified based on the direct emissions avoided by the displaced fuel plus the indirect emissions added by the increased use of electricity. To calculate this, the avoided energy (i.e., negative value) generated by the fossil-fueled appliance(s) must be quantified and then multiplied by the appropriate fuel emission factor. The additional energy (i.e., positive value) generated by the electric alternative

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[15] The quantification methods do not account for potential future renewable energy curtailment (i.e., the deliberate reduction in power output below what could have been generated to balance supply and demand), which could reduce expected emissions savings from certain renewable energy measures.

appliance(s) must be quantified and then multiplied by the electricity provider-specific emission factor.[16] The sum of these two emissions represents the net emission reduction. Quantified measures that target building decarbonization described in this section include Measures E-12 through E-17.

Measures for Methane Recovery

Decomposition of waste and organic material in landfills and at wastewater treatment facilities generates CH_4. Capturing CH_4 through recovery systems directly reduces GHG emissions. Additional reductions can be achieved if the captured CH_4 is combusted to generate electricity for onsite energy needs, which displaces the associated indirect GHG emissions from electricity production. Emissions reductions from CH_4 recovery systems that include electricity generation are quantified using similar methods as described above for measures to increase renewable energy generation. Quantified measures that target CH_4 recovery described in this section include Measures E-18 and E-19.

Combining Emissions Reductions from Energy Measures

The total reductions claimed by a user for energy measures should not exceed 100 percent of project energy emissions, unless a measure would result in additional excess energy capacity that would be sold to an electricity provider or other project. This may include renewable energy generation systems tied into the grid. These additional emission reductions may be used to offset other categories of emissions, with approval of the agency reviewing the project. In these cases of excess capacity, the quantified excess emissions must be carefully verified to ensure that any credit allowed for these additional reductions is truly additional.[17]

Reduced Effectiveness of Energy Measures in Future Years

Senate Bill 100 requires that 100 percent of electricity supplied to California end-use customers be from eligible renewable energy resources and zero-carbon resources by 2045. As retail sellers of electricity procure increasing amounts of renewable energy to displace fossil fuels in their energy generation mix, the emission factors of local electricity providers will decrease over time. Because some energy measures reduce electricity consumption or displace grid energy, the annual GHG reduction from these measures will be less in future years. As noted above, however, the shift to a larger portfolio of renewable energy will make building decarbonization measures more effective. Further, if the local electricity provider for a project already has carbon-free electricity, then energy reduction measures would not reduce electricity emissions as they would already be zero or near zero.[18] Users should take care to appropriately account for this

[16] One method for determining energy consumption for an electric alternative appliance is to convert the natural gas consumption, typically measured in therms, into British thermal units, which can then be converted into the electricity energy consumption metric of kWh. However, this method does not account for the differing energy efficiencies of natural gas versus electricity or potential differences in the technical specifications of the associated appliances. Accordingly, the Handbook does not use this basic conversion method. Instead, the Handbook recommends using actual reported energy consumption for electric alternative appliances.

[17] For more detailed information on offset verification protocols visit https://www.climateactionreserve.org/how/future-protocol-development/criteria/.

[18] Senate Bill 100 requires 100 percent renewable for retail sales but not for all power generation/supply (e.g., grid balancing or in-facility usage). Thus, emission factors may not be exactly zero by 2045.

possibility by using the electricity provider-specific, year-specific emission factors presented in Tables E-4.3 and E-4.4 in Appendix C, *Emissions Factors and Data Tables*.[19]

Similarly, measures that reduce building energy consumption may become less effective over time because of increasingly stringent Title 24, California Building Standards Code, standards. Strengthening of Title 24 requirements, including provisions for zero net energy (ZNE) buildings (i.e., energy efficiency improvements and onsite renewable energy), will improve energy efficiency and reduce energy consumption in new construction. The quantification methods presented in this report include measures that exceed minimum regulatory requirements of the 2019 Title 24 standards. Some measures in this Handbook may become obsolete if they are made mandatory for all new buildings as part of future Title 24 standards. As such, users should take care to determine whether the measures in this Handbook still exceed the Title 24 requirements at the time of project implementation. If the user's project exceeds the requirements of Title 24, then they can take credit for the resulting reductions.

[19] The default electricity provider emission factors reflect the annual average emissions intensity of delivered electricity. Depending on the time of day and load, measures that reduce electricity consumption may offset emissions from marginal power sources, yielding greater emissions reductions than estimated when using average annual emission factors.

E-1. Exceed 2019 Title 24 Building Envelope Energy Efficiency Standards

GHG Mitigation Potential

99%

Up to 99% of GHG emissions from building electricity and/or natural gas use

Co-Benefits (icon key on pg. 34)

Climate Resilience

Increased energy efficiency can reduce the strain on the overall grid, particularly the risk of power outages during peak loads. Increased efficiency can also reduce energy costs, particularly if extreme heat would otherwise increase these costs.

Health and Equity Considerations

More energy efficient buildings can help residents to save money on utility costs and reduce exposure to extreme heat, supporting greater resilience to climate health impacts. This can be especially critical for low-income and vulnerable residents.

Measure Description

This measure requires new buildings to exceed the energy efficiency requirements of the building energy standards of the 2019 version of Title 24. GHGs are emitted because of activities in residential and commercial buildings that use electricity and natural gas as energy sources. By committing to a percent improvement over Title 24, the building's energy use is reduced, thereby reducing GHG emissions. Title 24 Part 6 regulates energy uses including space heating and cooling, hot water heating, ventilation, and integrated lighting. End use categories not subject to Title 24 requirements include appliances, electronics, and miscellaneous "plug-in" uses.

Subsector

Energy Efficiency Improvements

Scale of Application

Project/Site

Implementation Requirements

Reduce energy use from any of the following end uses: space heating and cooling, hot water heating, ventilation, and integrated lighting.

Cost Considerations

In order to make buildings even more energy efficient, developers will face greater upfront costs to purchase higher-quality materials, which may be passed on to the property owner. However, property owners will realize cost savings from reduced energy use. Property owners will also avoid potential retrofitting costs in the future if efficiency standards are made more stringent.

Expanded Mitigation Options

Pair with Measure E-2, *Require Energy Efficient Appliances*, to reduce energy use from both end use categories that are subject to Title 24 requirements and those that are not to yield increased GHG reductions.

GHG Reduction Formula

A = -C × E

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from building electricity and/or natural gas consumption	[ ]	0–99%	calculated
User Inputs				
B	Building/housing type	[ ]	text	user input
C	Percent improvement beyond 2019 Title 24	0–100	% expressed as a whole number	user input
Constants, Assumptions, and Available Defaults				
D	Electricity Demand Forecast Zone	Figure E-1.1 Table E-1.1	integer	CEC 2017
E	Percent reduction in building electricity or natural gas consumption for 1% improvement over 2019 Title 24 Standards	Tables E-1.2 through Table E-1.5	%	CEC 2020, 2021

Further explanation of key variables:

- (A) – The output provides the percent reduction in GHG emissions from either building electricity or natural gas consumption, depending on which energy source the user is interested in calculating (E). To determine the percent reduction in GHG emissions from building energy (i.e., electricity plus natural gas), the user would need to know the percent of total GHG emissions from each energy source. For example, if 40 percent of building energy emissions come from electricity and 60 percent come from natural gas consumption, the percent reduction in GHG emissions from building energy could be calculated as follows.

$$A_{energy} = (40\% \times A_{electricity}) + (60\% \times A_{natural\ gas})$$

Further, to determine the percent reduction in GHG emissions for a project with multiple buildings, the user would need to know the percent of total building energy emissions from each building. For example, if 67 percent of building energy emissions come from Building 1 and 33 percent come from Building 2, the percent reduction in GHG emissions from all building energy could be calculated as follows.

$$A_{energy\_total} = (67\% \times A_{energy\_1})\ `+ (33\% \times A_{energy\_2})$$

- (B) – The building and housing types are needed to lookup the percent reduction in electricity or natural gas consumption over 2019 Title 24 Standards (E).
- (D) – The California Energy Commission (CEC) has specified 28 distinct Electricity Demand Forecast Zones (EDFZs) in California. Users should refer to Figure E-1.1 in

Appendix C to determine the EDFZ for their project. This measure relies on energy consumption data from the year 2019 tied to the CEC's 2018-2030 Uncalibrated Commercial Sector Forecast (Commercial Forecast) and the 2019 RASS (CEC 2020, 2021). Because data from all 28 EDFZs are not included in the Commercial Forecast and RASS, representative data from similar EDFZs may need to be used. Users should refer to Table E-1.1 for the proxy EDFZ that corresponds with those listed in Tables E-1.2 through E-1.5.

- (E) – See Tables E-1.2 through E-1.5 for the percent reduction in building electricity and natural consumption by EDFZ and land use type. There are two tables for residential land uses and two for non-residential land uses. This information is based on the percent of total building energy that comes from end use categories subject to Title 24 requirements (e.g., space heating and cooling, hot water heating, ventilation) (CEC 2020, 2021).[20, 21] For example, for a general office building in EDFZ 1, 65 percent of electricity and 79 percent of natural gas consumption come from end use categories subject to Title 24 requirements. Thus, a 1 percent improvement in building energy efficiency standards results in a 0.65 percent reduction in electricity use and a 0.79 percent reduction in natural gas consumption.

GHG Calculation Caps or Maximums

Measure Maximum

(C_{max}) The percent improvement beyond 2019 Title 24 standards is capped at 100.

It is assumed that the energy demand of the user's project is currently being met by grid electricity that requires *some* amount of fossil fuel–based energy generation and/or onsite natural gas, both of which emit GHGs from fuel combustion. In other words, the local electricity provider has an energy intensity factor (lb of CO_2e per MWh) greater than zero and/or the project consumes natural gas onsite for building energy. For all-electric projects that are served by electricity providers already with a renewable portfolio of 100 percent, this measure could have no reduction in GHG emissions. If the electricity provider is using renewable energy credits (REC) to meet a 100 percent renewable portfolio goal, then some emissions reductions may be achieved. This measure would still result in the co-benefits of reduced electricity use and enhanced energy security.

Mutually Exclusive Measures

If the user selects Measure E-15, *Require All-Electric Development*, they may not also take credit for any natural gas–related efficiency gains under this measure. In other words, ($A_{natural\ gas}$) should be zeroed out in the above equation.

Example GHG Reduction Quantification

The user reduces building energy by exceeding energy efficiency standards. In this example, the user commits to a 10 percent improvement over 2019 Title 24 requirements (C) for

[20] End use categories not subject to Title 24 requirements include appliances, electronics, and miscellaneous "plug-in" uses.

[21] Hardwired lighting is part of Title 24 Part 6. However, it is not part of the building envelope energy and, therefore, not considered as part of this measure.

their project located in EDFZ 3 (D). The project includes Building 1, a day-care center, and Building 2, apartments (mid-rise) (B). The user would reduce GHG emissions from the day-care center from electricity and natural gas by 8.1 percent and 9.9 percent, respectively. GHG emissions from the apartment from electricity and natural gas would be reduced by 2.4 percent and 9.5 percent, respectively.

$A_{electricity\_1}$ = -10 × 0.81% = -8.1% day care electricity emissions

$A_{natural\ gas\_1}$ = -10 × 0.99% = -9.9% day care natural gas emissions

$A_{electricity\_2}$ = -10 × 0.24% = -2.4% apartment electricity emissions

$A_{natural\ gas\_2}$ = -10 × 0.95% = -9.5% apartment natural gas emissions

The percent reduction in GHG emissions from building energy (i.e., electricity plus natural gas) per building can also be calculated if the user knows the percent of total GHG emissions from each energy source. In this example, 40 percent of the day-care building's energy emissions come from electricity and 60 percent come from natural gas consumption, while 45 percent of the apartment building's energy emissions come from electricity and 55 percent come from natural gas consumption. Energy sector GHG emissions from the day-care and apartment would be reduced by 9.2 percent and 6.3 percent, respectively.

A_{energy_1} = (40% × -8.1%) + (60% × -9.9%) = -9.2% day care energy emissions

A_{energy_2} = (45% × -2.4%) + (55% × -9.5%) = -6.3% apartment energy emissions

Further, the percent reduction in GHG emissions for the project can be calculated if the user knows the percent of total building energy emissions from each building. In this example, 33 percent of building energy emissions come from the day-care and 67 percent come from the apartment. The percent reduction in GHG emissions from all building energy would be 7.9 percent.

A_{energy_total} = (33% × -9.2%) + (77% × -6.3%) = -7.9% building energy emissions

Quantified Co-Benefits

Improved Air Quality

Electricity supplied by statewide fossil-fueled or bioenergy power plants generates criteria pollutants. However, because these power plants are located throughout the state, the reduction in electricity use from this measure will not reduce localized criteria pollutant emissions at the project site.

The reduction in natural gas consumption from this measure would result in local improvements in air quality because the building natural gas combustion regulated under Title 24 Part 6 occurs on the project site (e.g., space heating, water heating).

The percent reduction in criteria pollutants from natural gas ($A_{naturalgas}$) is the same as the percent reduction in building natural gas consumption achieved by the measure.

Energy and Fuel Savings

The percent reduction in electricity use achieved by the measure is the same as the percent reduction in GHG emissions from electricity ($A_{electricity}$). The percent reduction in natural gas consumption achieved by the measure is the same as the percent reduction in GHG emissions from natural gas ($A_{naturalgas}$).

Sources

- California Energy Commission (CEC). 2017. *California Electricity Demand Forecast Zones*. Available: https://cecgis-caenergy.opendata.arcgis.com/datasets/86fef50f6f344fabbe545e58aec83edd_0/data?geometry=-165.327%2C31.004%2C-72.427%2C43.220. Accessed: June 2021.
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- California Energy Commission (CEC). 2021. Excel database with the 2018–2030 Uncalibrated Commercial Sector Forecast, provided to ICF. January 21, 2021.

E-2. Require Energy Efficient Appliances

GHG Mitigation Potential

Up to 15.0% of GHG emissions from building electricity

Co-Benefits (icon key on pg. 34)

Climate Resilience

Increased energy efficiency can reduce the strain on the overall grid, particularly the risk of power outages during peak loads. Increased efficiency can also reduce energy costs, particularly if extreme heat would otherwise increase these costs.

Health and Equity Considerations

The use of ENERGY STAR appliances can increase upfront purchase costs; thus, it should be clearly explained to occupants or buyers that these costs can be offset by reduced operational utility costs. This can be particularly beneficial for low-income residents.

Measure Description

This measure will require installation of ENERGY STAR-certified appliances that exceed the energy efficiency of conventional appliances. By committing to more efficient appliances, the building's energy use is reduced, thereby reducing GHG emissions.

Subsector

Energy Efficiency Improvements

Scale of Application

Project/Site

Implementation Requirements

This measure can be used for commercial refrigerators. It can also be used for residential refrigerators, clothes washers, dishwashers, and ceiling fans. This measure will only result in reductions associated with electricity use and does not apply to natural gas as no ENERGY STAR appliances that use natural gas were evaluated.

Cost Considerations

More energy-efficient appliances are typically more expensive than less efficient ones, leading to greater upfront costs. However, the replacement of less efficient appliances with more efficient models reduces energy consumption and thereby reduces long-term energy costs.

Expanded Mitigation Options

Pair with Measure E-1, *Exceed Title 24 Building Envelope Energy Efficiency Standards*, to reduce energy use from both end use categories subject to Title 24 requirements and those that are not to yield increased GHG reductions.

GHG Reduction Formula

$$A = (E_1 \times F_1) + (E_2 \times F_2) + (E_3 \times F_3) + (E_4 \times F_4)$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from building electricity	0–15.0	%	calculated
User Inputs				
B	Building/housing type	[ ]	text	user input
$C_{1,2,3\ldots}$	ENERGY STAR appliance(s) installed	[ ]	text	user input
Constants, Assumptions, and Available Defaults				
D	Electricity Demand Forecast Zone	Figure E-1.1 Table E-1.1	integer	CEC 2017
$E_{1,2,3\ldots}$	Percent reduction in electricity for ENERGY STAR appliance compared to conventional appliance	Table E-2.1	%	ENERGY STAR 2014; 2016; 2017; 2018a; 2018b
$F_{1,2,3\ldots}$	Percent of total building electricity by appliance	Table E-2.2 Table E-2.3	%	CEC 2020, 2021

Further explanation of key variables:

- (A) – The output provides the percent reduction in GHG emissions from building electricity. To determine the percent reduction in GHG emissions from building energy (i.e., electricity plus natural gas), the user would need to know the percent of total GHG emissions from electricity. For example, if 40 percent of building energy emissions come from electricity, the percent reduction in GHG emissions from building energy could be calculated as follows.

  $$A_{energy} = (40\% \times A_{electricity})$$

  Further, to determine the percent reduction in GHG emissions for a project with multiple buildings, the user would need to know the percent of total building energy emissions from each building. For example, if 67 percent of building energy emissions come from Building 1 and 33 percent come from Building 2, the percent reduction in GHG emissions from all building energy could be calculated as follows.

  $$A_{energy\_total} = (67\% \times A_{energy\_1}) + (33\% \times A_{energy\_2})$$

- (B) – The building and housing types are needed to lookup the percent of total building electricity by appliance (F). Commercial refrigerators were evaluated for the non-residential building types of grocery stores, restaurants, and refrigerated warehouses. Residential refrigerators, clothes washers, dishwashers, and ceiling fans were evaluated for all residential housing types.
- (D) – The CEC has specified 28 distinct EDFZs in California. Users should refer to Figure E-1.1 in Appendix C to determine the EDFZ for their project. This measure relies

on energy consumption data from the year 2019 tied to the CEC's Commercial Forecast and the 2019 RASS (CEC 2020, 2021). Because data from all 28 EDFZs are not included in the Commercial Forecast and RASS, representative data from similar EDFZs may need to be used. Users should refer to Table E-1.1 for the proxy EDFZ that corresponds with those listed in Table E-2.2 and Table E-2.3.

- (E) – See Table E-2.1 for the percent reduction in ENERGY STAR appliance electricity use compared to conventional appliances that meet the minimum federal efficiency standards (ENERGY STAR 2014; 2016; 2017; 2018a; 2018b).
- (F) – See Table E-2.2 and Table E-2.3 for the percent of total building electricity by appliance. There is one table for residential land uses and another for non-residential land uses. This information, excluding ceiling fans, is primarily based on data from the CEC (2020, 2021). RASS does not specify a ceiling fan end-use; rather, electricity use from ceiling fans is accounted for in the Miscellaneous category, which includes interior lighting, attic fans, and other miscellaneous plug-in loads. Because the electricity usage of ceiling fans alone is not specified, a value from a National Renewable Energy Laboratory (NREL) study is used. The study reports that the average energy use per ceiling fan is 84.1 kWh per year (NREL 2008). In this measure, it is assumed that each multi-family, single-family, and townhome residence has one ceiling fan. The electricity savings shown here are based on installing an ENERGY STAR ceiling fan and do not account for an occupant's decreased use of cooling devices such as air conditioners.

GHG Calculation Caps or Maximums

It is assumed that the electricity demand of the project's appliances is currently being met by grid electricity that requires *some* amount of fossil fuel–based energy generation, which emits GHGs from fuel combustion. In other words, the local electricity provider has an energy intensity factor (lb of CO_2e per MWh) greater than zero. For projects that are served by electricity providers already with a renewable portfolio of 100 percent, this measure could have no reduction in GHG emissions. If the electricity provider is using REC to meet a 100 percent renewable portfolio goal, then some emissions reductions may be achieved. This measure would still result in the co-benefits of reduced electricity use and enhanced energy security.

Example GHG Reduction Quantification

The user reduces building energy by requiring the builder supply appliances that exceed the energy efficiency of conventional appliances. In this example, the user's project includes Building 1, a supermarket, and Building 2, single-family home (B) located in EDFZ 1 (D). The user would commit to ENERGY STAR commercial refrigerators in the grocery store and ENERGY STAR residential refrigerators, clothes washers, dishwashers, and ceiling fans in the single-family housing (C). GHG emissions from the supermarket and single-family home from electricity would be reduced by 4.6 percent and 2.8 percent, respectively.

$A_{electricity\_1}$ = -20% × 23% = -4.6% supermarket electricity emissions

$A_{electricity\_2}$ = (-9% × 18%) + (-25% × 1.1%) + (-12% × 1.1%) + (-60% × 1.3%) = -2.8% housing electricity emissions

The percent reduction in GHG emissions from building energy (i.e., electricity plus natural gas) per building can also be calculated if the user knows the percent of total GHG emissions from each energy source. In this example, 60 percent of the supermarket's energy emissions come from electricity and 50 percent of the single-family home's energy emissions come from electricity. GHG emissions from the supermarket and single-family home would be reduced by 2.8 percent and 1.4 percent, respectively.

A_{energy_1} = (60% × -4.6%) = -2.8% supermarket energy emissions

A_{energy_2} = (50% × -2.8%) = -1.4% housing energy emissions

Further, the percent reduction in GHG emissions for the project can be calculated if the user knows the percent of total building energy emissions from each building. In this example, 67 percent of building energy emissions come from the supermarket and 33 percent come from the single-family home. The percent reduction in GHG emissions from all building energy would be 2.3 percent.

A_{energy_total} = (67% × -2.8%) + (33% × -1.4%) = -2.3% building energy emissions

Quantified Co-Benefits

Energy and Fuel Savings

The percent reduction in electricity use achieved by the measure is the same as the percent reduction in GHG emissions from electricity ($A_{electricity}$).

Sources

- California Energy Commission (CEC). 2017. *California Electricity Demand Forecast Zones*. Available: https://cecgis-caenergy.opendata.arcgis.com/datasets/86fef50f6f344fabbe545e58aec83edd_0/data?geometry=-165.327%2C31.004%2C-72.427%2C43.220. Accessed: June 2021.
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E-3-A. Require Energy Efficient Residential Boilers

GHG Mitigation Potential

14%

Up to 14.0 % of GHG emissions from boiler fuel consumption

Co-Benefits (icon key on pg. 34)

Climate Resilience

If the boilers are electric, increased energy efficiency can reduce the strain on the overall grid, particularly the risk of power outages during peak loads. Increased efficiency can also reduce energy costs.

Health and Equity Considerations

If the boilers use natural gas, propane, or home heat oil, a more efficient model can directly reduce fuel combustion in the home and thus help reduce indoor air pollution, supporting improvements to public health.

Measure Description

This measure requires installation of a residential boiler with a higher energy efficiency than what is required by regulation. Improving boiler efficiency decreases fuel consumption for the same amount of energy output, thereby reducing associated GHG emissions.

Subsector

Energy Efficiency Improvements

Scale of Application

Project/Site

Implementation Requirements

This measure is only appropriate for residential boilers. A *residential boiler*, as defined in the Code of Federal Regulations (C.F.R.), means a product that utilizes only single-phase electric current, or single-phase electric current or DC current in conjunction with natural gas, propane, or home heating oil and that (1) is designed to be the principal heating source for the living space of residence; and (2) has a heat input rate of less than 300,000 British Thermal Units (Btus) per hour.

Cost Considerations

More energy-efficient boilers are typically more expensive than less efficient ones, leading to greater upfront costs. However, the use of more efficient models reduces energy consumption and thereby reduces long-term energy costs. Boilers with improved insulation—a metric in improved energy efficiency—are also less likely to freeze and burst, potentially avoiding cold weather repair costs and water damage.

Expanded Mitigation Options

Pair with Measure E-12, *Install Alternative Type of Water Heater in Place of Gas Storage Tank Heater in Residences*, to reduce energy use from both space heating and water heating to yield increased GHG reductions.

GHG Reduction Formula

A = D

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from boiler fuel consumption	1.2–14.0	%	calculated
User Inputs				
B	Boiler type	[ ]	text	user input
C	Annual fuel utilization efficiency of boiler with measure	83–96	%	user input
Constants, Assumptions, and Available Defaults				
D	Boiler fuel savings with measure compared to minimum requirement	Table E-3-A.1	%	U.S. DOE 2015

Further explanation of key variables:

- (C) – The U.S. Department of Energy's (U.S. DOE) 2016 Conservation Standards for Residential Boilers (10 C.F.R. 430) set increased energy efficiency requirements for residential boilers, effective January 2021. The annual fuel utilization efficiency (AFUE) is a common metric for determining residential boiler efficiency as it represents the ratio of the total useful heat delivered to the heat value from the annual amount of fuel consumed. The project boiler AFUE must exceed the minimum AFUE required by the standards to result in GHG emission reductions. Boiler efficiency should be obtainable from manufacturer specifications.
- (D) – The U.S. DOE calculated the average annual fuel use and savings of boilers at various AFUEs above the minimum requirement of the standards based on historical consumption data. This information is summarized in Table E-3-A.1 in Appendix C.

GHG Calculation Caps or Maximums

Measure Maximum

(C_{max}) The annual fuel utilization efficiency of the proposed boiler is capped at the "Max Tech" percentage for each boiler type, which is presented in Table E-3-A.1 in Appendix C.

Mutually Exclusive Measures

If the user selects Measure E-15, *Require All-Electric Development*, the user cannot also select this measure, given that it calls for use of gas- and oil-fired boilers.

Example GHG Reduction Quantification

The user reduces boiler fuel use by requiring installation of a boiler with a higher AFUE than what is required by the 2016 Conservation Standards for Residential Boilers. If the boiler is a gas-fired hot water boiler (B) with an AFUE of 96 percent (C), the user would reduce GHG emissions from boiler fuel consumption by 14 percent based on Table E-3-A.1 in Appendix C.

A = -14%

Quantified Co-Benefits

Improved Air Quality

The reduction in fuel consumption (i.e., natural gas or oil) from this measure would result in local improvements in air quality because pollutants from fuel consumption would be reduced at the project site. The percent reduction in GHG emissions (A) is the same as the percent reduction in criteria pollutant emissions achieved by the measure.

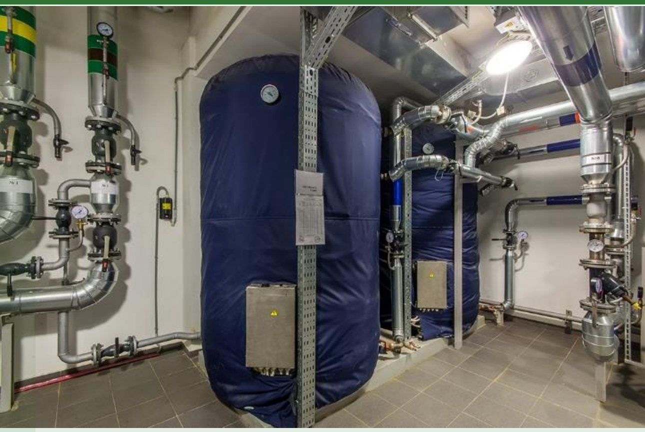
Energy and Fuel Savings

The percent reduction in fuel consumption achieved by the measure is the same as the percent reduction in GHG emissions (A).

Sources

- U.S. Department of Energy (U.S. DOE). 2015. *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Boilers*. March. Available: https://www.regulations.gov/docketBrowser?rpp=25&so=DESC&sb=commentDueDate&po=0&dct=SR%2BO&D=EERE-2012-BT-STD-0047. Accessed: January 2021.

E-3-B. Require Energy Efficient Commercial Packaged Boilers



GHG Mitigation Potential

16%

Up to 16.0% of GHG emissions from boiler fuel consumption

Co-Benefits (icon key on pg. 34)

Climate Resilience

Increased energy efficiency can reduce the strain on the overall grid, particularly the risk of power outages during peak loads. Increased efficiency can also reduce energy costs.

Health and Equity Considerations

Reduction of fuel combustion in commercial spaces can help reduce indoor pollution.

Measure Description

This measure requires installation of a commercial packaged boiler with a higher energy efficiency than what is required by regulation. Improving boiler efficiency decreases fuel consumption for the same amount of energy output, thereby reducing associated GHG emissions.

Subsector

Energy Efficiency Improvements

Scale of Application

Project/Site

Implementation Requirements

This measure is only appropriate for a *commercial packaged boiler*, which, as defined in the C.F.R., means a type of packaged low pressure boiler that is industrial equipment with a capacity (rated maximum input) of 300,000 Btus per hour or more, which, to any significant extent, is distributed in commerce (1) for heating or space conditioning applications in buildings, or (2) for service water heating in buildings, but does not meet the definition of *hot water supply boiler* (as defined in 10 C.F.R. 431).

Cost Considerations

More energy-efficient boilers are typically more expensive than less efficient ones, leading to greater upfront costs. However, the replacement of less efficient boilers with more efficient models reduces energy consumption and thereby reduces long-term energy costs.

Expanded Mitigation Options

Non-applicable.

GHG Reduction Formula

A = D

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from boiler fuel consumption	1.1–16.0	%	calculated
User Inputs				
B	Boiler type	[ ]	text	user input
C	Thermal or combustion efficiency of boiler with measure	83–99	%	user input
Constants, Assumptions, and Available Defaults				
D	Boiler fuel savings with measure compared to minimum requirement	Table E-3-B.1 Table E-3-B.2	%	U.S. DOE 2016

Further explanation of key variables:

- (C) –U.S. DOE's Conservation Standards for Commercial Packaged Boilers (10 C.F.R. 431) were amended in July 2009 to set increased energy efficiency requirements for commercial packaged boilers installed after March 2012. In March 2020, U.S. DOE increased the standards, which will affect boilers installed after January 10, 2023. The minimum thermal efficiency (TE) and combustion efficiency (CE) are the metrics for determining commercial packaged boiler efficiency. TE is the ratio of the heat energy absorbed by the water to the heat energy available in the fuel burned. CE is the ratio of heat energy released by the fuel to the heat energy available in the fuel burned. The project boiler TE or CE must exceed the minimum required by the standards to result in GHG emission reductions. Boiler efficiency should be obtainable from manufacturer specifications.
- (D) – U.S. DOE calculated the average annual fuel use and savings of boilers at various TEs and CEs above the minimum requirement of the 2009 and 2020 standards based on historical consumption data. If the proposed boiler would be installed before January 10, 2023, the user should reference the annual fuel savings relative to the 2009 standards, summarized in Table E-3-B.1 in Appendix C. If the proposed boiler would be installed after January 10, 2023, the user should reference the annual fuel savings relative to the 2020 standards, summarized in Table E-3-B.2 in Appendix C.

GHG Calculation Caps or Maximums

Measure Maximum

(C_{max}) The TE or CE of the proposed boiler is capped at the "Max Tech" percentage for each boiler type, which is presented in Tables E-3-B.1 and E-3-B.2 in Appendix C.

Mutually Exclusive Measures

If the user selects Measure E-15, *Require All-Electric Development*, the user cannot also select this measure, given that it calls for use of gas- and oil-fired boilers.

Example GHG Reduction Quantification

The user reduces boiler fuel use by requiring installation of a boiler with a higher CE or TE than what is required by the 2009 or 2020 Conservation Standards for Commercial Packaged Boilers. If the proposed boiler is a 350,000 Btu/hour gas-fired hot water boiler installed in 2022 (B) with a TE of 99 percent (C), the user would reduce GHG emissions from boiler fuel consumption by 16 percent based on Table E-3-B.1 in Appendix C.

A = -16%

Quantified Co-Benefits

Improved Air Quality

The reduction in fuel consumption (i.e., natural gas or oil) from this measure would result in local improvements in air quality, because pollutants from fuel consumption would be reduced at the project site. The percent reduction in GHG emissions (A) is the same as the percent reduction in criteria pollutant emissions achieved by the measure.

Energy and Fuel Savings

The percent reduction in fuel consumption achieved by the measure is the same as the percent reduction in GHG emissions (*A*).

Sources

- U.S. Department of Energy (U.S. DOE). 2016. *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Packaged Boilers*. December. Available: https://www.regulations.gov/docket?D=EERE-2013-BT-STD-0030. Accessed: January 2021.

E-4. Install Cool Roofs and/or Cool Walls in Residential Development

GHG Mitigation Potential

Potentially small reduction in GHG from building energy use

Co-Benefits (icon key on pg. 34)

(icon key on pg. 34)

Climate Resilience

Cool roofs and walls absorb less heat and keep buildings cool, increasing the building's adaptive capacity to extreme heat. This also reduces the strain on the electric grid, particularly the risk of power outages during peak loads, and can reduce energy costs. If implemented across a development or throughout a community, cool roofs and walls can reduce the urban heat island effect, building not just individual but also communitywide resilience to extreme heat.

Health and Equity Considerations

Cool roofs and walls can protect the health of vulnerable and low-income residents during heat waves and extreme heat days. In colder climate zones, cool roofs and walls can potentially increase winter heating costs, but the increase may be offset by reduced electricity bills in summer.

Measure Description

This measure will install cool roofs and/or walls in place of dark roofs and/or conventional walls for residential development. Cool roofs have been designed to reflect more sunlight and absorb less heat than a standard roof, keeping buildings cooler in the summertime and thus reducing air-conditioning loads. Complementary to cool roofs, cool walls achieve a similar result through using more reflective paints or materials. This reduces the electricity needed to provide cooling but can potentially increase the energy needed to provide winter heating, thereby reducing associated GHG emissions depending on the project parameters (e.g., climate, level of implementation, carbon intensity of local electricity provider). However, the winter heating penalty may be small with lower levels of winter sunlight due to shorter daylight hours and more overcast skies.

Subsector

Energy Efficiency Improvements

Scale of Application

Project/Site

Implementation Requirements

Cool roofs can be made of tiles, shingles, coatings, membranes, or metal, among other materials, in a wide range of colors (not just white). Similarly, cool wall paints and materials come in a range of colors, though light-colored paints have the greatest cooling effect. To apply the effectiveness reported by the literature, the albedo of the proposed surface must be at least 0.25 for walls and at least 0.4 for roofs.

Cost Considerations

Installing cool roofs and walls leads to substantial cost savings for relatively low additional input costs. Low-effort residential maintenance options, like painting walls with light-colored or more reflective paint, cost about the same as darker paint colors, and yet immediately reduce the cost of cooling the building. Cool roofs can have higher initial costs, depending on the material chosen, but these costs can be offset by lifetime energy savings.

Expanded Mitigation Options

Pair with Measure E-21, *Install Cool Pavement*, to install cool pavements. This measure could also be paired Measure E-15, *Require All-Electric Development*, to eliminate the implementation disbenefit of worsened air quality, further discussed below under *Quantified Co-Benefits*.

GHG Reduction Formula

$$H_T = H_N + H_S + H_E + H_W$$

$$L_T = \sum L_z \times \frac{H_z}{H_T}$$

$$A = \left[\left(\left(I_R \times G_R \times H_R\right) + \left(I_T \times L_T \times H_T\right)\right) \times M \times O \times Q \times R\right]$$

$$-\left[\left(\left(J_R \times G_R \times H_R\right) + \left(J_T \times L_T \times H_T\right)\right) \times N \times P \times Q \times R\right]$$

GHG Calculation Variables

Many of the values for the variables in this equation can be obtained from the Lawrence Berkeley National Laboratory's Cool Surface Savings Explorer (Explorer) (Levinson et al. 2019). The Explorer is an Excel tool that parses a database containing the results of whole-building model simulations that calculate the building energy changes from the use of cool walls and cool roofs under various scenarios for different building types in California.

ID	Variable	Value	Unit	Source
Output				
A	Reduction in GHG emissions from building energy	[ ]	MT CO_2e per year	calculated
L_T	Composite solar availability factor of non-roof building sides to be cooled	[ ]	unitless	calculated
H_T	Total area of non-roof building sides to be cooled (N+S+E+W)	[ ]	KSF	calculated
User Inputs				
B	Building type	[ ]	text	user input
C	Building climate zone	1–16	integer	user input
D	Building orientation	[ ]	text	user input
E	Building side(s) to be cooled (N, S, E, W & roof)	[ ]	text	user input
F	Albedo of cool surface(s)	0.25–0.60	unitless	user input
G_R	Coverage of cool roof material	0–100	%	user input
H_z	Coverage of cool building side z (N, S, E, W, R [roof])	[ ]	KSF	user input
Constants, Assumptions, and Available Defaults				
I_R	Change in natural gas use of building (roof only)	Savings Explorer	therm per year per m^2	Levinson et al. 2019
I_T	Change in natural gas use of non-roof building sides (N+S+E+W)	Savings Explorer	therm per year per m^2	Levinson et al. 2019

ID	Variable	Value	Unit	Source
J_R	Change in electricity use of building (roof only)	Savings Explorer	kWh per year per m^2	Levinson et al. 2019
J_T	Change in electricity use of non-roof building sides (N+S+E+W)	Savings Explorer	kWh per year per m^2	Levinson et al. 2019
K_z	Wall canyon aspect ratio of building side z (N, S, E, W)	Table E-4.1	unitless	Levinson 2019
L_z	Solar availability factor of building side z (N, S, E, W)	Table E-4.2	unitless	Levinson 2019
M	Carbon intensity of residential natural gas	117	lb CO_2e per MMBtu	U.S. EPA 2020
N	Carbon intensity of local electricity provider	Tables E-4.3 and E-4.4	lb CO_2e per MWh	CA Utilities 2021
O	Conversion from therm to MMBtu	0.1	MMBtu per therm	conversion
P	Conversion from kWh to MWh	0.001	MWh per kWh	conversion
Q	Conversion from lb to MT	0.000454	MT per lb	conversion
R	Conversion from KSF to m^2	92.9	m^2 per KSF	conversion

Further explanation of key variables:

- (B) – The building type is needed to run the Explorer, further discussed under (I). The Explorer provides two types of residential buildings and eight types of commercial buildings.
- (C) – Climate zones are specific geographic areas of similar climatic characteristics, including temperature, weather, and other factors that affect building energy use. The CEC has specified numerous EDFZs in California, which are referenced in CEC's Commercial Forecast and RASS. Note that this measure references the 16 building climate zones (BCZs) that were developed for Title 24 Standards and differ from the EDFZs. Users should ensure that they are selecting the appropriate BCZ by referring to Figure E-4.1 in Appendix C (CEC 2020). Alternatively, users can search for the appropriate BCZ by looking up the project address or zip code in the CEC's web-based interactive map (CEC 2018). The BCZ is needed to run the Explorer, further discussed under (I).
- (D) – The building orientation is needed to run the Explorer, further discussed under (I). Building orientation refers to whether the building's longer axis runs east-west or north south.
- (E) – The building side(s) to be cooled is needed to run the Explorer, further discussed under (I). The Explorer provides 16 combinations of sides for the user to choose from. Note that the user cannot select roof at the same time as a wall, so the Explorer will need to be run twice for projects that include both cool walls and cool roofs.
- (F) – The albedo of the cool surface is needed to run the Explorer, further discussed under (I). The energy changes outputted by the Explorer are based on a scenario of a roof with an aged roof albedo of 0.10 and walls with an aged albedo of 0.25. The Explorer provides several options for modified albedo: walls = 0.4, 0.6; roofs = 0.25,

0.4, and 0.6. Users should exercise caution in interpreting their results if the project would have different albedos than provided.

- (G_R) – The coverage of the cool roof material represents the percent of the roof area that is a cool roof.
- (H_Z) – The area of building side to be cooled represents the area of the building side minus any area that would not be covered in cool materials.
- (I_R, I_T, J_R and J_T) –The change in annual building electricity use and natural gas consumption per square meter of building surface modified can be obtained from the Explorer. Increased cool surfaces would result in a heating penalty (i.e., increase in gas consumption to heat the building and, for select commercial buildings, any electricity that provides auxiliary heat) and a cooling savings (i.e., decrease in electricity to cool and fan the building).[22] Users can run the Explorer to output these values using the following instructions.[23]
  1. Download the tool and database from the ZIP archive online at http://bit.ly/2Kwvtpu. To install, copy the two files to a local folder.
  2. Open the Savings Explorer file. Click the "Launch Simulation Selector" button.
  3. The following inputs should be the same for all projects: simulation region = California; building vintage = new,[24] property = site energy; metric = savings intensity.
  4. The first query of the Explorer should be done to output energy intensity values for roofs (I_R and J_R). The second query should be done for building sides (I_T and J_T).
     a. The following inputs should be specified based on project-specific information.
        i. Building type (class/category) = (B).
        ii. Building climate zone (location) = (C).
        iii. Building orientation = (D).
        iv. Building side(s) to be cooled = (E). The first query should be roofs only, if applicable. The second should be the applicable building sides.
        v. Albedo of cool surface(s) = (F).
     b. Once all inputs are specified from #3 and #4, the Explorer will update the variables and results in columns A and B of the workbook.
     c. Sum the results from Column B for cooling, electric heating, and fan. This represents the change in electricity use for cool roofs (J_R). Take the gas heating results from Column B, which represents the change in natural gas use for cool roofs (I_R).
  5. Repeat #4 for the building sides to output (J_T and I_T).
- (K_z) – Table E-4.1 presents the four canyon aspect ratios used by Levinson (2019) to determine standard solar availability factors (SAF) for each wall direction. The canyon aspect ratio is the ratio of the project wall height to nearest building separation. The

[22] As the effects of climate change become more severe, temperatures and solar radiation during the winter may continually increase. The heating penalty may therefore be lower in future years, making this measure more effective at reducing GHG emissions.

[23] See additional instruction in Appendix P, Section 4 of Levinson et al. (2019).

[24] New as termed in the Explorer refers to buildings compliant with the 2016 Title 24 Standards. The latest Title 24 Standards are from 2019 and are updated every 3 years. Users should exercise caution in interpreting their results for future years subject to more stringent Title 24 Standards.

user should select the canyon aspect ratio that best corresponds to each project's cool wall to appropriately lookup the SAFs (Lz) in Table E-4.2.

- (L_z) – Table E-4.2 presents the average U.S. SAFs by cardinal direction and canyon aspect ratio. The SAFs are presented for two scenarios, one in which the neighboring building has cool walls and one in which it has conventional walls. The solar availability of the walls at the project building can be lowered by shadows cast by neighboring buildings and raised by sunlight reflected from neighboring buildings. The SAFs are used in the GHG reduction formula to adjust the values for energy use change from Levinson et al. (2019), which were based on model simulations with isolated buildings that were not surrounded by any buildings.
- (M) – The carbon intensity of residential natural gas was calculated in terms of CO_2e by multiplying the U.S. natural gas combustion emission factors for CO_2, CH_4, and N_2O (U.S. EPA 2020) by the corresponding 100-year GWP values from the IPCC's Fourth Assessment Report (IPCC 2007). See Table E-4.5 in Appendix C for more natural gas emission factors.
- (N) – GHG intensity factors for major California electricity providers are provided in Tables E-4.3 and E-4.4 in Appendix C. If the project study area is not serviced by a listed electricity provider, or the user is able to provide a project-specific value (i.e., for the future year not referenced in Appendix C), the user should use that specific value in the GHG calculation formula. If the electricity provider is not known, users may elect to use the statewide grid average carbon intensity.

GHG Calculation Caps or Maximums

It is assumed that the electricity demand of the user's project is currently being met by grid energy that requires *some* amount of fossil fuel-based energy generation, which emits GHGs from fuel combustion. In other words, the local electricity provider has an energy intensity factor (lb of CO_2e per MWh) greater than zero. For projects that are served by electricity providers already with a renewable portfolio of 100 percent, this measure could have no reduction on GHG emissions. If the electricity provider is using REC to meet a 100 percent renewable portfolio goal, then some emissions reductions may be achieved. In situations where the electricity from the electricity provider is already carbon free, this measure would increase GHG emissions by requiring additional natural gas consumption for building heating. This measure would still result in the co-benefit of reduced electricity use, enhanced energy security, and reduced urban heat island effect.

Mutually Exclusive Measures

If the user selects Measure E-15, *Require All-Electric Development*, they should exercise caution in quantifying the effect of this measure, given that it was developed assuming the residence would be supplied with natural gas (e.g., space heating).

Example GHG Reduction Quantification

The user reduces building energy emissions by providing a cool roof and walls in place of dark roofs and walls. In this example, the measure would be implemented in BCZ 7 (C) for a single-family home (B) with a fully covered (i.e., 100%) 1 KSF cool roof (G_R), and all building sides of 1 KSF covered in cool materials (H_z or H_N, H_S, H_E, H_W, and H_R). The project is located on a residential street with conventional surrounding buildings and has a canyon aspect ratio of 0.2 for all walls (K_z). Using this information, the SAFs (L_z) can be looked up in Table E-4.2. The electricity and natural gas use changes for the roof (I_R and J_R) and walls (I_T and J_T) can be looked up using the Explorer. The project is in San Diego Gas and Electric's service territory and would begin operation by 2022. It would, therefore, have an electricity carbon intensity of 542 lb CO_2e per MWh (N). In this example, emissions would be reduced by 0.3 MT CO_2e per year.

$$H_T = 1\ \text{KSF} + 1\ \text{KSF} + 1\ \text{KSF} + 1\ \text{KSF} = 4\ \text{KSF}$$

$$L_T = \left(1.02 \times \frac{1\ \text{KSF}}{4\ \text{KSF}}\right) + \left(0.95 \times \frac{1\ \text{KSF}}{4\ \text{KSF}}\right) + \left(0.96 \times \frac{1\ \text{KSF}}{4\ \text{KSF}}\right) + \left(0.95 \times \frac{1\ \text{KSF}}{4\ \text{KSF}}\right) = 0.9$$

$$A = \left[\left(\left(\frac{\text{-}0.003\ \text{therm}}{\text{yr}\cdot\text{m}^2} \times 100\% \times 1\ \text{KSF}\right) + \left(\frac{\text{-}0.005\ \text{therm}}{\text{yr}\cdot\text{m}^2} \times 0.97 \times 4\ \text{KSF}\right)\right) \times \frac{117\ \text{lb}\ CO_2e}{\text{MMBtu}} \times \frac{0.1\ \text{MMBtu}}{\text{therm}} \times \frac{0.000454\ \text{MT}}{\text{lb}} \times \frac{92.9\ \text{m}^2}{\text{KSF}}\right]$$
$$- \left[\left(\left(\frac{2.383\ \text{kWh}}{\text{yr}\cdot\text{m}^2} \times 100\% \times 1\ \text{KSF}\right) + \left(\frac{2.242\ \text{kWh}}{\text{yr}\cdot\text{m}^2} \times 0.97 \times 4\ \text{KSF}\right)\right) \times \frac{542\ \text{lb}\ CO_2e}{\text{MWh}} \times \frac{0.001\ \text{MWh}}{\text{kWh}} \times \frac{0.000454\ \text{MT}}{\text{lb}} \times \frac{92.9\ \text{m}^2}{\text{KSF}}\right] = \frac{\text{-}0.3\ \text{MT}\ CO_2e}{\text{yr}}$$

Quantified Co-Benefits

While the measure will achieve electricity savings, it can increase fuel consumption and potentially worsen ambient air quality. This measure also has direct climate resiliency benefits. Refer to Measure EH-3, *Install Heat-Reducing Roof*, in Chapter 4, *Assessing Climate Exposures and Measures to Reduce Vulnerabilities*.

Worsened Air Quality

While not quantified in this Handbook, lowered ambient air temperatures as a result of the reduced urban heat island effects (which can be significant if adoption is widespread) can decrease ozone formation, improving air quality.

If natural gas is used for heating, the increase in natural gas fuel consumption from this measure could result in local worsening of air quality. If electric heating is used at the project site, then there would not be an increase in criteria pollutants or worsened air quality. The increase in criteria pollutant emissions (U) resulting from the measure can be calculated as follows.

Energy Savings (Increased Fuel)

The increase in building natural gas consumption (S) and decrease in electricity use (T) achieved by the measure can be calculated as follows.

Natural Gas Increase Formula

$$S = ((I_R \times G_R \times H_R) + (I_T \times L_T \times H_T)) \times R$$

Electricity Reduction Formula

$$T = ((J_R \times G_R \times H_R) + (J_T \times L_T \times H_T)) \times R$$

Criteria Pollutant Emission Increase Formula

$$U = O \times V \times S \times W$$

Criteria Pollutant Emission Increase Calculation Variables

ID	Variable	Value	Unit	Source
Output				
U	Increase in criteria pollutant emissions from building energy	[ ]	ton per year	calculated
User Inputs				
	None			
Constants, Assumptions, and Available Defaults				
V	Criteria pollutant emission factors of natural gas	Table E-4.5	lb per MMBtu	U.S. EPA 1998
W	Conversion from lb to ton	0.0005	tons per lb	conversion

Further explanation of key variables:

- (V) – Table E-4.5 presents the criteria pollutant emission factors of natural gas for residential and commercial uses (U.S. EPA 1998).
- Please refer to the *GHG Calculation Variables* table above for definitions of variables that have been previously defined.

Sources

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E-5. Install Green Roofs in Place of Dark Roofs

GHG Mitigation Potential

Small

Potentially small reduction in GHG emissions from building energy use

Co-Benefits (icon key on pg. 34)

Climate Resilience

Installing green roofs increases resilience by absorbing less heat and keeping buildings cool, increasing the building's adaptive capacity to extreme heat. This also reduces the strain on the overall grid, particularly the risk of power outages during peak loads, and can reduce energy costs. Green roofs have a smaller heat island reduction effect than certified cool roofs but nonetheless are an improvement over conventional roofs.

Health and Equity Considerations

Green roofs provide additional insulation that can keep buildings cooler in the summer and warmer in the winter, reducing energy costs year-round. This can help protect health and increase economic resilience for vulnerable and low-income residents.

Measure Description

This measure will install green roofs in place of dark roofs. Green roofs consist of a layer of vegetation on top of buildings, which provides natural insulation and climate control benefits. This reduces the electricity and natural gas needed to provide cooling and heating, thereby reducing associated GHG emissions.

Subsector

Energy Efficiency Improvements

Scale of Application

Project/Site

Implementation Requirements

See measure description.

Cost Considerations

Green roofs are usually more expensive to install than conventional dark roofs; however, these costs can be quickly offset by reduced energy usage through better insulation, improved stormwater management, and, in some cases, an extended lifespan. Green roof maintenance costs include irrigation, weed control, and fertilizer in order to maintain the vegetation; however, green roofs generally cost substantially less than conventional roofs or cool roofs over a 50-year lifecycle.

Expanded Mitigation Options

Use native plants on the roof for improved ecosystem health, drought-tolerant plants for water conservation, or plant an edible garden for enhanced food security.

GHG Reduction Formula

A = D × [(-E × G × I × J) + (-F × H × K × J)]

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Reduction in GHG emissions from building energy	[ ]	MT CO_2e per year	calculated
User Inputs				
B	Building type	[ ]	text	user input
C	Project location (city)	[ ]	text	user input
D	Roof area	[ ]	KSF	user input
Constants, Assumptions, and Available Defaults				
E	Natural gas savings with measure	Table E-5.1	therm per year per KSF	Sailor et al. 2008
F	Electricity savings with measure	Table E-5.1	kWh per year per KSF	Sailor et al. 2008
G	Carbon intensity of natural gas	Table E-4.5	lb CO_2e per MMBtu	U.S. EPA 2020
H	Carbon intensity of local electricity provider	Tables E-4.3 and E-4.4	lb CO_2e per MWh	CA Utilities 2021
I	Conversion from therm to MMBtu	0.1	MMBtu per therm	conversion
J	Conversion from lb to MT	0.000454	MT per lb	conversion
K	Conversion from kWh to MWh	0.001	MWh per kWh	conversion

Further explanation of key variables:

- (B) – The housing and building types are needed to look up the energy savings for residential and office development (E and F). If the user's building type of interest is not presented in Table E-5.1 in Appendix C, they should exercise caution in extrapolating the results from the listed building types.
- (C) – The project location (i.e., city) is used to look up the energy savings for residential and commercial development (E and F). If the user's city of interest is not presented in Table E-5.1, they should use their judgment to select a listed city that has similar climate and precipitation.
- (E and F) – The Green Roof Energy Calculator is a free, web-based tool developed in 2008 by academic researchers on behalf of the U.S. Green Building Council. The purpose of the tool is to enable architects, developers, and others to obtain quick estimates of how green roof design decisions might affect building energy use. To provide the user with a range of energy savings, the tool was run for the two available building types and five California cities using conservative values for the remainder of the tool inputs. These results are summarized in Table E-5.1. If the user can provide

project-specific values for tool inputs (i.e., growing media depth, leaf area index, irrigation, percent of total roof coverage, roof material albedo), then they should run the tool themselves and use the outputted energy savings in place of the values in Table E-5.1 (Sailor et al. 2008). Additionally, the user can consider calculating their energy savings from this measure using U.S. DOE's EnergyPlus, a more complex, robust model that requires more energy expertise and project inputs (U.S. DOE 2020).

- (G) – The carbon intensity of natural gas was calculated in terms of CO_2e by multiplying the U.S. natural gas combustion emission factors for CO_2, CH_4, and N_2O (U.S. EPA 2020) by the corresponding 100-year GWP values from the IPCC's Fourth Assessment Report (IPCC 2007). Table E-4.5 in Appendix C provides natural gas CO_2e emission factors for residential and commercial uses.
- (H) – GHG intensity factors for major California electricity providers are provided in Tables E-4.3 and E-4.4 in Appendix C. If the project study area is not serviced by a listed electricity provider, or the user is able to provide a project-specific value (i.e., for the future year not referenced in Tables E-4.3 and E-4.4), the user should use that specific value in the GHG calculation formula. If the electricity provider is not known, the user may elect to use the statewide grid average carbon intensity.

GHG Calculation Caps or Maximums

It is assumed that the energy demand of the user's project is currently being met by grid electricity that requires *some* amount of fossil fuel–based energy generation and/or onsite natural gas, both of which emit GHGs from fuel combustion. In other words, the local electricity provider has an energy intensity factor (lb of CO_2e per MWh) greater than zero and/or the project consumes natural gas onsite for building energy. For all-electric projects that are served by electricity providers already with a renewable portfolio of 100 percent, this measure could have no reduction in GHG emissions. If the electricity provider is using REC to meet a 100 percent renewable portfolio goal, then some emissions reductions may be achieved. This measure would still result in the co-benefits of reduced electricity use, enhanced energy security, and reduced urban heat island effect.

Mutually Exclusive Measures

If the user selects Measure E-15, *Require All-Electric Development*, they should exercise caution in quantifying the effect of this measure, given that some of the constants and available defaults were developed with the assumption that the building would be supplied with natural gas.

One option for including the quantified emissions reduction from this measure alongside those achieved by Measure E-15 would be to exclude all of the natural gas–related effects from this measure. In other words, (E) should be zeroed out in the above equation. Note that doing this may result in an underestimation of emissions reductions; green roofs provide additional insulation that can keep buildings warmer in the winter, as evidenced by Table E-5.1.

Example GHG Reduction Quantification

The user reduces building energy emissions by providing a green roof in place of a dark roof. In this example, the measure would be implemented in the city of Sacramento (C) for a mid-rise apartment complex (B) that has a roof area of 5 KSF. Therefore, the natural gas savings would be 8.2 therms per year per KSF (E), and the additional electricity savings would be 37.6 kilowatt-hours per year per KSF (F). The project is in Sacramento Municipal Utility District's (SMUD's) service territory and would begin operation by 2022. It would therefore have an electricity carbon intensity of 344 lb CO_2e per MWh (H). The mitigated emissions would be reduced by 0.32 MT CO_2e per year.

$$A = \mathbf{5\ KSF} \times \left[\left(\frac{\text{-8.2 therm}}{\text{yr}\cdot\text{KSF}} \times \frac{117\ \text{lb}\ CO_2e}{\text{MMBtu}} \times \frac{0.1\ \text{MMBtu}}{\text{therm}} \times \frac{0.000454\ \text{MT}}{\text{lb}}\right) + \left(\frac{\text{-126.7 kWh}}{\text{yr}\cdot\text{KSF}} \times \frac{344\ \text{lb}\ CO_2e}{\text{MWh}} \times \frac{0.001\ \text{MWh}}{\text{kWh}} \times \frac{0.000454\ \text{MT}}{\text{lb}}\right)\right] = -0.32\ \frac{\text{MT}\ CO_2e}{\text{yr}}$$

Quantified Co-Benefits

This measure also has direct climate resiliency benefits. Refer to Measure EH-3, Install Heat-Reducing Roof, in Chapter 4, *Assessing Climate Exposures and Measures to Reduce Vulnerabilities*.

Energy and Fuel Savings

The user would decrease the building natural gas consumption (E X D X I) and, depending on the climate zone for the project area, either decrease or increase the electricity use (F X D X K).

Improved Air Quality

The reduction in natural gas fuel consumption from this measure would result in local improvements in air quality because the fuel consumption occurs on site of the project. The reduction in criteria pollutant emissions (L) achieved by the measure can be calculated as follows.

Criteria Pollutant Emission Reduction Formula

$$L = \mathbf{D} \times -E \times M \times I \times N$$

Criteria Pollutant Emission Reduction Calculation Variables

ID	Variable	Value	Unit	Source
Output				
L	Reduction in criteria pollutant emissions from building energy	[ ]	tons per year	calculated
User Inputs				
	None			

Constants, Assumptions, and Available Defaults				
M	Criteria pollutant emission factors of natural gas	Table E-4.5	lb per MMBtu	U.S. EPA 1998
N	Conversion from lb to ton	0.0005	tons per lb	conversion

Further explanation of key variables:

- (M) – Table E-4.5 presents the criteria pollutant emission factors of natural gas for residential and commercial uses (U.S. EPA 1998).
- Please refer to the *GHG Calculation Variables* table above for definitions of variables that have been previously defined.

Sources

- California Utilities. 2021. Excel database of GHG emission factors for delivered electricity, provided to the Sacramento Metropolitan Air Quality Management District and ICF. January through March 2021.
- Intergovernmental Panel on Climate Change (IPCC). 2007. *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp. Available: https://www.ipcc.ch/report/ar4/wg1/. Accessed: January 2021.
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E-6. Encourage Residential Participation in Existing Demand Response Program(s)

GHG Mitigation Potential

0.02%

Up to 0.02% reduction in GHG emissions from residential building electricity

Co-Benefits (icon key on pg. 34)

Climate Resilience

Strategic energy conservation during demand response events reduces the strain on the overall grid, particularly the risk of power outages during peak loads. It can also reduce energy costs, particularly if extreme heat would otherwise increase these costs.

Health and Equity Considerations

Demand response programs can help residents save money on utility costs and reduce exposure to extreme heat, supporting greater resilience to climate health impacts. This can be especially critical for low-income and vulnerable residents.

Measure Description

This measure will require marketing and promotion of the local utility's manual (i.e., behavioral) demand response program(s) to encourage participation from residents in the project area. Buildings contribute to GHG indirectly through electricity consumption. During demand response events, program users shift or conserve electricity, thereby reducing the associated indirect GHG emissions. Methods of engaging customers in demand response efforts include offering time-based rates, such as time-of-use pricing, critical peak pricing, variable peak pricing, real-time pricing, and critical peak rebates. Users are encouraged to respond to time-based rates or other forms of financial incentives with smart phone app, email, phone call, and/or text notifications.

Subsector

Energy Efficiency Improvements

Scale of Application

Project/Site or Plan/Community

Implementation Requirements

See measure description.

Cost Considerations

The cost of providing the demand response program is borne by the local utility. Property owners will realize cost savings from reduced electricity use.

Expanded Mitigation Options

The electricity reduction cited in the GHG emissions quantification methodology is based on a *manual* demand response program. Residential participation in an *automated* program, which requires smart appliances for the relevant end uses and appliances (e.g., heating and cooling, dishwashers, washing machines), can reduce user fatigue while improving the electricity reduction rates, yielding improved GHG emissions reductions.

GHG Reduction Formula

$$A = -\left(B \times C \times \frac{D}{E}\right)$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from residential electricity	0–0.2	%	calculated
User Inputs				
B	Level of participation	0–100	%	user input
Constants, Assumptions, and Available Defaults				
C	Electricity reduction during demand response event	18	%	CEC 2020
D	Average number of demand response events	100	hours per year	U.S. DOE 2010
E	Hours in a year	8,760	hours per year	conversion

Further explanation of key variables:

- (A) – The output provides the percent reduction in GHG emissions from residential building *electricity*. To determine the percent reduction in GHG emissions from total residential building *energy* (i.e., electricity plus natural gas), the user would need to know the percent of total GHG emissions from electricity. For example, if 40 percent of building energy emissions come from electricity, the percent reduction in GHG emissions from total building energy could be calculated as follows.

  $$A_{energy} = (40\% \times A_{electricity})$$

  Further, to determine the percent reduction in GHG emissions for a project with multiple residential buildings, the user would need to know the percent of total building energy emissions from each building. For example, if 67 percent of building energy emissions come from Building 1 and 33 percent come from Building 2, the percent reduction in GHG emissions from all building energy could be calculated as follows.

  $$A_{energy\_total} = (67\% \times A_{energy\_1}) + (33\% \times A_{energy\_2})$$

- (B) – The level of participation refers to the percentage of households in the project area that enroll in the demand response program.
- (C) – OhmConnect is a demand response provider that challenges its users to reduce consumption during critical energy periods (i.e., events). OhmConnect measures the users' actual consumption against a calculated historical baseline and rewards them for the difference. A study of California OhmConnect users found that, on average, users reduced their energy consumption by 0.15 kWh, or 18 percent, during an

OhmConnect demand response event relative to what they would have consumed without an event (CEC 2020).

- (D) – It was estimated that demand response for managing peak loads involves, at most, 100 hours a year (U.S. DOE 2010). The user should input a project-specific value in the GHG reduction formula, if available.

GHG Calculation Caps or Maximums

It is assumed that the project's electricity demand is currently being met by grid electricity that requires *some* amount of fossil fuel–based energy generation, which emits GHGs from fuel combustion. In other words, the local electricity provider has an energy intensity factor (lb of CO_2e per MWh) greater than zero. For projects that are served by electricity providers already with a renewable portfolio of 100 percent, this measure could have no reduction in GHG emissions. If the electricity provider is using REC to meet a 100 percent renewable portfolio goal, then some emissions reductions may be achieved. This measure would still result in the co-benefits of reduced electricity use and enhanced energy security.

Example GHG Reduction Quantification

The user reduces the residential electricity consumption by providing incentives for expanded participation in an existing demand response program. In this example, the expected level of participation is 100 percent of households in the study area (B). The user would reduce GHG emissions from residential electricity by 0.2 percent.

$$A = -\left(\mathbf{100\%} \times 18\% \times \frac{100\ \frac{hr}{yr}}{8{,}760\ \frac{hr}{yr}}\right) = -0.2\%$$

Quantified Co-Benefits

Energy and Fuel Savings

The percent reduction in residential building electricity achieved by the measure is the same as the percent reduction in GHG emissions (A).

Sources

- California Energy Commission (CEC). 2020. *Identifying Effective Demand Response Program Designs for Residential Customers*. November. Available: https://innovation.luskin.ucla.edu/wp-content/uploads/2021/01/Identifying-Effective-Demand-Response-Program-Designs-for-Residential-Customers.pdf. Accessed: October 2021.
- U.S. Department of Energy (U.S. DOE). 2010. *The Smart Grid: An Estimation of the Energy and CO_2 Benefits*. January. Available: https://energyenvironment.pnnl.gov/news/pdf/PNNL-19112_Revision_1_Final.pdf. Accessed: October 2021.

E-7. Require Higher Efficacy Public Street and Area Lighting

GHG Mitigation Potential

Potentially moderate reduction in GHG emissions from street lighting

Co-Benefits (icon key on pg. 34)

Climate Resilience

Installation of more efficient lights can reduce the strain on the overall grid and reduce energy costs.

Health and Equity Considerations

Blue or full spectrum light may increase perceptions of safety but inhibit sleep patterns of nearby residents and reduce night sky visibility. Work with communities to determine appropriate color temperatures.

Measure Description

This measure will require the installation of higher efficacy public street and area lighting in place of typical or existing lamps. Lighting sources contribute to GHG indirectly through the production of the electricity that powers the lights. Installing more efficacious lamps, such as light-emitting diodes (LEDs), will use less electricity while producing the same amount of light, thereby reducing the associated indirect GHG emissions. In a 2012 survey of 212 California cities, 852,000 of the 1,100,000 streetlights (76 percent) were identified as high-pressure sodium lamps, while only 2 percent were LEDs (CLTC 2012).

Subsector

Energy Efficiency Improvements

Scale of Application

Plan/Community

Implementation Requirements

Users may take credit only if they are retrofitting existing street and area lights. This includes streetlights, pedestrian pathway lights, area lighting for parks and parking lots, and outdoor lighting around public buildings.

Cost Considerations

More energy-efficient lighting options are typically more expensive than less efficient ones, leading to greater installation costs. However, the replacement of less efficient lighting with more efficient bulbs reduces energy consumption and thereby reduces energy costs. Additionally, the rated life of more efficient bulbs is typically longer than less efficient ones, which reduces the frequency of replacement costs.

Expanded Mitigation Options

Incorporation of solar fixtures onto the street and area traffic lights would further reduce grid-supplied electricity consumption and associated emissions.

GHG Reduction Formula

$$A = \frac{B_1 \times C_1 - B_2 \times C_2}{B_1 \times C_1}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from outdoor street and area lighting	[ ]	%	calculated
User Inputs				
B_1	Number of existing lighting heads to be replaced	[ ]	lighting heads	user input
B_2	Number of proposed new lighting heads	[ ]	lighting heads	user input
C_1	Average power rating of existing lamp type	[ ]	watts	user input
C_2	Average power rating of proposed lamp type	[ ]	watts	user input
Constants, Assumptions, and Available Defaults				
	None			

Further explanation of key variables:

- (B_1 and B_2) – The number of existing and proposed lighting heads are required in the GHG reduction formula in case the new type of lamp results in less heads needing to be installed.
- (C_1 and C_2) – Lumens are the measure of the amount of light perceived by the human eye. Luminous efficacy is the amount of visible light emitted for a given amount of power. This measure assumes that the replacement lighting would provide the same number of lumens per area as the existing lighting and that only the power rating would change. See Table E-7.1 in Appendix C for a range of typical power ratings and efficacies of various outdoor lamp types (CLTC 2015). These values are for reference only for providing the user a list of existing and replacement lighting options. The user should input project-specific values in the GHG reduction formula, if available.

GHG Calculation Caps or Maximums

It is assumed that the electricity demand of the project's lighting is currently being met by grid electricity that requires *some* amount of fossil fuel–based energy generation, which emits GHGs from fuel combustion. In other words, the local electricity provider has an energy intensity factor (lb of CO_2e per MWh) greater than zero. For projects that are served by electricity providers already with a renewable portfolio of 100 percent, this measure could have no reduction in GHG emissions. If the electricity provider is using REC to meet a 100 percent renewable portfolio goal, then some emissions reductions may be achieved. This measure would still result in the co-benefits of reduced electricity use and enhanced energy security.

Example GHG Reduction Quantification

The user reduces the energy consumption of outdoor lighting by installing higher efficacy lighting. If the number of existing and proposed lighting heads are both 100 (B_1 and B_2), the power rating of the existing high-pressure sodium lamps is 120 watts, and the power rating of the proposed LED lamps is 80 watts, the user would reduce GHG emissions from outdoor lighting by 33.3 percent.

$$A = \frac{100 \text{ heads} \times 120 \text{ watts} - 100 \text{ heads} \times 80 \text{ watts}}{100 \text{ heads} \times 120 \text{ watts}} = -33.3\%$$

Quantified Co-Benefits

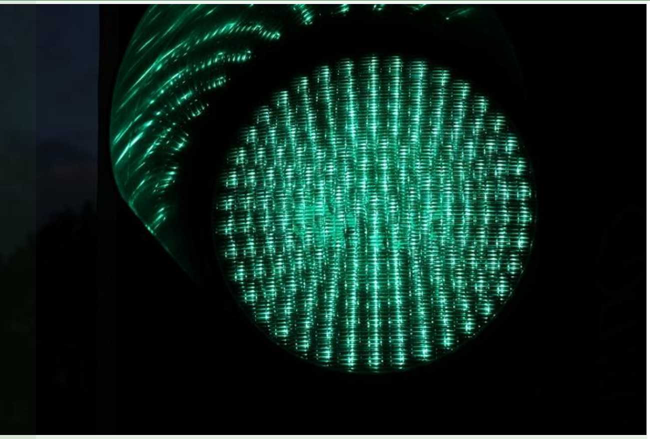
Energy and Fuel Savings

The percent reduction in electricity achieved by the measure is the same as the percent reduction in GHG emissions (A).

Sources

- California Lighting Technology Center (CLTC). 2012. *The State of Street Lighting in California, 2012.* University of California, Davis. February. Available: https://cltc.ucdavis.edu/publication/state-street-lighting-california-2012. Accessed: January 2021.
- California Lighting Technology Center (CLTC). 2015. *2013 Title 24, Part 6 Outdoor Lighting Guide.* University of California, Davis. March. Available: https://cltc.ucdavis.edu/sites/default/files/files/publication/2013-title-24-outdoor-lighting-guide-mar15.pdf. Accessed: January 2021.

E-8. Replace Incandescent Traffic Lights with LED Traffic Lights



GHG Mitigation Potential

Large

Potentially large reduction in GHG emissions from traffic light electricity use

Co-Benefits (icon key on pg. 34)

Climate Resilience

Installation of more efficient lights can reduce the strain on the overall grid and reduce energy costs.

Health and Equity Considerations

LED signal lights last longer than their incandescent counterparts, potentially improving traffic safety as they burn out less frequently.

Measure Description

This measure will replace incandescent traffic lights with more energy-efficient LED traffic lights. Installing LEDs reduces electricity demand and thus results in a reduction in indirect GHG emissions.

Subsector

Energy Efficiency Improvements

Scale of Application

Plan/Community. Not applicable at the Project/Site-scale, unless the development project requires modification of existing roadway infrastructure, including traffic lights.

Implementation Requirements

New traffic lights are required to be LED and meet minimum federal efficiency standards. User may take credit only if they are retrofitting existing incandescent traffic lights. Also, this measure may not be suitable in areas that receive substantial snowfall, which may cover and block light, unless the traffic lights are outfitted with winter-ready designs that prevent snow accumulation

Cost Considerations

LED lights are much more energy-efficient than incandescent lights, and greatly reduce energy consumption and increase cost savings. LED lights are typically more expensive than less efficient incandescent and incur greater costs from the initial purchase. However, the rated life of LEDs is typically longer than that of less efficient bulbs, which reduces the frequency of replacement costs.

Expanded Mitigation Options

Incorporation of solar fixtures onto the traffic lights would further reduce grid-supplied electricity consumption and associated emissions.

GHG Reduction Formula

A = **B** × C

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from traffic light electricity use	0–85	%	calculated
User Inputs				
B	Percentage of incandescent traffic lights in project study area to be retrofitted	0–100	%	user input
Constants, Assumptions, and Available Defaults				
C	Percent reduction in power consumption from LED lights compared to incandescent lights	85	%	U.S. DOE 2004

Further explanation of key variables:

- (B) – This methodology assumes that all the existing traffic lights only use incandescent bulbs. If the existing traffic lights are a mix of incandescent and LED bulbs, the LEDs should be excluded from the total number of lights that is used to determine the percentage for this variable.
- (C) – The percent reduction of 85 percent in power consumption is based on an average incandescent bulb power of 109 watts and an average LED bulb power of 17 watts (U.S. DOE 2004). The user should replace this default with a project-specific percent reduction in power consumption if the user knows the average wattage of the existing incandescent bulbs and/or the proposed LED bulbs.

GHG Calculation Caps or Maximums

It is assumed that the electricity demand of the project's traffic lights is currently being met by grid electricity that requires *some* amount of fossil fuel–based energy generation, which emits GHGs from fuel combustion. In other words, the local electricity provider has an energy intensity factor (lb of CO_2e per MWh) greater than zero. For projects that are served by electricity providers already with a renewable portfolio of 100 percent, this measure could have no reduction in GHG emissions. If the electricity provider is using REC to meet a 100 percent renewable portfolio goal, then some emissions reductions may be achieved. This measure would still result in the co-benefits of reduced electricity use and enhanced energy security.

Example GHG Reduction Quantification

If the user's project includes incandescent traffic lights, the user can reduce traffic light electricity by replacing the lights with LEDs. If all (i.e., 100 percent) of the incandescent lights are replaced with LED lights (B), the user would reduce GHG emissions from electricity used to power the incandescent traffic lights by 85 percent. The example measure emission reduction is calculated below.

$$A = 100\% \times 85\% = 85\%$$

Quantified Co-Benefits

Energy and Fuel Savings

(C) represents the percent energy savings for this measure. The project's electricity use from traffic lights in the study area would be reduced by up to 85 percent.

Sources

- U.S. Department of Energy (U.S. DOE). 2004. *State Energy Program Case Studies: California Says "Go" to Energy-Saving Traffic Lights*. Available: http://www.nrel.gov/docs/fy04osti/35551.pdf. Accessed: January 2021.

E-9. Utilize a Combined Heat and Power System

GHG Mitigation Potential

Small

Potentially small reduction in GHG emissions from CHP energy generation

Co-Benefits (icon key on pg. 34)

Climate Resilience

CHP systems reduce sensitivity to fuel price shocks or scarcity and can contribute to generation capacity, reducing energy costs and the risk of outages. These systems can also provide backup energy to a building if the main grid fails during an extreme weather event.

Health and Equity Considerations

Reduction of natural gas combustion would help improve indoor air quality. However, CHP systems still involve natural gas usage, and thus localized effects of emissions on communities should be reviewed closely.

Measure Description

This measure involves using combined heat and power (CHP) systems in place of separate heat and power (SHP) systems. For the same level of power output, CHP systems use less input energy than traditional SHP generation, resulting in lower CO_2 emissions. In traditional SHP systems, heat created as a by-product is wasted as it is released into the surrounding environment. CHP systems harvest the thermal energy and use it to heat onsite uses or for processes in proximity, which reduces the amount of natural gas or other fuel that would otherwise be combusted for heating or for use in those processes. CHP systems also result in a reduced demand for electricity from the grid, which displaces the CO_2 emissions from the production of electricity from the grid.

Subsector

Energy Efficiency Improvements

Scale of Application

Project/Site

Implementation Requirements

It is possible that certain CHP systems may not be appropriate for certain locations, where the carbon intensity of the electricity provider is relatively low. In these instances, the emissions reduction will be negative, which indicates an emissions increase.

Cost Considerations

CHP systems are more efficient than systems where heat and power are produced separately. As long as the system is located near to where the power and heat are being used, CHP systems are quick and relatively inexpensive to install. Coupled with the energy savings associated with the improved efficiency, CHP systems represent a long-term potential cost savings.

Expanded Mitigation Options

Non-applicable.

GHG Reduction Formula

This section describes how to estimate emissions reductions from utilizing a CHP system to supply energy demands that would otherwise have been provided by separate heat and power systems (e.g., electricity from the grid for uses requiring electricity and boilers for thermal demand). The user should quantify emissions reductions using the U.S. EPA's (2020) CHP Energy and Emission Calculator (CHP Tool), which allows users to estimate the energy savings from displaced electricity and thermal production from 10 CHP technologies: reciprocating engine (rich burn, lean burn, and diesel) microturbine, fuel cell, combustion turbine, boiler/steam turbine, other prime mover, and waste-heat-to-power (power only, and power and thermal).

The user has the option to input project-specific data, such as fuels types, duct burner operation, cooling demand, and boiler efficiencies. The CHP Tool has the capabilities to calculate GHG emissions reduction directly from the use of CHP systems, and the user can choose to use the calculator for that purpose. To ensure consistency with the methods and factors used for other measures in this document, the user can also use the calculator to determine the energy savings and calculate the GHG reductions separately, using the methodology provided in this section.

$$A1 = [(B \times C \times D) + (E \times F) - (G \times F)] \times H$$

$$A2 = \frac{(D + G) - B}{(D + G)}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A1	Reduction in GHG emissions from use of CHP System	[ ]	MT CO_2e	calculated by user or in CHP Tool
A2	Percent reduction in GHG emissions from use of CHP System	[ ]	%	calculated by user or in CHP Tool
User Inputs				
	None			
Constants, Assumptions, and Available Defaults				
G	Fuel consumption of CHP system	[ ]	MMBtu per year	calculated in CHP Tool
F	Carbon intensity of commercial natural gas	119	lb CO_2e per MMBtu	U.S. EPA 2020
B	Displaced electricity production from CHP use	[ ]	MMBtu per year	calculated in CHP Tool
C	Conversion from MMBtu to kWh	0.2931	MWh per MMBtu	conversion

ID	Variable	Value	Unit	Source
D	Carbon intensity of local electricity provider	Tables E-4.3 and E-4.4	lb CO_2e per MWh	CA Utilities 2021
E	Displaced thermal production from CHP use	[ ]	MMBtu per year	calculated in CHP Tool
H	Conversion from lb to MT	0.000454	MT per lb	conversion

Further explanation of key variables:

- (A1) – The methodology shown for (A1) involves the use of the fuel consumption results provided by the CHP Tool (Table 1 of the Results tab in the CHP Tool). However, the user can also use the CHP Tool to calculate GHG reductions directly (Table 2 of the Results tab in the CHP Tool). The CHP Tool allows the user to choose an electricity emissions factor (the "displaced electricity generation profile") from a pre-determined list, or it allows the user to enter a custom emission factor. If calculating GHG emissions directly in the CHP Tool, the user should enter a custom emission factor that corresponds to the applicable electricity provider for only CO_2 emissions. The CHP Tool does not allow the user to enter a CO_2e factor.
- (B, D, G) – Standard assumptions to calculate these energy quantities are from EPA's CHP Tool, which can be inputted by the user, are included below. The user should enter project-specific values if available.
  - Operation of 8,760 hours per year.
  - Provides heat only (no cooling).
  - Combusts natural gas fuel (1,028 Btu/ft^3 heat content).
  - No supplementary duct burner.
  - Assumes 4.8 percent transmission loss for displaced electricity (based on Western Interconnect assumptions from the CHP Tool).
  - Assumes thermal demand for a boiler with 80 percent efficiency.

GHG Calculation Caps or Maximums

- All caps and maximums are indicated in the EPA's CHP Tool.
- Because the electric power sector is progressively becoming a zero-carbon source, this measure may not achieve GHG reductions for some combinations of CHP system types, sizes, and other variables inputted into the CHP Tool. In those cases, the CHP Tool will return negative energy savings or emissions reductions, meaning that using a CHP system would result in an increase in energy consumption and emissions relative to using SHP generation. If considering a CHP system to reduce GHG emissions and save energy, the user should ensure that the CHP set-up actually results in reductions.

Example GHG Reduction Quantification

The user's project includes a single unit 600 kW microturbine CHP system fueled by natural gas and used for heating-only with no duct burners. The CHP system is assumed to operate for 8,760 hours per year and is displacing a new gas boiler. Parameters for both the microturbine CHP system and the displaced new gas boiler are assumed from the CHP

Tool. The electricity that is displaced by the CHP system is derived entirely from a natural gas-based powerplant. The electricity provider for the project area is Imperial Irrigation District and the analysis year is 2025. The carbon intensity of electricity is, therefore, 225 lb CO_2e per megawatt-hour (D). The energy quantities calculated from the CHP Tool are displaced electricity production (40,252 MMBtu), displaced thermal production (25,258 MMBtu), and a CHP system consumption of (59,831MMBtu). The example scenario results in a 662 MT CO_2e reduction.

$$A1 = [\left(40{,}252 \text{ MMBtu} \times 0.2931 \frac{\text{MWh}}{\text{MMBtu}} \times 225 \frac{\text{lb } CO_2e}{\text{MWh}}\right) + \left(25{,}258 \text{ MMBtu} \times 119 \frac{\text{lb } CO_2e}{\text{MMBtu}}\right) - (59{,}831 \text{ MMBtu} \times 119 \frac{\text{lb } CO_2e}{\text{MMBtu}})] \times 0.000454 \frac{\text{MT}}{\text{lb}} = \text{-662 MT } CO_2e$$

$$A2 = \frac{(40{,}252 \text{ MMBtu} + 25{,}258 \text{ MMBtu}) - 59{,}831 \text{ MMBtu}}{(40{,}252 \text{ MMBtu} + 25{,}258 \text{ MMBtu})} = 9\%$$

Quantified Co-Benefits

Improved Air Quality

The CHP Tool can calculate reductions in two criteria air pollutants (NO_x and SO_2). To quantify this co-benefit, the user should use the CHP Tool.

Energy and Fuel Savings

To calculate the energy savings for this measure (H), the user should add the displaced electricity production (D) and displaced thermal production (G) from the CHP Tool and then subtract the CHP system energy consumption (B) from the CHP Tool.

Energy Savings Formula

$$H = (D + G) - B$$

Sources

- California Utilities. 2021. Excel database of GHG emission factors for delivered electricity, provided to the Sacramento Metropolitan Air Quality Management District and ICF. January through March 2021.
- U.S. Environmental Protection Agency (U.S. EPA). 2020. *Combined Heat and Power Energy and Emissions Savings Calculator*. Available: https://www.epa.gov/chp/chp-energy-and-emissions-savings-calculator. Accessed: January 2021.

E-10-A. Establish Onsite Renewable Energy Systems–Generic

GHG Mitigation Potential

Varies

Variable reduction in GHG emissions from building energy use depending on renewable electricity generation compared to building energy consumption

Co-Benefits (icon key on pg. 34)

Climate Resilience

Installing onsite renewable energy systems provides backup generation sources that can contribute to generation capacity and reduce the risk of outages, particularly if an extreme event disrupts the grid. Onsite renewable energy can also reduce energy costs.

Health and Equity Considerations

Onsite renewable energy can provide protection against grid disruptions, which can be critical to protect the health of vulnerable people, such as seniors and those who use electric medical equipment.

Measure Description

This measure requires electricity to be generated from an onsite renewable or zero-emission power system. This displaces the electricity demand that would ordinarily be supplied by the local electricity provider. Electricity generation provided by local electricity providers have varying carbon intensities based on the portfolio of energy sources. Some renewable energy systems, such as fuel cells, may not be completely GHG emissions-free, but may still have lower emissions than the electricity provided by the local electricity provider (unless the electricity provider has a relatively high renewable portfolio), thereby reducing GHG emissions. Zero-emissions power systems, such as PV panels, result in the greatest magnitude of emissions reductions. Onsite renewable systems can also provide back-up power as an alternative to diesel generators in the event of grid power outages or demand response events.

Subsector

Renewable Energy Generation

Scale of Application

Project/Site

Implementation Requirements

Renewable energy systems powered by solar and/or wind should be quantified under Measures E-10-B or E-10-C, respectively.

Cost Considerations

Installation costs for onsite renewable energy generation vary greatly depending on the type of energy system and the size of the installation, but overall, installation costs can be high. These costs are recouped by large cost savings as the property owner can use electricity produced on site instead of purchased from the grid, or even a net profit if excess energy is sold to an electricity provider. Additionally, initial installation costs can be partially offset by credits and rebates meant to encourage renewable energy generation.

Expanded Mitigation Options

Pair with Measure E-23, *Use Microgrids and Energy Storage*, in Table 3-2 to store and then deploy surplus electricity generated from the renewable energy system. This would improve the capacity of the system to displace more grid-supplied electricity, further reducing associated emissions.

GHG Reduction Formula

$$A = \frac{-B}{C} \times \frac{E - D}{E}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from electricity use	0–100	%	calculated
User Inputs				
B	Electricity provided by onsite power system with measure	[ ]	kWh per year	user input
C	Total electricity demand	[ ]	kWh per year	user input
D	Carbon intensity of onsite power system	[ ]	lb CO_2e per MWh	user input
Constants, Assumptions, and Available Defaults				
E	Carbon intensity of local electricity provider	Tables E-4.3 and E-4.4	lb CO_2e per MWh	CA Utilities 2021

Further explanation of key variables:

- (D) – If the onsite power system is a zero-emission source, then the GHG emission reduction (A) is effectively equivalent to the ratio of electricity from the zero-emission system (B) to the total electricity demand (C). If the onsite power system is not a zero-emission source, then the GHG emission reduction calculation needs to consider the GHG intensity factor of the onsite power system (D) and the local electricity provider (E).
- (E) – GHG intensity factors for major California electricity providers are provided in Tables E-4.3 and E-4.4 in Appendix C. If the project study area is not serviced by a listed electricity provider, or the user is able to provide a project-specific value (i.e., for the future year not referenced in Tables E-4.3 and E-4.4), the user should use that specific value in the GHG calculation formula. If the electricity provider is not known, users may elect to use the statewide grid average carbon intensity.

GHG Calculation Caps or Maximums

It is assumed that the electricity demand of the project is currently being met by grid energy that requires *some* amount of fossil fuel–based energy generation, which emits GHGs from fuel combustion. In other words, the local electricity provider has an energy intensity factor (lb of CO_2e per kWh) greater than zero. For projects that are served by electricity providers with a renewable portfolio standard of 100 percent, this measure would effectively have no reduction in GHG emissions, although it would still result in the co-benefit of enhanced energy security.

Example GHG Reduction Quantification

If the user's project consumes electricity from a local electricity provider with a non-zero carbon intensity, the user can reduce the project's emissions from electricity consumption by displacing the electricity demand met by the local electricity provider with an onsite power system. In this example, the onsite power system would provide 2,000 kWh per year (B) at a carbon intensity of 50 lb CO_2e per megawatt-hour (D). The proposed project would have a total electricity demand of 10,000 kWh per year (C). It would be constructed in Southern California Edison's service territory and would begin operation by 2022. Without this measure, the project would, therefore, have an electricity carbon intensity of 351 lb CO_2e per MWh (E). The user would reduce GHG emissions from electricity use by 17 percent.

$$A = \frac{\frac{-2{,}000\ \text{kWh}}{\text{yr}}}{\frac{10{,}000\ \text{kWh}}{\text{yr}}} \times \frac{\frac{351\ \text{lb}\ CO_2e}{\text{MWh}} - \frac{50\ \text{lb}\ CO_2e}{\text{MWh}}}{\frac{351\ \text{lb}\ CO_2e}{\text{MWh}}} = -17\%$$

Quantified Co-Benefits

Successful implementation of this measure would reduce grid electricity, and a portion of this electricity is supplied by statewide fossil-fueled power plants, which generates criteria pollutants. However, because these power plants are located throughout the state, the reduction in electricity use from this measure will not reduce localized criteria pollutant emissions and are, therefore, not discussed.

Sources

- California Utilities. 2021. Excel database of GHG emission factors for delivered electricity, provided to the Sacramento Metropolitan Air Quality Management District and ICF. January through March 2021.

E-10-B. Establish Onsite Renewable Energy Systems–Solar Power

GHG Mitigation Potential

Varies

Variable reduction in GHG emissions from building energy use depending on renewable electricity generation compared to building energy consumption

Co-Benefits (icon key on pg. 34)

Climate Resilience

Installing onsite renewable energy systems provides backup generation sources that can contribute to generation capacity and reduce the risk of outages, particularly if an extreme event disrupts the grid. Onsite renewable energy can also reduce energy costs.

Health and Equity Considerations

Solar panels may conflict with tree canopies, which reduces temperatures and improves public health; projects should be carefully designed to minimize these conflicts.

Measure Description

This measure requires electricity to be generated from onsite PV systems, displacing the electricity demand that would ordinarily be supplied by the local electricity provider. Electricity generation provided by local electricity providers have varying carbon intensities based on the portfolio of energy sources. Because PV systems generate zero GHG emissions, this measure displaces the emissions that would have been produced had electricity been supplied by the local electricity provider, and thus results in a reduction in GHG emissions. Onsite renewable systems can also provide back-up power as an alternative to diesel generators in the event of grid power outages.

Subsector

Renewable Energy Generation

Scale of Application

Project/Site

Implementation Requirements

See measure description.

Cost Considerations

Installation costs for solar power vary on the type and size of the generator; however, initial costs are still considered high. These costs are recouped by large cost savings as the property owner can use electricity produced on site, or even a net profit if excess energy is sold to an electricity provider. Additionally, initial installation costs can be at least partially offset by credits and rebates meant to encourage renewable energy use. Solar power may require the purchase of additional property large enough to host the generators.

Expanded Mitigation Options

Pair with Measure E-23, *Use Microgrids and Energy Storage*, in Table 3-2 to store and then deploy surplus electricity generated from the renewable energy system. This would improve the capacity of the system to displace more grid-supplied electricity, further reducing associated emissions.

GHG Reduction Formula

$$A = \frac{-B}{C}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from electricity use	0–100	%	calculated
User Inputs				
B	Electricity provided by PV system with measure	[ ]	kWh per year	user input
C	Total electricity demand	[ ]	kWh per year	user input
Constants, Assumptions, and Available Defaults				
	None			

Further explanation of key variables:

- (B) – The amount of electricity generated by a PV system depends on the size and type of the PV system and the location of the project. The user can use a publicly available solar calculator, such as the NREL PVWatts® Calculator, to estimate the size of the PV system needed to generate the desired amount of electricity. The only input required for this calculator is the location (i.e., zip code). Estimates of the amount of electricity that can be generated from 3, 5, and 10 kilowatt PV systems in cities around California are shown in Table E-10-B.1 in Appendix C (NREL 2017). Other calculators include Google's Project Sunroof (Google n.d.) and solar-estimate.org (2021).

GHG Calculation Caps or Maximums

It is assumed that the electricity demand of the user's project is currently being met by grid energy that requires *some* amount of fossil fuel–based energy generation, which emits GHGs from fuel combustion. In other words, the local electricity provider has an energy intensity factor (lb of CO_2e per kWh) greater than zero. For projects that are served by electricity providers with a renewable portfolio standard of 100 percent, this measure would effectively have no reduction in GHG emissions, although it would still result in the co-benefit of enhanced energy security.

Example GHG Reduction Quantification

If the user's project consumes electricity from a local electricity provider with a non-zero carbon intensity, the user can reduce the project's emissions from electricity consumption by displacing the electricity demand met by the local electricity provider with an onsite solar photovoltaic system. If the total electricity demand is 10,000 kWh per year (C), and the solar power system provides 5,000 kWh per year (B), the user would reduce GHG emissions from electricity use by 50 percent. The example measure emission reduction is calculated below.

$$A = \frac{\frac{-5{,}000\ kWh}{yr}}{\frac{10{,}000\ kWh}{yr}} = -50\%$$

Quantified Co-Benefits

Successful implementation of this measure would reduce grid electricity, and a portion of this electricity is supplied by statewide fossil-fueled power plants, which generates criteria pollutants. However, because these power plants are located throughout the state, the reduction in electricity use from this measure will not reduce localized criteria pollutant emissions and are, therefore, not discussed.

Sources

- Google. no date. *Project Sunroof*. Available: https://www.google.com/get/sunroof.
- National Renewable Energy Laboratory (NREL). 2017. NREL's PVWatts® Calculator. August. Available: https://pvwatts.nrel.gov/index.php. Accessed: January 2021.
- Solar-Estimate. 2021. Solar Calculator. Available: https://www.solar-estimate.org/residential-solar/solar-panel-calculators. Accessed: January 2021.

E-10-C. Establish Onsite Renewable Energy Systems–Wind Power

GHG Mitigation Potential

Varies

Variable reduction in GHG emissions from building energy, depending on renewable electricity generation compared to building energy consumption

Co-Benefits (icon key on pg. 34)

Climate Resilience

Installing onsite renewable energy systems provides backup generation sources that can contribute to generation capacity and reduce the risk of outages, particularly if an extreme event disrupts the grid. Onsite renewable energy can also reduce energy costs.

Health and Equity Considerations

Consider noise impacts in places with nearby sensitive receptors.

Measure Description

This measure requires electricity to be generated from onsite wind power systems, displacing the electricity demand that would ordinarily be supplied by the local electricity provider. Electricity generation provided by local electricity providers have varying carbon intensities based on the portfolio of energy sources. Since wind turbines generate zero GHG emissions, this measure displaces the emissions that would have been produced had electricity been supplied by the local electricity provider and thus results in a reduction in GHG emissions. Onsite renewable systems can also provide back-up power as an alternative to diesel generators in the event of grid power outages.

Subsector

Renewable Energy Generation

Scale of Application

Project/Site

Implementation Requirements

See measure description.

Cost Considerations

Installation costs for wind power generation vary based on the type and size of the turbine, however, initial costs are still considered high. These costs are recouped by large cost savings as the property owner can use electricity produced on site instead of purchased from the grid, or even at a net profit if excess energy is sold to an electricity provider. Additionally, initial installation costs can be at least partially offset by credits and rebates meant to encourage renewable energy generation.

Expanded Mitigation Options

Pair with Measure E-23, *Use Microgrids and Energy Storage*, in Table 3-2 to store and then deploy surplus electricity generated from the renewable energy system. This would improve the capacity of the system to displace more grid-supplied electricity, further reducing associated emissions.

GHG Reduction Formula

$$A = \frac{-B}{C}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from electricity use	0–100	%	calculated
User Inputs				
B	Electricity provided by wind power system with measure	[ ]	kWh per year	user input
C	Total electricity demand	[ ]	kWh per year	user input
Constants, Assumptions, and Available Defaults				
	None			

Further explanation of key variables:

- (B) – The amount of electricity that can be supplied by wind power is highly dependent on location. To implement this measure, users should consider their project's location and other factors that may determine onsite wind power feasibility, such as cost, neighboring land uses, and local ordinances. The U.S. DOE has resources available for wind energy in California, such as wind speed maps (U.S. DOE n.d.). Additionally, the NREL's Wind Prospector is an interactive mapping tool, where users can determine if their project's location is likely to have suitable wind capacity factors (NREL n.d.).

GHG Calculation Caps or Maximums

It is assumed that the electricity demand of the user's project is currently being met by grid energy that requires *some* amount of fossil fuel–based energy generation, which emits GHGs from fuel combustion. In other words, the local electricity provider has an energy intensity factor (lb of CO_2e per kWh) greater than zero. For projects that are served by electricity providers with a renewable portfolio standard of 100 percent, this measure would effectively have no reduction in GHG emissions, although it would still result in the co-benefit of enhanced energy security.

Example GHG Reduction Quantification

If the user's project consumes electricity from a local electricity provider with a non-zero carbon intensity, the user can reduce the project's emissions from electricity consumption by displacing the electricity demand met by the local electricity provider with an onsite wind power system. If the total electricity demand is 10,000 kWh per year (C), and the wind power system provides 1,000 kWh per year (B), the user would reduce GHG emissions from electricity use by 10 percent. The example measure emission reduction is calculated below.

$$A = \frac{\frac{-1{,}000\ kWh}{yr}}{\frac{10{,}000\ kWh}{yr}} = -10\%$$

Quantified Co-Benefits

Successful implementation of this measure would reduce grid electricity, and a portion of this electricity is supplied by statewide fossil-fueled power plants, which generates criteria pollutants. However, because these power plants are located throughout the state, the reduction in electricity use from this measure will not reduce localized criteria pollutant emissions and are, therefore, not discussed.

Sources

- National Renewable Energy Laboratory (NREL). No date. *Wind Prospector*. Available: https://maps.nrel.gov/wind-prospector/?aL=MlB4Hk%255Bv%255D%3Dt%26VMGtY3%255Bv%255D%3Dt%26VMGtY3%255Bd%255D%3D1&bL=clight&cE=0&lR=0&mC=40.21244%2C-91.625976&zL=4. Accessed: March 4, 2021.
- U.S. Department of Energy – Office of Energy Efficiency and Renewable Energy (U.S. DOE). No date. *Wind Energy in California*. Available: https://windexchange.energy.gov/states/ca#maps. Accessed: March 4, 2021.

E-11. Procure Electricity from Lower Carbon Intensity Power Supply

GHG Mitigation Potential

100%

Up to 100% of GHG emissions from electricity use

Co-Benefits (icon key on pg. 34)

Climate Resilience

Procuring electricity from lower carbon intensity power supplies can reduce sensitivity to fuel price shocks or scarcity.

Health and Equity Considerations

Reducing demand for electricity from fossil-fuel sources will help to improve air quality at electrical plants currently using fossil fuels.

Measure Description

This measure will commit the project to procuring electricity with a lower carbon intensity than the primary product offered by the local provider (often an investor-owned utility). This would displace the electricity demand that would ordinarily be supplied by the local electricity provider's energy mix. Electricity provided by local electricity providers have varying carbon intensities based on the portfolio of energy sources. Procurement of electricity of a lower carbon intensity would displace the emissions that would have been produced had the electricity been supplied by the default energy mix and thus results in a reduction in GHG emissions. Green power supply options include utility green power products, community choice aggregation, shared renewables (e.g., community solar), and power purchase agreements.

Subsector

Renewable Energy Generation

Scale of Application

Project/Site and Plan/Community

Implementation Requirements

Purchase electricity from a green power supplier, including utility green power products, community choice aggregation, shared renewables (e.g., community solar), and power purchase agreements.

Cost Considerations

The least carbon-intensive fuels are renewable fuels; however, even switching from high carbon-intensity fossil fuels, like coal and petroleum, to lower intensity fossil fuels, like natural gas, represents a cost savings. The costs associated with building renewable energy generating capacity up to a utility scale are high and require constructing large-scale renewable energy plants and power storage facilities. However, the cost of building new carbon intensive power generation plants is similar, if not higher. Renewable energy plants can usually be completed more quickly than a fossil-fueled energy plant, saving construction costs. Renewable energy facilities may also have a significant operational cost savings, as many, like solar and wind, do not require fuel inputs.

Expanded Mitigation Options

Procure electricity from a zero-carbon power supply to eliminate all emissions from building electricity.

GHG Reduction Formula

$$A = \frac{B}{C} - 1$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from electricity	0–100	%	calculated
User Inputs				
B	Average carbon intensity of power supply with green power	[ ]	lb CO_2e per MWh	user input
Constants, Assumptions, and Available Defaults				
C	Carbon intensity of local electricity provider without measure	Tables E-4.3 and E-4.4	lb CO_2e per MWh	CA Utilities 2021

Further explanation of key variables:

- (B) – The carbon intensity of the green power supply may be available online directly from the power provider and/or indirectly from the relevant state agencies (e.g., CEC, CARB). If publicly unavailable, the user should request this information from the power provider for the year(s) of interest.
- (C) – GHG intensity factors for major California electricity providers are provided in Tables E-4.3 and E-4.4 in Appendix C. If the project study area is not serviced by a listed electricity provider, or the user is able to provide a project-specific value (i.e., for the future year not referenced in Tables E-4.3 and E-4.4), the user should use that specific value in the GHG calculation formula. If the electricity provider is not known, users may elect to use the statewide grid average carbon intensity.

GHG Calculation Caps or Maximums

It is assumed that the electricity demand of the user's project is currently being met by grid energy that requires some amount of fossil fuel-based energy generation, which emits GHGs from fuel combustion. In other words, the local electricity provider has an energy intensity factor (lb of CO_2e per kilowatt-hour) greater than zero. For projects that are served by electricity providers already with a renewable portfolio standard of 100 percent, this measure would effectively have no reduction on GHG emissions.

Example GHG Reduction Quantification

The user displaces indirect emissions from electricity by committing the project to procuring power with a lower carbon intensity than the primary local provider. In this example, the green power supply has a carbon intensity of zero (B) because 100 percent of the electricity is from zero-emission energy sources. The project is in the SMUD service territory and would be operational in 2030. The electricity provider's carbon intensity factor is 224 lb CO_2e per MWh (C). The user would reduce GHG emissions from electricity by 100 percent.

$$A = \frac{\mathbf{0\ \frac{lb\ CO_2e}{MWh}}}{224\ \frac{lb\ CO_2e}{MWh}} - 1 = \text{-}100\%$$

Quantified Co-Benefits

Successful implementation of this measure would reduce grid electricity, and a portion of this electricity is supplied by statewide fossil-fueled power plants, which generates criteria pollutants. However, because these power plants are located throughout the state, the reduction in electricity use from this measure will not reduce localized criteria pollutant emissions and are, therefore, not discussed.

Sources

- California Utilities. 2021. Excel database of GHG emission factors for delivered electricity, provided to the Sacramento Metropolitan Air Quality Management District and ICF. January through March 2021.

E-12. Install Alternative Type of Water Heater in Place of Gas Storage Tank Heater in Residences

GHG Mitigation Potential

Moderate

Potentially moderate reduction in GHG emissions from building natural gas

Co-Benefits (icon key on pg. 34)

Climate Resilience

Using alternative types of water heaters that use less fuel can reduce sensitivity to fuel price shocks or scarcity; however, they may decrease resilience if they are the only option available during a power outage. This measure may also power the appliance from the grid rather than from fuel, offering more reliability if the grid has been adapted to climate change or less reliability if the grid has not been adapted.

Health and Equity Considerations

Reduction of natural gas combustion in homes can help reduce indoor pollution.

Measure Description

This measure requires installation of a water heater that is less emissions intensive than a natural gas conventional storage tank water heater in residential developments. Alternatives analyzed in this measure are electric conventional storage tanks, solar water heaters with natural gas backup, and solar water heaters with electric backup. Each alternative reduces GHG emissions in a slightly different way. An electric storage tank heater displaces natural gas consumption with electricity use, replacing more emissions-intensive natural gas with less emissions-intensive electricity. A solar water heater with electric backup reduces GHG emissions by displacing natural gas with zero-emission solar energy when water is heated by the system's solar collectors and grid electricity when the back-up function is utilized. A solar water heater with natural gas backup reduces emissions by displacing natural gas with solar energy when water is heated by the solar collectors.

Subsector

Building Decarbonization

Scale of Application

Project/Site and Plan/Community

Implementation Requirements

Alternative water heaters analyzed in this measure include electric conventional storage tanks, solar water heaters with natural gas backup, and solar water heaters with electric backup.

Cost Considerations

Non-conventional heaters can have high initial and construction costs (e.g., upgrading the electric panel). However, alternatives to natural gas storage tank heaters are more energy efficient and cost less to operate once they are installed. Common alternatives also require less fuel, maintenance, and upkeep than natural gas heaters, leading to additional long-term cost savings.

Expanded Mitigation Options

Pair with Measure E-3-A, *Require Energy Efficiency Residential Boilers,* to reduce energy use from both space heating and water heating, yielding increased GHG reductions. Also, a heat pump is another option for an alternative water heater that is highly efficient, though the associated energy reductions were not quantified as part of this measure (see Measure E-25, *Install Electric Heat Pumps*, in Table 3-2).

GHG Reduction Formula

$$A1 = (-E \times C \times G \times I \times J) + (F_1 \times C \times H \times K \times J)$$

$$A2 = (F_2 - E) \times C \times G \times I \times J$$

GHG Calculation Variables

Based on 2019 survey data, approximately 73 percent of California residences use conventional storage tank heaters fueled by natural gas for primary water heating (CEC 2020). Therefore, for the purposes of this measure, natural gas storage tanks are the type of water heater that the user would be displacing.

ID	Variable	Value	Unit	Source
Output				
A1	Reduction in GHG emissions from building energy for electric storage tank heater or solar water heater with electric backup	[ ]	MT CO_2e per year	calculated
A2	Reduction in GHG emissions from building energy for solar water heater with natural gas backup	[ ]	MT CO_2e per year	calculated
User Inputs				
B	Housing type	[ ]	text	user input
C	Number of dwelling units	[ ]	du	user input
Constants, Assumptions, and Available Defaults				
D	Electricity Demand Forecast Zone	Figure E-1.1 Table E-1.1	integer	CEC 2017
E	Fuel consumption for storage tank heater	Table E-12.1	therm per year per du	CEC 2020
F_1	Electricity use for electric storage tank heater or solar water heater with electric backup	Table E-12.1	kWh per year per du	CEC 2020
F_2	Fuel consumption for solar water heater with natural gas backup	Table E-12.1	therm per year per du	CEC 2020
G	Carbon intensity of residential natural gas	117	lb CO_2e per MMBtu	U.S. EPA 2020
H	Carbon intensity of local electricity provider	Table E-4.3 Table E-4.4	lb CO_2e per MWh	CA Utilities 2021
I	Conversion from therm to 1 million Btu (MMBtu)	0.1	MMBtu per therm	conversion
J	Conversion from lb to metric ton (MT)	0.000454	MT per lb	conversion
K	Conversion from kWh to MWh	0.001	MWh per kWh	conversion

Further explanation of key variables:

- (B) – The housing types are needed to look up the energy use by type of heater (F_1 and F_2) in Table E-12.1.
- (D) – The CEC has specified 28 distinct EDFZs in California. Users should refer to Figure E-1.1 in Appendix C to determine the EDFZ for their project. This measure relies on energy consumption data from the year 2019 tied to the CEC's (2020) 2019 RASS. Because data from all 28 EDFZs are not included in the RASS, representative data from similar EDFZs may need to be used. Users should refer to Table E-1.1 for the proxy EDFZ that corresponds with those listed in Table E-12-1.
- (E, F_1, and F_2) – The CEC administered the statewide RASS in 2019. The study yielded energy consumption estimates for 27 electric and 10 natural gas residential end uses, including hot water heaters. Based on this data for the year 2019, the average natural gas and electricity consumption by heater type for each EDFZ and housing type is provided in Table E-12.1 in Appendix C. If the data is unavailable for a specific EDFZ, users may elect to use the statewide averages. If the user is able to provide a project-specific value, then the user should replace the defaults in the GHG calculation formula. CEC's 2019 Building Energy Standards provide detailed equations for this calculation (CEC 2019).
- (G) – The carbon intensity of residential natural gas was calculated in terms of CO_2e by multiplying the U.S. natural gas combustion emission factors for CO_2, CH_4, and N_2O (U.S. EPA 2020) by the corresponding 100-year GWP values from the IPCC's Fourth Assessment Report (IPCC 2007). See Table E-4.5 in Appendix C for more natural gas emission factors.
- (H) – GHG intensity factors for major California electricity providers are provided in Tables E-4.3 and E-4.4. If the project study area is not serviced by a listed electricity provider, or the user is able to provide a project-specific value (i.e., for a future year not referenced in Tables E-4.3 and E-4.4), the user should use that specific value in the GHG calculation formula. If the electricity provider is not known, users may elect to use the statewide grid average carbon intensity.

GHG Calculation Caps or Maximums

Mutually Exclusive Measures

If the user selects Measure E-15, *Require All-Electric Development*, they may not also take credit for this measure (Measure E-12) or Measure E-13, *Install Electric Ranges in Place of Gas Ranges,* which electrify select appliances. Measure E-15 accounts for the combined GHG reductions achieved by each of these measures, as well as the electrification of other end uses. To combine the GHG reductions from Measure E-15 with Measure E-12 or Measure E-13 would be considered double counting.

Example GHG Reduction Quantification

The user reduces building energy emissions by installing in a proposed residential development an alternative type of water heater in place of a natural gas storage tank heater. In this example, 10 single-family homes (B and C) would be constructed in EDFZ 7 (D) with a solar water heater with electric backup. Therefore, the fuel consumption for each home's storage tank heater would be 260 therms per year (E), and the electricity consumption for a solar water heater with electric backup would be 483 kilowatt-hours per year (F1), based on Table E-12.1. The homes are in Los Angeles Department of Water and Power's service territory and would be constructed by 2022. It would, therefore, have an electricity carbon intensity of 694 lb CO_2e per MWh (H). The mitigated emissions would be reduced by 12.3 MT CO_2e per year.

$$A1 = \left(\frac{-260\ \text{therm}}{\text{yr}\cdot\text{du}} \times \mathbf{10\ du} \times \frac{117\ \text{lb}\ CO_2e}{\text{MMBtu}} \times \frac{0.1\ \text{MMBtu}}{\text{therm}} \times \frac{0.000454\ \text{MT}}{\text{lb}}\right) + \left(\frac{483\ \text{kWh}}{\text{yr}\cdot\text{du}} \times \mathbf{10\ du} \times \frac{694\ \text{lb}\ CO_2e}{\text{MWh}} \times \frac{0.001\ \text{MWh}}{\text{kWh}} \times \frac{0.000454\ \text{MT}}{\text{lb}}\right) = -12.3\ \frac{\text{MT}\ CO_2e}{\text{yr}}$$

Quantified Co-Benefits

Energy and Fuel Savings

Energy use conversion from major natural gas appliances to their equivalent electric replacements tends not to be straightforward given that most significant gas appliances (e.g., water heaters, space heaters, ovens and cooktops) have varying input-to-output efficiencies and losses from product to product. Equivalent electric appliances also have differing efficiencies, and usage patterns for these equivalent appliances may differ in some way. If installing an electric storage tank heater or solar water heater with electric backup (A_1), the user would decrease the building natural gas consumption (E) and increase the electricity use (F_1). If installing a solar water heater with natural gas backup (B_2), the user would decrease the building natural gas consumption (F_2-E).

Improved Air Quality

The reduction in natural gas fuel consumption from this measure would result in local improvements in air quality because the fuel consumption occurs on site of the project. The reduction in criteria pollutant emissions (L_1 and L_2) achieved by the measure can be calculated as follows.

Criteria Pollutant Emission Reduction Formula

Use (L_1) if installing an electric storage tank heater or solar water heater with electric backup. Use (L_2) if installing a solar water heater with natural gas backup.

$$L1 = -E \times \mathbf{C} \times M \times I \times N$$

$$L2 = (F_2 - E) \times \mathbf{C} \times M \times I \times N$$

Criteria Pollutant Emission Reduction Calculation Variables

ID	Variable	Value	Unit	Source
Output				
L1	Reduction in criteria pollutant emissions from building energy for electric storage tank heater or solar water heater with electric backup	[ ]	tons per year	calculated
L2	Reduction in criteria pollutant emissions from building energy for solar water heater with natural gas backup	[ ]	tons per year	calculated
User Inputs				
	None			
Constants, Assumptions, and Available Defaults				
M	Criteria pollutant emission factors of natural gas	Table E-4.5	lb per MMBtu	U.S. EPA 1998
N	Conversion from lb to ton	0.0005	tons per lb	conversion

Further explanation of key variables:

- (M) – Table E-4.5 presents the criteria pollutant emission factors of natural gas for residential and commercial uses (U.S. EPA 1998). For projects in Bay Area Air Quality Management District or South Coast Air Quality Management territory, see the footnote in Table E-4.5 about a regionally specific NO_x emission factor.
- Please refer to the GHG Calculation Variables table above for definitions of variables that have been previously defined.

Sources

- California Energy Commission (CEC). 2017. *California Electricity Demand Forecast Zones*. Available: https://cecgis-caenergy.opendata.arcgis.com/datasets/86fef50f6f344fabbe545e58aec83edd_0/data?geometry=-165.327%2C31.004%2C-72.427%2C43.220. Accessed: June 2021.
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- California Utilities. 2021. Excel database of GHG emission factors for delivered electricity, provided to the Sacramento Metropolitan Air Quality Management District and ICF. January through March 2021.
- Intergovernmental Panel on Climate Change (IPCC). 2007. *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp. Available: https://www.ipcc.ch/report/ar4/wg1/. Accessed: January 2021.
- U.S. Environmental Protection Agency (U.S. EPA). 2020. Emission Factors for Greenhouse Gas Inventories. March. Available: https://www.epa.gov/sites/production/files/2020-04/documents/ghg-emission-factors-hub.pdf. Accessed: March 2021.
- U.S. Environmental Protection Agency (U.S. EPA). 1998. *AP 42, Fifth Edition, Volume I. Chapter 1: External Combustion Sources*. 1.4, *Natural Gas Combustion*. July. Available: https://www3.epa.gov/ttnchie1/ap42/ch01/final/c01s04.pdf. Accessed: January 2021.

E-13. Install Electric Ranges in Place of Gas Ranges

GHG Mitigation Potential

Small

Potentially small reduction in GHG emissions from building natural gas

Co-Benefits (icon key on pg. 34)

Climate Resilience

Installing electric ranges that use electricity rather than fuel can reduce sensitivity to fuel price shocks or scarcity. Electric ranges also offer more reliability if the grid has been adapted to climate change or less reliability if the grid has not been adapted.

Health and Equity Considerations

Natural gas ranges are a primary sources of residential indoor air pollution (e.g., NOx, CO, and formaldehyde), with the impacts being greater in smaller living spaces and kitchens with inefficient or no vent hoods—disproportionately affecting low-income residents and renters. Replacing natural gas ranges with electric ones thus vastly improves indoor air quality.

Measure Description

This measure requires that residential or commercial developments install an electric range (i.e., cooktop plus oven) in place of a gas range. An electric range displaces natural gas consumption with electricity use, replacing a more emissions-intensive fossil fuel-based source of energy with electricity from the grid that is increasingly transitioning to renewable sources.

Subsector

Building Decarbonization

Scale of Application

Project/Site

Implementation Requirements

The electric range must have an electric or induction cooktop and an electric oven. Because induction cooktops are superior in performance to traditional electric cooktops and comparable to gas, the use of induction cooktops is strongly recommended to help overcome any user hesitancy or preference for gas.

Cost Considerations

Electric cooktops are twice as energy efficient as gas ranges, representing a large cost savings from reduced energy consumption. Electric stoves have similar costs as natural gas stoves and are relatively inexpensive to install. Induction cooktops have higher upfront costs compared to gas ranges but similar cost savings (induction cooktops do not radiate heat, which translates into reduced home cooling costs during warm days). Buyer costs include the purchase of magnetic-based pots and pans (e.g., stainless steel or cast iron) specialized for use on induction cooktops.

Expanded Mitigation Options

Limit gas barbecue grills, which would provide additional GHG mitigation and improved localized air quality.

GHG Reduction Formula

$$A = (-E \times C \times G \times I \times J) + (F \times C \times H \times K \times J)$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Reduction in GHG emissions from building energy	[ ]	MT CO_2e per year	calculated
User Inputs				
B	Housing or building type	[ ]	text	user input
C	Number of du or size of commercial building	[ ]	du or 1,000 gross square feet (KSF)	user input
Constants, Assumptions, and Available Defaults				
D	Electricity Demand Forecast Zone	Figure E-1.1 Table E-1.1	integer	CEC 2017
E	Fuel consumption for natural gas range	Table E-15.1 or Table E-15.2	therm per year per du or therm per year per KSF	CEC 2020, 2021
F	Electricity use for electric cooktop	Table E-15.1 or Table E-15.2	kWh per year per du or kWh per year per KSF	CEC 2020, 2021
G	Carbon intensity of natural gas (commercial/residential)	119/117	lb CO_2e per MMBtu	U.S. EPA 2020
H	Carbon intensity of local electricity provider	Tables E-4.3 and E-4.4	lb CO_2e per MWh	CA Utilities 2021
I	Conversion from therm to MMBtu	0.1	MMBtu per therm	conversion
J	Conversion from lb to MT	0.000454	MT per lb	conversion
K	Conversion from kWh to MWh	0.001	MWh per kWh	conversion

Further explanation of key variables:

- (B) – The housing and building types are needed to look up the energy use by type of cooking appliance (E).
- (D) – The CEC has specified 28 distinct EDFZs in California. Users should refer to Figure E-1.1 in Appendix C to determine the EDFZ for their project. This measure relies on energy consumption data from the year 2019 tied to the CEC's Commercial Forecast and the 2019 RASS (2020, 2021). Because data from all 28 EDFZs are not included in the Commercial Forecast or RASS, representative data from similar EDFZs may need to be used. Users should refer to Table E-1.1 for the proxy EDFZ that corresponds with those listed in Tables E-15.1 and E-15.2.

- (E and F) – The CEC administered the statewide RASS in 2019. The study yielded energy consumption estimates for 27 electric and 10 natural gas residential end uses, including cooking appliances. Based on this data for the year 2019, the average natural gas and electricity consumption by cooking appliance type for each EDFZ and housing type is provided in Table E-15.1 in Appendix C. If the data is missing for the EDFZ, users may elect to use the statewide averages. If the user is able to provide a project-specific value, then the user should replace the defaults in the GHG calculation formula. CEC's 2019 Building Energy Standards provide detailed equations for this calculation (CEC 2019).

  The CEC prepared the Commercial Forecast in October 2019. The Commercial Forecast is generated by a computer model developed by the CEC to forecast electricity and natural gas consumption for commercial building types in California. The data that informs the model includes previous commercial end use surveys, floor space and vacancy estimates (based on econometric and demographic data), adopted building and appliances standards, weather data (cooling and heating degree days), and electricity and natural gas rates. The Commercial Forecast provides energy consumption estimates for 13 commercial end uses, including cooking. Based on this data for 2019, the average statewide natural gas and electricity consumption for cooking appliances for each building type is provided in Table E-15.2. If the user can provide a project-specific value, then the user should replace the defaults in the GHG calculation formula.
- (G) – The carbon intensity of residential and commercial natural gas was calculated in terms of CO_2e by multiplying the U.S. natural gas combustion emission factors for CO_2, CH_4, and N_2O (U.S. EPA 2020) by the corresponding 100-year GWP values from the IPCC's Fourth Assessment Report (IPCC 2007). See Table E-4.5 in Appendix C for more natural gas emission factors.
- (H) – GHG intensity factors for major California electricity providers are provided in Tables E-4.3 and E-4.4 in Appendix C. If the project study area is not serviced by a listed electricity provider, or the user is able to provide a project-specific value (i.e., for the future year not referenced in Appendix C), the user should replace the default in the GHG calculation formula. If the electricity provider is not known, users may elect to use the statewide grid average carbon intensity.

GHG Calculation Caps or Maximums

Mutually Exclusive Measures

If the user selects Measure E-15, *Require All-Electric Development*, they may not also take credit for Measure E-12, *Install Alternative Type of Water Heater in Place of Gas Storage Tank Heater in Residences,* or this measure (Measure E-13), which electrify select appliances. Measure E-15 accounts for the combined GHG reductions achieved by each of these measures, as well as the electrification of other end uses. To combine the GHG reductions from Measure E-15 with Measure E-12 or Measure E-13 would be considered double counting.

Example GHG Reduction Quantification

The user reduces building energy emissions by installing in the proposed residential development an electric range in place of a natural gas range. In this example, the measure would be implemented for 20 low-rise apartments (C) to be constructed in EDFZ 3 (D).

Therefore, the fuel consumption for a natural gas range would be 21 therms per year per du (E), and the electricity consumption for an electric cooktop per du would be 115 kilowatt-hours per year (F_1). The project is in Pacific Gas & Electric's service territory and would begin operation by 2022. It would, therefore, have an electricity carbon intensity of 206 lb CO_2e per MWh (G). The mitigated emissions would be reduced by 2.0 MT CO_2e per year.

$$A = \left(\frac{-21\ \text{therm}}{\text{yr·du}} \times \textbf{20 du} \times \frac{117\ \text{lb}\ CO_2e}{\text{MMBtu}} \times \frac{0.1\ \text{MMBtu}}{\text{therm}} \times \frac{0.000454\ \text{MT}}{\text{lb}}\right) + \left(\frac{115\ \text{kWh}}{\text{yr·du}} \times \textbf{20 du} \times \frac{206\ \text{lb}\ CO_2e}{\text{MWh}} \times \frac{0.001\ \text{MWh}}{\text{kWh}} \times \frac{0.000454\ \text{MT}}{\text{lb}}\right) = -2.0\ \frac{\text{MT}\ CO_2e}{\text{yr}}$$

Quantified Co-Benefits

While the measure will achieve fuel savings, it will also increase electricity consumption. For more information on the public health effects of gas cooking appliances, refer to the resources available from the Rocky Mountain Institute (Rocky Mountain Institute 2020).

Fuel Savings (Increased Electricity)

Energy use conversion from major natural gas appliances to their equivalent electric replacements tends not to be straightforward given that most significant gas appliances (e.g., water heaters, space heaters, ovens, and cooktops) have varying input-to-output efficiencies and losses from product to product. Equivalent electric appliances also have differing efficiencies, and usage patterns for these equivalent appliances may differ in some way. If installing an electric cooktop, the user would decrease the building natural gas consumption (E) and increase the electricity use (F).

Improved Air Quality

The reduction in natural gas fuel consumption from this measure would result in local improvements in air quality because the fuel consumption occurs on site of the project. The reduction in criteria pollutant emissions (L) achieved by the measure can be calculated as follows.

Criteria Pollutant Emission Reduction Formula

$$L = -E \times \mathbf{C} \times M \times I \times N$$

Criteria Pollutant Emission Reduction Calculation Variables

ID	Variable	Value	Unit	Source
Output				
L	Reduction in criteria pollutant emissions from building energy	[ ]	tons per year	calculated
User Inputs				
	None			

Constants, Assumptions, and Available Defaults				
M	Criteria pollutant emission factors of natural gas	Table E-4.5	lb per MMBtu	U.S. EPA 1998
N	Conversion from lb to ton	0.0005	tons per lb	conversion

Further explanation of key variables:

- (M) – Table E-4.5 presents the criteria pollutant emission factors of natural gas for residential and commercial uses (U.S. EPA 1998).
- Please refer to the *GHG Calculation Variables* table above for definitions of variables that have been previously defined.

Sources

- California Energy Commission (CEC). 2017. *California Electricity Demand Forecast Zones*. Available: https://cecgis-caenergy.opendata.arcgis.com/datasets/86fef50f6f344fabbe545e58aec83edd_0/data?geometry=-165.327%2C31.004%2C-72.427%2C43.220. Accessed: June 2021.
- California Energy Commission (CEC). 2019. *Residential Alternative Calculation Method Reference Manual for the 2019 Building Energy Efficiency Standards.* May. Available: https://www.energy.ca.gov/sites/default/files/2020-10/2019%20Residential%20ACM%20Reference%20Manual_ada.pdf. Accessed: January 2021.
- California Energy Commission (CEC). 2020. Excel database with the 2019 Residential Appliance Saturation Study (RASS), provided to ICF. November 13, 2020.
- California Energy Commission (CEC). 2021. Excel database with the 2018-2030 Uncalibrated Commercial Sector Forecast, provided to ICF. January 21, 2021.
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E-14. Limit Wood Burning Devices and Natural Gas/Propane Fireplaces in Residential Development

GHG Mitigation Potential

Large

Potentially large reduction in GHG emissions from wood burning devices

Co-Benefits (icon key on pg. 34)

Climate Resilience

Limiting wood burning and natural gas/propane fireplaces and replacing them with electric appliances can reduce sensitivity to fuel price shocks or scarcity; however, they may decrease resilience if they are the only option available during a power outage. This also offers more reliability if the grid has been adapted to climate change or less reliability if the grid has not been adapted.

Health and Equity Considerations

This may increase winter heating costs for some residents in colder climate zones. Eliminating wood burning and combustion of natural gas and propane in homes can help reduce indoor pollution and greatly reduce outdoor air pollution.

Measure Description

This measure requires committing to not installing any wood burning devices (i.e., woodstoves and fireplaces) or natural gas or propane fireplaces in proposed residential developments. This avoids the combustion of biomass, natural gas, and propane, thereby reducing associated biogenic and non-biogenic GHG emissions. The most efficient alternatives to wood burning devices or gas fireplaces are electric fireplace inserts and electric heat pumps.

Subsector

Building Decarbonization

Scale of Application

Project/Site and Plan/Community

Implementation Requirements

This measure may not be applicable in areas where wood burning devices in new development are already prohibited. In such areas, this measure could be applied for informational purposes, to determine the GHG and air quality benefits in new development achieved by restrictions on wood burning devices. However, users should exercise caution in taking credit for any emissions benefit from this measure in areas where the existing baseline already prohibits wood burning devices.

Cost Considerations

Wood, natural gas, and propane fireplaces use more energy and fuel to heat an area than centralized heating systems and have additional costs to purchase fuel for the fireplace. Electric imitation fireplaces meant for cosmetic purposes are less expensive to install and much more energy efficient. For heat production purposes, portable space heaters that run on electricity have the same benefits in cost reduction and allow the owner to use the same device in multiple locations, saving the cost of installing more units.

Expanded Mitigation Options

Consider electrifying all end uses (e.g., space heating, water heating) by implementing Measure E-15, *Require All-Electric Development*.

GHG Reduction Formula

$$A = -D \times \left[\left(\left(\left((E_1 \times K_1 + E_2 \times K_2 + E_3 \times K_3 + E_4 \times K_4) \times G\right) + F_1 \times L_1 \times H\right) \times N\right) + \left((F_2 \times L_2 + F_3 \times L_3) \times I \times J \times M\right)\right] \times O$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Reduction in GHG emissions from wood burning devices	[ ]	MT CO_2e per year	calculated
User Inputs				
B	Project location	[ ]	air basin, air district, county	user input
C	Housing type	[ ]	multi-family or single-family	user input
D	Number of du	[ ]	du	user input
Constants, Assumptions, and Available Defaults				
E_1	Percent of du with conventional woodstoves	Table E-14.1	%	CA Air Districts 2021
E_2	Percent of du with catalytic woodstoves	Table E-14.1	%	CA Air Districts 2021
E_3	Percent of du with non-catalytic woodstoves	Table E-14.1	%	CA Air Districts 2021
E_4	Percent of du with pellet woodstoves	Table E-14.1	%	CA Air Districts 2021
F_1	Percent of du with wood fireplaces	Table E-14.1	%	CA Air Districts 2021
F_2	Percent of du with natural gas fireplaces	Table E-14.1	%	CA Air Districts 2021
F_3	Percent of du with propane fireplaces	Table E-14.1	%	CA Air Districts 2021
G	Wood mass for stove	Table E-14.1	lb per year	CA Air Districts 2021
H	Wood mass for fireplace	Table E-14.1	lb per year	CA Air Districts 2021
I	Daily usage of fireplace	Table E-14.1	hour per day	CA Air Districts 2021
J	Annual usage of fireplace	Table E-14.1	day per year	CA Air Districts 2021

ID	Variable	Value	Unit	Source
K_1	Carbon intensity of conventional woodstove	Table E-14.2	lb biogenic CO_2e per ton wood burned	U.S. EPA 1996a
K_2	Carbon intensity of catalytic woodstove	Table E-14.2	lb biogenic CO_2e per ton wood burned	U.S. EPA 1996a
K_3	Carbon intensity of non-catalytic woodstove	Table E-14.2	lb biogenic CO_2e per ton wood burned	U.S. EPA 1996a
K_4	Carbon intensity of pellet woodstove	Table E-14.2	lb biogenic CO_2e per ton wood burned	U.S. EPA 1996a
L_1	Carbon intensity of wood fireplace	Table E-14.2	lb biogenic CO_2e per ton wood burned	U.S. EPA 1996b
L_2	Carbon intensity of natural gas	Table E-14.2	lb non-biogenic CO_2e per MMBtu	U.S. EPA 2020
L_3	Carbon intensity of propane	Table E-14.2	lb non-biogenic CO_2e per MMBtu	U.S. EPA 2020
M	Heating rate of natural gas and propane	0.06	MMBtu per hour	SCAQMD 2008
N	Conversion from lb to ton	0.0005	ton per lb	conversion
O	Conversion from lb to MT	0.000454	MT per lb	conversion

Further explanation of key variables:

- (B and C) – The project location and housing type are needed to lookup the percent of du with various types of woodstoves and fireplaces (E_1 through E_4 and F_1 through F_3).
- (E_1 through J) – The percent of du with various types of woodstoves and fireplaces, amount of wood burned by woodstoves and fireplaces, and fireplace usage is based on data supplied by local air districts and state defaults (CA Air Districts 2021). Table E-14.1 in Appendix C presents this information by housing type for each county, air basin, and air district.
- (K_1 through L_3) – The carbon intensity of the various woodstoves and fireplace fuels were calculated in terms of CO_2e by multiplying the emission factors for CO_2, CH_4, and N_2O (U.S. EPA 1996a, 1996b, 2020) by the corresponding 100-year GWP values from the IPCC's Fourth Assessment Report (IPCC 2007). See Table E-14.2 in Appendix C for these emission factors.
- (K_1 through L_1) – GHG emissions from the combustion of wood or biomass are considered biogenic emissions, meaning they are derived from living cells, as opposed to fossil fuels that have been transformed by geological processes. Some protocols do not consider these emissions to be part of an emission inventory. In these instances, users should take care to keep them distinct from non-biogenic emissions caused by natural gas and propane fireplaces (L_2 and L_3).

- (M) – The heating rate of natural gas and propane is based on the upper range provided in the South Coast Air Quality Management District's environmental assessment for Rule 445, Wood Burning Devices (SCAQMD 2008).

GHG Calculation Caps or Maximums

None.

Example GHG Reduction Quantification

The user avoids emission from wood burning devices by eliminating woodstoves and fireplaces from the proposed residential development. In this example, the proposed project would be a 100-unit (D) multi-family housing development (C) located in the Great Basin Valley Air Basin (B). Based on this information, Table E-14.1 can be used to determine the percent of du with various types of woodstoves and fireplaces, the amount of wood burned by woodstoves and fireplaces, and the fireplace usage (E_1 through J). The mitigated emissions would be reduced by -151 MT CO_2e per year.

$$A = \textbf{-100 units} \times \Bigg[\Bigg(\Bigg(\Bigg(\Bigg(0\% \times \frac{3{,}792 \text{ lb } CO_2e}{\text{ton wood}} + 5\% \times \frac{3{,}277 \text{ lb } CO_2e}{\text{ton wood}} + 5\% \times \frac{3{,}400 \text{ lb } CO_2e}{\text{ton wood}} + 0\% \times \frac{3{,}400 \text{ lb } CO_2e}{\text{ton wood}}\Bigg) \times \frac{3{,}019.2 \text{ lb wood}}{\text{yr}}\Bigg) + 35\% \times \frac{3{,}480 \text{ lb } CO_2e}{\text{ton wood}} \times \frac{3{,}078.4 \text{ lb wood}}{\text{yr}}\Bigg) \times \frac{0.005 \text{ ton}}{\text{lb}}\Bigg) + \Bigg(\Bigg(55\% \times \frac{117 \text{ lb } CO_2e}{\text{MMBtu}} + 0\% \times \frac{141.3 \text{ lb } CO_2e}{\text{MMBtu}}\Bigg) \times \frac{3 \text{ hours}}{\text{day}} \times \frac{82.0 \text{ days}}{\text{yr}} \times \frac{0.06 \text{ MMBtu}}{\text{hour}}\Bigg)\Bigg] \times \frac{0.000454 \text{ MT}}{\text{lb}} = \frac{-151 \text{ MT } CO_2e}{\text{yr}}$$

Quantified Co-Benefits

Improved Air Quality

The reduction in wood, natural gas, and propane combustion from this measure would result in local improvements in air quality because the combustion occurs on site of the project. The reduction in criteria pollutant emissions (Q) achieved by the measure would be calculated the same way as the GHG reduction equation, except for the following differences.

- (K_1 through L_3) – Use the criteria pollutant emission factors in Table E-14.2 in Appendix C instead of the GHG emission factors (U.S. EPA 1996a, 1996b, 2015; CARB 2011).
- (N) – Replace (O) with (N) because criteria pollutant emissions are reported as tons of pollutant per year, whereas GHG emissions are reported in units of metric tons.

Energy and Fuel Savings

The reduction in natural gas and propane fuel consumption (P) achieved by this measure, in units of MMBtu per year, can be calculated as follows.

Fuel Reduction Formula

$$P = -D \times (F_2 + F_3) \times I \times J \times M$$

Sources

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E-15. Require All-Electric Development

GHG Mitigation Potential

Large

Potentially large reduction in GHG emissions from building energy use

Co-Benefits (icon key on pg. 34)

Climate Resilience

Requiring all-electric development can reduce sensitivity to fuel price shocks or scarcity and offer more reliability if electricity providers have been adapted to climate change. However, this may decrease resilience if the grid has not been adapted to climate change and if there are no non-electric backup options during a power outage.

Health and Equity Considerations

Elimination of natural gas combustion in homes will improve indoor air quality, as natural gas appliances produce pollutants such as NOx, formaldehyde, and CO. Plans, backups, and contingencies should be in place in the event of extended power failure (consider implementing with Measure E-23, *Use Microgrids and Energy Storage*, in Table 3-2).

Measure Description

This measure requires that residential or commercial developments use all-electric appliances and end uses. Using electric instead of natural gas-powered appliances and end uses replaces a more emissions-intensive fossil fuel source of energy with a less emissions-intensive source of energy, electricity from the grid that is increasingly transitioning to renewable sources.

Subsector

Building Decarbonization

Scale of Application

Project/Site and Plan/Community

Implementation Requirements

It is expected that user's building would electrify the most common natural gas end uses—space heating, water heating, and range (i.e., cooktop plus oven). Additional natural gas end uses include dryer, auxiliary heat, pool heat, spa heat, solar water heater with natural gas backup, and miscellaneous, as discussed below under *GHG Calculation Variables*.

Cost Considerations

Although electric appliances for residential and commercial properties sometimes cost more to purchase and install, they are more energy efficient than conventional natural gas appliances. This can lead to long-term cost savings through reduced energy consumption. Electric appliances also usually require less maintenance than conventional appliances.

Expanded Mitigation Options

One of the most efficient ways to provide space heating with electricity is to use heat pumps, which provides increased efficiency relative to traditional electric resistance heating (see Measure E-25, *Install Electric Heat Pumps*, in Table 3-2). The associated energy reduction from heat pumps was not quantified as part of this measure.

GHG Reduction Formula

A = (-E × C × G × I × J) + (F × C × H × K × J)

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Reduction in GHG emissions from building energy	[ ]	MT CO_2e per year	calculated
User Inputs				
B	Housing or building type	[ ]	text	user input
C	Number of du or size of commercial building	[ ]	du or KSF	user input
Constants, Assumptions, and Available Defaults				
D	Electricity Demand Forecast Zone	Figure E-1.1 Table E-1.1	integer	CEC 2017
E	Existing fuel consumption for natural gas end uses without measure	Table E-15.1 Table E-15.2	therm per year per du or therm per year per KSF	CEC 2020, 2021
F	Additional electricity use for equivalent electrified end uses with measure	Table E-15.1 Table E-15.2	kWh per year per du or kWh per year per KSF	CEC 2020, 2021
G	Carbon intensity of natural gas (commercial/residential)	119/117	lb CO_2e per MMBtu	U.S. EPA 2020
H	Carbon intensity of local electricity provider	Tables E-4.3 and E-4.4	lb CO_2e per MWh	CA Utilities 2021
I	Conversion from therm to MMBtu	0.1	MMBtu per therm	conversion
J	Conversion from lb to MT	0.000454	MT per lb	conversion
K	Conversion from kWh to MWh	0.001	MWh per kWh	conversion

Further explanation of key variables:

- (B) – The housing and building types are needed to look up the energy use for electric and natural gas end uses for residential and commercial development (E and F).
- (D) – The CEC has specified 28 distinct EDFZs in California. Users should refer to Figure E-1.1 in Appendix C to determine the EDFZ for their project. This measure relies on energy consumption data from the year 2019 tied to the CEC's Commercial Forecast and the 2019 RASS (CEC 2020, 2021). Because data from all 28 EDFZs are not included in the Commercial Forecast and RASS, representative data from similar EDFZs may need to be used. Users should refer to Table E-1.1 for the proxy EDFZ that corresponds with those listed in Tables E-15.1 and E-15.2.

- (E and F) – The CEC administered the statewide RASS in 2019. The study yielded energy consumption estimates for 27 electric and 10 natural gas residential end uses. Based on this data for the year 2019, the average natural gas and electricity consumption by end use for each EDFZ and housing type is provided in Table E-15.1. The natural gas end uses included in the RASS and reflected in this measure include space heating, water heating, range/oven, dryer, auxiliary heat, pool heat, spa heat, solar water heater with natural gas backup,[25] and miscellaneous.[26] There are electric equivalent end uses for each of these end uses, with the addition of heat pumps as an option for space heating and the exception of pool heat, which requires a manual user input. Users should only evaluate the end uses applicable to their project. For example, most residences will not be built with spas, and only single-family housing has solar water heaters. A minimum recommendation is that the primary natural gas end uses that are commonly electrified be included—space heating, water heating, and range/oven. If the data is missing for the EDFZ or end use, users may elect to use the statewide averages. If users are able to provide a project-specific value, then they should replace the defaults in the GHG calculation formula.

  The CEC prepared the Commercial Forecast in October 2019. The Commercial Forecast is generated by a computer model developed by the CEC to forecast electricity and natural gas consumption for commercial building types in California. The data that informs the model includes previous commercial end use surveys, floor space and vacancy estimates (based on econometric and demographic data), adopted building and appliances standards, weather data (cooling and heating degree days), and electricity and natural gas rates. The Commercial Forecast provides energy consumption estimates for 13 electric and 6 natural gas commercial end uses. Based on this data for 2019, the average statewide natural gas and electricity consumption by end use for each building type is provided in Table E-15.2. The natural gas end uses included in the Commercial Forecast and reflected in this measure include space heating, cooling, water heating, range/oven, refrigeration, and miscellaneous.[27] Users should only evaluate the end uses applicable to their project. A minimum recommendation is that the primary natural gas end uses that are commonly electrified be included—space heating, water heating, and range/oven. If the data is missing for the EDFZ or end use, users may elect to use the statewide averages. If users are able to provide a project-specific value, then they should replace the defaults in the GHG calculation formula.
- (G) – The carbon intensity of natural gas was calculated in terms of CO_2e by multiplying the U.S. natural gas combustion emission factors for CO_2, CH_4, and N_2O (U.S. EPA 2020) by the corresponding 100-year GWP values from the IPCC's Fourth Assessment Report (IPCC 2007). See Table E-4.5 in Appendix C for more natural gas emission factors.
- (H) – GHG intensity factors for major California electricity providers are provided in Tables E-4.3 and E-4.4. If the project study area is not serviced by a listed electricity provider, or the user is able to provide a project-specific value (i.e., for the future year not referenced in Tables E-4.3 and E-4.4), the user should use that specific value in the

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[25] Only allowed for single-family housing.

[26] The RASS "miscellaneous" end use category includes approximately 20 appliances, ranging from portable fans to wine coolers to aquariums. Users should exercise caution in applying the average energy consumption data for this category to their project.

[27] The commercial energy forecast "miscellaneous" end use category includes over 50 equipment types, ranging from specialized medical equipment for hospital buildings to ATM machines for retail buildings to shop tools for warehouses. Users should exercise caution in applying the average energy consumption data for this category to their project.

GHG calculation formula. If the electricity provider is not known, the user may elect to use the statewide grid average carbon intensity.

GHG Calculation Caps or Maximums

Mutually Exclusive Measures

If users select this measure (Measure E-15), they may not also take credit for Measure E-12, *Install Alternative Type of Water Heater in Place of Gas Storage Tank Heater in Residences*, or Measure E-13, *Install Electric Ranges in Place of Gas Ranges,* which electrify select appliances. This measure (Measure E-15) accounts for the combined GHG reductions achieved by each of these measures, as well as the electrification of other end uses. To combine the GHG reductions from this measure (Measure E-15) with Measure E-12 or Measure E-13 would be considered double counting.

Example GHG Reduction Quantification

The user reduces building energy emissions by electrifying the proposed development with electric end uses in place of natural gas end uses. In this example, the measure would be implemented at 20 apartments in a high-rise building (C) to be constructed in EDFZ 11 (D). Natural gas end uses without the measure include water heater, primary heat, range/oven, and dryer resulting in 261 therms per year per du (E). The electricity consumption to electrify these end uses would be 2,611 kilowatt-hours per year per du (F_1). The project is in City of Riverside's service territory and would begin operation by 2022. It would therefore have an electricity carbon intensity of 791 lb CO_2e per megawatt-hour (G). The mitigated emissions would be reduced by 9 MT CO_2e per year.

$$A = \left(\frac{\text{-261 therm}}{\text{yr}\cdot\text{du}} \times \mathbf{20\ du} \times \frac{\text{117 lb } CO_2e}{\text{MMBtu}} \times \frac{\text{0.1 MMBtu}}{\text{therm}} \times \frac{\text{0.000454 MT}}{\text{lb}}\right) + \left(\frac{\text{2,611 kWh}}{\text{yr}\cdot\text{du}} \times \mathbf{20\ du} \times \frac{\text{791 lb } CO_2e}{\text{MWh}} \times \frac{\text{0.001 MWh}}{\text{kWh}} \times \frac{\text{0.000454 MT}}{\text{lb}}\right) = -9\ \frac{\text{MT } CO_2e}{\text{yr}}$$

Quantified Co-Benefits

Energy and Fuel Savings

Energy use conversion from major natural gas appliances to their equivalent electric replacements tends not to be straightforward given that most significant gas appliances (e.g., water heaters, space heaters, ovens and cooktops) have varying input-to-output efficiencies and losses from product to product. Equivalent electric appliances also have differing efficiencies, and usage patterns for these equivalent appliances may differ in some way. If electrifying a building, the user would decrease the building natural gas consumption (E) and increase the electricity use (F).

Improved Air Quality

The reduction in natural gas fuel consumption from this measure would result in local improvements in air quality because the fuel consumption occurs on site of the project. The reduction in criteria pollutant emissions (L) achieved by the measure can be calculated as follows.

Criteria Pollutant Emission Reduction Formula

$$L = -E \times C \times M \times I \times N$$

Criteria Pollutant Emission Reduction Calculation Variables

ID	Variable	Value	Unit	Source
Output				
L	Reduction in criteria pollutant emissions from building energy	[ ]	tons per year	calculated
User Inputs				
	None			
Constants, Assumptions, and Available Defaults				
M	Criteria pollutant emission factors of natural gas	Table E-4.5	lb per MMBtu	U.S. EPA 1998
N	Conversion from lb to ton	0.0005	tons per lb	conversion

Further explanation of key variables:

- (M) – Table E-4.5 presents the criteria pollutant emission factors of natural gas for residential and commercial uses (U.S. EPA 1998).
- Please refer to the *GHG Calculation Variables* table above for definitions of variables that have been previously defined.

Sources

- California Energy Commission (CEC). 2017. *California Electricity Demand Forecast Zones*. Available: https://cecgis-caenergy.opendata.arcgis.com/datasets/86fef50f6f344fabbe545e58aec83edd_0/data?geometry=-165.327%2C31.004%2C-72.427%2C43.220. Accessed: June 2021.
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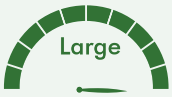
E-16. Require Zero Net Energy Buildings

GHG Mitigation Potential



Potentially large reduction in GHG emissions from building energy use

Co-Benefits (icon key on pg. 34)

Climate Resilience

Requiring ZNE buildings can reduce sensitivity to fuel price shocks or scarcity and offer more reliability if electricity providers have been adapted to climate change or less reliability if the grid has not been adapted. If the development produces and exports emission-free energy, this increases energy resilience and adds generation capacity to the overall grid, reducing risk of outages.

Health and Equity Considerations

As a ZNE building is likely to exclude or limit natural gas combustion, it would likely improve indoor and regional air quality.

Measure Description

This measure requires the user to operate their building at ZNE. A ZNE building foremost reduces GHG emissions by reducing energy use through more efficient design. Further, the building avoids GHG emissions either by using no emissions-generating energy sources or offsetting the building energy emissions by exporting emission-free energy (typically from onsite renewables). For residential buildings, the user can determine achievement of ZNE performance by entering the project details into the CEC's CBECC-Res 2019 executable file (Wilcox 2020). CBECC-Res 2019 uses the energy design rating, represented by the Time Dependent Valuation (TDV), as a way to express the energy consumption of a building as a rating score index (CEC 2018).

Subsector

Building Decarbonization

Scale of Application

Project/Site and Plan/Community

Implementation Requirements

CEC defines a ZNE Code Building as one where the net energy produced by onsite renewables is equal to the building energy consumption, measured using the CEC's TDV metric. The California Department of General Services defines ZNE more broadly, including not only buildings but campuses, portfolios, and communities (BluePoint Planning 2018).

Cost Considerations

ZNE buildings would have highly variable costs, including building onsite renewable energy, more expensive building materials to improve energy efficiency, and carbon offsets and/or renewable energy credits (RECs). While purchasing RECs may be less costly than building onsite generation, the project would not gain the co-benefits of greater energy resilience and contribution to grid capacity. And while all these costs may be high, the cost savings from reduced energy usage are also substantial.

Expanded Mitigation Options

Instead implement Measure E-17, *Require Renewable Surplus Buildings*, which results in a surplus of renewable energy and therefore increased GHG reductions and co-benefits.

GHG Reduction Formula

A = -100%

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from building energy	100	%	calculated
User Inputs				
	None			
Constants, Assumptions, and Available Defaults				
	None			

No further explanation of variables.

GHG Calculation Caps or Maximums

Measure Maximum

(A_{max}) The maximum, and, in fact, only percent reduction in GHG emissions from building energy for this measure is 100 percent. This assumes that the net amount of emissions displaced by onsite renewable energy resources is equal to the number of the emissions generated annually by the building electricity use and onsite fuel consumption.

Mutually Exclusive Measures

If the user selects this measure, they may not also select Measure E-17, *Require Renewable Surplus Buildings*, which represents a unique scenario in which the project produces more renewable energy than what is required to offset the emissions generated from energy consumed by the building and would be considered carbon-negative.

Example GHG Reduction Quantification

The user avoids building energy emissions by committing their project building to be ZNE. The user would reduce GHG emissions from building energy by 100 percent.

Quantified Co-Benefits

Energy and Fuel Savings

The percent reduction in electricity from an electricity provider and fuel consumption achieved by the measure is the same as the percent reduction in GHG emissions

(A). This measure, while not resulting in a net reduction in electricity consumption per se, would displace the building electricity from the grid.

Improved Air Quality

Electricity supplied by statewide fossil-fueled or bioenergy power plants generates criteria pollutants. However, because these power plants are located throughout the state and not typically in close proximity to the ZNE building site, the reduction in electricity use from this measure will not reduce localized criteria pollutant emissions.

For projects that are all electric or replace sources of fossil fuel combustion with electric infrastructure, the reduction in onsite fuel consumption from this measure would result in local improvements in air quality because the building fuel combustion occurs on site of the project (e.g., natural gas for space heating or water heating). The percent reduction in GHG emissions (A) is the same as the percent reduction in localized criteria pollutants from building energy achieved by the measure. In other cases, projects may achieve ZNE by offsetting emissions from onsite fuel combustion sources through the export of renewable energy generated to the electric grid. If the project would retain sources of fossil fuel combustion, there would not be a 100 percent reduction in local criteria pollutant emissions. The reduction in criteria pollutant emissions (B) achieved by the measure can be calculated as follows.

Criteria Pollutant Emission Reduction Formula

$$B = -C$$

Criteria Pollutant Emission Reduction Calculation Variables

ID	Variable	Value	Unit	Source
Output				
B	Percent reduction in criteria pollutant emissions from onsite fossil fuel use	[ ]	%	calculated
User Inputs				
C	Percent reduction in onsite fossil fuel use	0–100%	%	user input
Constants, Assumptions, and Available Defaults				
	None			

Further explanation of key variables:

- (B and C) – The reduction in criteria pollutant emissions may be less than 100 percent or even 0 percent if the project retains onsite fossil fuel sources (i.e., natural gas, propane) In this situation, the percent reduction in criteria pollutant emissions is equal to the percent reduction in onsite fossil fuel use.
- Please refer to the *GHG Calculation Variables* table above for definitions of variables that have been previously defined.

Sources

- Bluepoint Planning. 2018. *Commercial & District Zero Net Energy Framework.* April. Available: https://4eae5a23-44d0-418e-8d77-0e5a216d92ea.filesusr.com/ugd/cc790b_01490cf012b64cf7b369aab39a3750a9.pdf. Accessed: January 2021.
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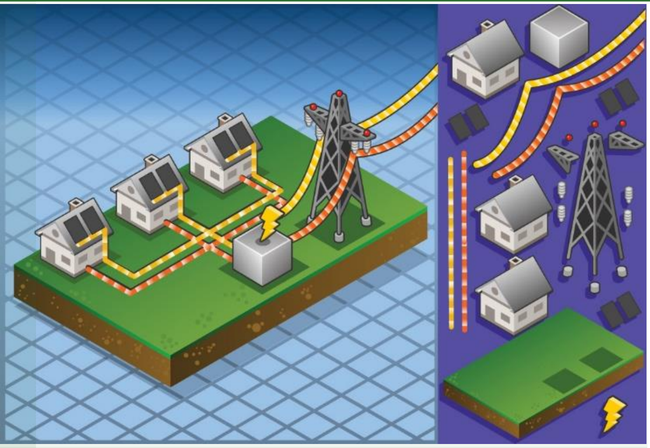
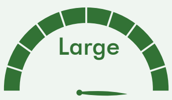
E-17. Require Renewable Surplus Buildings



GHG Mitigation Potential



Potentially large reduction in GHG emissions from building energy use

Co-Benefits (icon key on pg. 34)

Climate Resilience

Requiring renewable surplus buildings can add generation capacity to the overall grid, reducing energy costs and risk of outages.

Health and Equity Considerations

Providing surplus energy back into the grid can reduce the risk of power outages, which underserved communities are more vulnerable to because of disinvestment and historical redlining.

Measure Description

This measure will require that proposed development install onsite renewable energy in an amount that offsets more emissions than the amount generated from the development's electricity use and onsite fuel consumption. Installing zero-emission renewable energy displaces emissions from grid electricity that would otherwise be used, thereby reducing GHG emissions. Implementation of this measure would result in buildings that reduce more GHG emissions than they generate through surplus generation of energy from renewables, sometimes known as *carbon-negative buildings*. The amount of renewable energy required for a building to have net negative GHG emissions is largely determined by the number of emissions from onsite fuel consumption and the carbon intensity of the local electricity provider.

Subsector

Building Decarbonization

Scale of Application

Project/Site and Plan/Community

Implementation Requirements

Onsite renewable energy should be installed in an amount that offsets more emissions than the amount generated from the development's electricity and onsite fuel consumption. The excess renewably energy must be sold to displace non-zero emission grid electricity.

Cost Considerations

The costs associated with building only renewable-surplus structures are very high, as each building will need to be maximally energy efficient and generate renewable energy on site. However, by definition, energy costs would be entirely eliminated, and surplus energy would be sold back to the electricity provider. This is not only a cost savings, but also an additional revenue stream for each building.

Expanded Mitigation Options

When requiring development with surplus renewable generation, a best practice is to also electrify the building (see Measure E-15, *Require All-Electric Development*) so that emissions from onsite fuel consumption, such as natural gas, are eliminated.

GHG Reduction Formula

$$A = B + [(C - D) \times E \times F \times G]$$

$$A_{\%} = \frac{A - (B + C \times E \times F \times G)}{(B + C \times E \times F \times G)}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	GHG emissions from building energy	[ ]	MT CO_2e per year	calculated
$A_{\%}$	Percent reduction in GHG emissions from building energy	>100	%	calculated
User Inputs				
B	Emissions from building onsite fuel consumption	[ ]	MT CO_2e per year	user input
C	Building electricity use	[ ]	kWh per year	user input
D	Onsite renewable energy production	[ ]	kWh per year	user input
Constants, Assumptions, and Available Defaults				
E	Carbon intensity of local electricity provider	Tables E-4.3 and E-4.4	lb CO_2e per MWh	CA Utilities 2021
F	Conversion from lb to MT	0.000454	MT per lb	conversion
G	Conversion from kWh to MWh	0.001	MWh per kWh	conversion

Further explanation of key variables:

- (B) – Emissions from building onsite fuel combustion may come from natural gas, propane, or other fuels. The user should take care to properly quantify these emissions using accepted methodologies (such as CalEEMod). If the project would be an all-electric development (see Measure E-15), then there would be no onsite fuel consumption, and the value for this variable would be zero.
- (C) – It is assumed that the building electricity comes from a non–zero-emission source (e.g., grid electricity with fossil fuel mix). However, if a project would be all-electric, and the local electricity provider supplying the project's electricity sources 100 percent of its electricity from renewable energy sources, then this measure would not reduce building energy emissions, as they would already be zero. The measure would still result in the co-benefit of enhanced energy supply because it adds its energy surplus as additional capacity back to the grid.
- (D) – It is assumed that the onsite renewable energy comes from a zero-emission source (e.g., solar, wind, geothermal, biomass, eligible hydroelectric). See Measures E-10-A through E-10-C for discussion of how to calculate the energy generated from various renewable energy systems. This value should be greater than the value for (C) because the renewable energy generated will need to more than offset the electricity consumed and onsite fuel consumption.

- (E) – GHG intensity factors for major California electricity providers are provided in Tables E-4.3 and E-4.4 in Appendix C. If the project study area is not serviced by a listed electricity provider, or the user is able to provide a project-specific value (i.e., for the future year not referenced in Tables E-4.3 and E-4.4), the user should use that specific value in the GHG calculation formula. If the electricity provider is not known, a user may elect to use the statewide grid average carbon intensity.

  Note that the GHG intensity factor of electricity providers will decrease in future years as the electricity providers continue to improve their energy mix to meet the requirements of SB 100 for 50 percent carbon-free electricity by 2025, 60 percent by 2030, and 100 percent by 2045. Accordingly, this measure will reduce fewer and fewer emissions in future years as the energy it displaces becomes cleaner.

GHG Calculation Caps or Maximums

Measure Maximum

($A_{\%}$) The percent reduction in GHG emissions from building energy for this measure should be greater than 100 percent. This is based on the requirement that the displaced electricity emissions from the onsite renewable sources must exceed the combined building energy emissions from electricity and onsite fuel consumption.

Mutually Exclusive Measures

If the user selects this measure, they may not also select Measure E-16, *Require Zero Net Energy Buildings*, which represents a unique scenario in which the project produces an amount of renewable energy that displaces an equal number of emissions from building electricity and onsite fuel consumption (i.e., ZNE).

Example GHG Reduction Quantification

$$A = \frac{0.1\ \text{MT CO}_2\text{e}}{\text{yr}} + \left[\left(\frac{9{,}000\ \text{kWh}}{\text{yr}} - \frac{16{,}000\ \text{kWh}}{\text{yr}}\right) \times \frac{473\ \text{lb CO}_2\text{e}}{\text{MWh}} \times \frac{0.000454\ \text{MT}}{\text{lb}} \times \frac{0.001\ \text{MWh}}{\text{kWh}}\right] = \frac{-1.4\ \text{MTCO}_2\text{e}}{\text{yr}}$$

$$A_{\%} = \frac{\frac{-1.4\ \text{MT CO}_2\text{e}}{\text{yr}} - \left(\frac{0.1\ \text{MT CO}_2\text{e}}{\text{yr}} + \frac{9{,}000\ \text{kWh}}{\text{yr}} \times \frac{473\ \text{lb CO}_2\text{e}}{\text{MWh}} \times \frac{0.000454\ \text{MT}}{\text{lb}} \times \frac{0.001\ \text{MWh}}{\text{kWh}}\right)}{\frac{0.1\ \text{MT CO}_2\text{e}}{\text{yr}} + \frac{9{,}000\ \text{kWh}}{\text{yr}} \times \frac{473\ \text{lb CO}_2\text{e}}{\text{MWh}} \times \frac{0.000454\ \text{MT}}{\text{lb}} \times \frac{0.001\ \text{MWh}}{\text{kWh}}} = -169\%$$

The user constructs onsite renewable energy infrastructure that displaces more emissions than the amount generated from electricity and onsite fuel consumption. In this example, a single-family home would be constructed in Roseville Electric's service territory and would begin operation by 2022. It would therefore have an electricity carbon intensity of 473 lb CO2e per megawatt-hour (E). If the emissions from building onsite fuel consumption are 0.1 MT CO_2e per year (B), the building electricity use is 9,000 KWh per year (C), and the onsite renewable energy production is 16,000 KWh per year (D), the mitigated emissions would be -1.4 MT CO_2e per year, or a reduction of 169 percent.

Quantified Co-Benefits

Energy and Fuel Savings

This measure, while not resulting in a net reduction in electricity consumption per se, would completely displace the building electricity from the grid (C) and provide surplus generation capacity from onsite renewable sources (D).

Sources

- California Utilities. 2021. Excel database of GHG emission factors for delivered electricity, provided to the Sacramento Metropolitan Air Quality Management District and ICF. January through March 2021.

E-18. Establish Methane Recovery in Landfills

GHG Mitigation Potential

Varies

Variable reduction in GHG emissions from landfill waste decomposition depending on the capture program and system size

Co-Benefits (icon key on pg. 34)

Climate Resilience

Establishing CH_4 recovery provides backup fuels if extreme weather events disrupt main sources of fuel.

Health and Equity Considerations

Combustion of CH_4 may increase local air pollution. Potential effects of combustion emissions on adjacent sensitive receptors needs to be evaluated during project design.

Measure Description

This measure involves the capture and treatment of landfill gas (LFG) emitted from decomposition of organic waste in landfills. Landfill gas contains about 50 percent CH_4 by volume, which has a GWP 25 times that of CO_2. This measure addresses emissions savings from LFG that is captured and either flared or combusted for energy. Flaring LFG will reduce the amount of CH_4 emitted into the atmosphere. Combusting LFG to generate electricity for onsite energy needs reduces GHG emissions in two ways: it reduces direct CH_4 emissions, and it displaces electricity demand and the associated indirect GHG emissions from electricity production. Municipal solid waste management teams should calculate the GHG savings from both flaring and combustion for energy recovery to see the relative benefits for each option.

Subsector

Methane Recovery

Scale of Application

Project/Site

Implementation Requirements

See measure description.

Cost Considerations

Landfills that have no current system for capturing CH_4 would face high installation costs for a CH_4 recovery system. Costs would be much lower for landfills that already have a system for trapping or cleaning captured gases. In California, CH_4 reclaimed from waste could represent a large additional revenue stream for landfills if the gases are managed and sold as offsets or RECs on the Low Carbon Fuel Standard or U.S. Renewable Fuel Standards markets.

Expanded Mitigation Options

Additional reductions may be achieved if the LFG is used as a transportation fuel or injected into a regional natural gas pipeline for downstream uses. Quantitative methods for these alternatives are not specifically addressed by this measure.

GHG Reduction Formula

$A1 = [(\mathbf{G} \times O \times L) + (\mathbf{G} \times P \times M)] \times Q$

$B = \mathbf{G} \times N$

$A2 = B \times R \times S \times T$

$A3 = A1 + A2$

$C = [\mathbf{D} \times [\mathbf{E} \times I \times J \times \mathbf{F} \times K] \times (1 - H)] \times L$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A1	Emissions from LFG flaring or combustion	[ ]	MT CO_2e	calculated
B	Energy savings from flaring or combustion of LFG for energy	[ ]	MMBtu	calculated
A2	Additional emissions from LFG combustion if energy is generated	[ ]	MT CO_2e	calculated
A3	Total emissions from LFG use (flaring and energy use)	[ ]	MT CO_2e	calculated
C	CH_4 generation potential emissions	[ ]	MT CO_2e	calculated
User Inputs				
D	Municipal Solid Waste affected by measure	[ ]	tons	user input
E	CH_4 correction factor	0.6–1	unitless	IPCC 2007
F	Fraction of CH_4 in landfill gas	0.4–0.6	unitless	IPCC 2007
G	LFG flared of combusted for energy	[ ]	standard cubic foot (scf)	U.S. EPA 2018
Constants, Assumptions, and Available Defaults				
H	Oxidation rate	0.10	percent	IPCC 2007
I	Dissolved organic carbon (DOC)	19.8%	percent	CalRecycle 2014
J	Fraction of DOC that is ultimately degraded	0.6	unitless	IPCC 2007
K	Stoichiometric ratio between CH_4 and carbon	16/12	g of CH_4 per g of C	conversion
L	GWP of CH_4	25	unitless	IPCC 2007
M	GWP of N_2O	298	unitless	IPCC 2007
N	Heating value of LFG	0.000485	MMBtu per scf	U.S. EPA 2018

ID	Variable	Value	Unit	Source
O	CH_4 emission factor for LFG combustion	0.001552	g CH_4 per scf	U.S. EPA 2018
P	N_2O emission factor for LFG combustion	0.000306	g N_2O per scf	U.S. EPA 2018
Q	Conversion from g to MT	10^{-6}	MT per g	conversion
R	MWh to MMBTU	3.412142	MWh per MMBtu	conversion
S	Carbon intensity of local electricity provider	Table E-4.3 and E-4.4	lb CO_2e per MWh	CA Utilities 2021
T	Conversion from lb to MT	0.000454	MT per lb	conversion

Further explanation of key variables:

- (E) – The CH_4 correction factor accounts for CH_4 generation from managed or unmanaged landfills. For example, unmanaged landfills produce less CH_4 from a given amount of waste than managed landfills because a larger fraction of waste decomposes aerobically in the top layers of a landfill.
  - Managed = 1.0
  - Unmanaged (≥5 meter (m) deep) = 0.8
  - Unmanaged (<5 m deep) = 0.4
  - Uncategorized = 0.6
- (C) – The generation potential follows the IPCC 2007 "good practices" guidelines for estimating CH_4 emissions for a landfill that does not have LFG capture technology.
- (F) – The fraction of CH_4 in landfill gas is based on the organic matter content of the landfill. This fraction can range from 0.4 to 0.6, but the default is usually taken as 0.5.
- (I) – CalRecycle published a 2016 study on the composition of California's overall disposed waste stream. From this study, an average California DOC was calculated to determine organic content of waste in landfills.
- (D) – This input is the amount of waste that the user will know will have some amount of LFG capture technology.

GHG Calculation Caps or Maximums

None.

Example GHG Reduction Quantification

In this example, a user decides to implement an LFG capture program and use the LFG to produce energy to offset utility electricity usage. The landfill contains 1,000 short tons of waste, is managed and has 0.5 fraction of CH_4 in the LFG with a 75 percent collection efficiency. Twenty million scf LFG was combusted. The project is in Redding Electric Utility's service territory and would begin operation by 2024. It would therefore have an electricity carbon intensity of 341 lb CO_2e per MWh (S). This example scenario results in a total net GHG reduction (A3) of 5,126.6 MT CO_2e.

$$A1 = \left[\left(\mathbf{20{,}000{,}000\ scf} \times 0.001552 \frac{g\ CH_4}{scf} \times 25\right) + \left(\mathbf{20{,}000{,}000\ scf} \times 0.000306 \frac{g\ N_2O}{scf} \times 298\right)\right] \times 10^{-6} = 2.6\ MT\ CO_2e$$

$$B = \mathbf{20{,}000{,}000\ scf} \times 0.000485 \frac{MMBtu}{scf} = 9{,}700\ MMBtu$$

$$A2 = 9{,}700\ MMBtu \times 3.412142 \frac{MWh}{MMBtu} \times 341 \frac{lb}{MWh} \times 0.000454 \frac{MT}{lb} = 5{,}124\ MT\ CO_2e$$

$$A3 = 2.6\ MT\ CO_2e + 5{,}124\ MT\ CO_2e = 5{,}126.6\ MT\ CO_2e$$

$$C = \left[\mathbf{1{,}000\ tons} \times \left[1 \times 19.8\% \times 0.6 \times \mathbf{0.5} \times \frac{16}{12}\ \frac{g\ CH_4}{g\ C}\right] \times (1 - 0.1)\right] \times 25 = 1{,}782\ MTCO_2e$$

Quantified Co-Benefits

Energy and Fuel Savings

Energy savings from flaring or combustion of LFG for energy are calculated above as (B).

Sources

- CalRecycle 2014. *2014 Disposal-Facility-Based Characterization of Solid Waste in California.* November 4, 2015. Available: https://www2.calrecycle.ca.gov/Publications/Details/1546. Accessed: January 2021.
- Environmental Protection Agency (U.S. EPA). 2018. *Center for Corporate Climate Leadership. Emission Factors for Greenhouse Gas Inventories.* March 9. Available: https://www.epa.gov/sites/production/files/2018-03/documents/emission-factors_mar_2018_0.pdf. Accessed: January 2021.
- California Utilities. 2021. Excel database of GHG emission factors for delivered electricity, provided to the Sacramento Metropolitan Air Quality Management District and ICF. January through March 2021.
- Intergovernmental Panel on Climate Change (IPCC). 2007. *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor and H. L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp. Available: https://www.ipcc.ch/report/ar4/wg1/. Accessed: January 2021.

E-19. Establish Methane Recovery in Wastewater Treatment Plants

GHG Mitigation Potential

Large

Potentially large reduction in GHG emissions from plant operations

Co-Benefits (icon key on pg. 34)

Climate Resilience

Establishing CH_4 recovery provides backup fuels if extreme weather events disrupt main sources of fuel.

Health and Equity Considerations

Combustion of CH_4 may increase air pollution. Potential effects of combustion emissions on adjacent sensitive receptors needs to be evaluated during project design.

Measure Description

This measure requires capturing CH_4 from an existing wastewater treatment plant and either (1) combusting or flaring it to prevent escape into the atmosphere or (2) combusting or flaring it and using the heat to generate electricity for onsite energy needs. Using the combusted CH_4 as an energy source reduces GHG emissions by displacing electricity demand and the associated indirect GHG emissions from electricity production. This measure is most applicable to wastewater treatment plants that have anaerobic digestion infrastructure, which facilitates the biological decomposition of the wastewater and produces the CH_4 that is either flared or harnessed for energy.

Subsector

Methane Recovery

Scale of Application

Project/Site

Implementation Requirements

See measure description. Also, this measure may not be appropriate for wastewater treatment plants that use lagoons to process wastewater.

Cost Considerations

Wastewater treatment plants that have no current system for capturing CH_4 would face high installation costs for a CH_4 recovery system. Costs would be lower for plants that already have a system for trapping or cleaning captured gases. In California, CH_4 reclaimed from wastewater treatment could represent a large additional revenue stream for the plants if the gases are managed and sold as offsets or RECs on the Low Carbon Fuel Standard or U.S. Renewable Fuel Standards markets.

Expanded Mitigation Options

Additional reductions may be achieved if the CH_4 is processed and used as a transportation fuel or injected into a regional natural gas pipeline for downstream uses. Captured waste biogas may also be used to support the production of biodegradable biopolymers, which serve as natural alternatives to conventional plastics.

GHG Reduction Formula

$A1 = C \times [D - (E \times F \times G \times H \times (1 - I) \times J \times K \times L)]$ (Emissions Reduction)

$B = (C \times E \times F \times G \times M \times N \times O)$ (Energy Savings, if applicable)

$A2 = B \times P \times Q \times R$ (Additional Emissions Reduction, if applicable)

$A3 = A1 + A2$ (Total Net Emissions Reduction)

$A4 = \frac{A3}{C \times D}$ (% Reduction)

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A1	Emissions reduction from CH_4 flaring or combustion	[ ]	MT CO_2e	calculated
B	Energy savings from CH_4 capture, combustion and energy generation	[ ]	kWh	calculated
A2	Additional emissions reduction if energy is generated	[ ]	MT CO_2e	calculated
A3	Total net emissions reduction	[ ]	MT CO_2e	calculated
A4	Percent reduction in GHG emissions from wastewater	0-100	%	calculated
User Inputs				
C	Wastewater affected by measure	[ ]	liters	user input
Constants, Assumptions, and Available Defaults				
D	Wastewater emission factor	2.85×10^{-6} or 1.93×10^{-6}	MT CO_2 per liter gal per liter	U.S. EPA 2020
E	Conversion from liters to gal	0.26417	sf per gal	conversion
F	Digester gas	0.01	unitless	U.S. EPA 2020
G	Fraction CH_4	0.65	%	U.S. EPA 2020
H	Density of CH_4	662	g CH_4 per m^3 CH_4	U.S. EPA 2020
I	Destruction efficiency	0.99	unitless	U.S. EPA 2020
J	Conversion from ft^3 to m	0.02832	m^3 per ft^3	conversion
K	Conversion from g to MT	$1e^{-6}$	g per MT	conversion
L	GWP of CH_4	25	unitless	IPCC 2007
M	Heating value of CH_4	1,028	BTU per ft^3 CH_4	ICLEI 2013
N	Conversion from kWh to BTU	0.000293	kWh per BTU	conversion
O	Efficiency factor	0.85	unitless	assumption
P	Conversion from kWh to MWh	0.001	MWh per kWh	conversion

ID	Variable	Value	Unit	Source
Q	Carbon intensity of local electricity provider	Tables E-4.3 and E-4.4	lb CO_2e per MWh	CA Utilities 2021
R	Conversion from lb to MT	0.000454	MT per lb	conversion

Further explanation of key variables:

- (A1) – The emissions calculated for this variable represent the emissions reduction that is achieved from the combustion of CH_4. Combusting the CH_4 prevents it from entering the atmosphere; however, during the combustion process, some fraction of CH_4 is not fully combusted and can leak into the atmosphere. The formula for this variable accounts for the fraction that is not fully combusted.
- (B) – This variable represents the energy savings that result from the combustion of CH_4 and then using the heat produced to generate energy. If CH_4 will only be combusted or flared but not used for energy, then there would not be energy savings for this measure. The user should set this variable to zero if there will be no energy generation.
- (A2) – The emissions reductions calculated for this variable represent the emissions that are offset from the generation of energy from the captured CH_4 instead of from typical fossil fuel sources. Combusting the CH_4 avoids the need for fossil fuel sources of energy that would have been generated in the absence of this measure.
- (A3) – The net emissions reductions achieved by this measure are calculated in this variable.
- (D) – The factors represent the emissions per liter of wastewater that is treated at facilities with either primary treatment or without primary treatment. These values are as follows.
  - Primary treatment factor: 1.93 x 10-6
  - Without primary treatment factor: 2.85×10^{-6}
- (E) – The digester gas variable represents the amount of digester gas that is generated per gal of wastewater. The value given here is determined by assumptions from the U.S. EPA's GHG inventory, with the amount of digester gas generated per person per day is 1 cubic foot and the amount of wastewater generated per person per day is 100 gallons (gal) (for publicly owned treatment works). Dividing these values (1/100) is equal to 0.01 cubic feet of digester gas per gal of wastewater.

GHG Calculation Caps or Maximums

None.

Example GHG Reduction Quantification

The user implements CH_4 capture and energy generation infrastructure at an existing wastewater treatment plant that processes 100 million liters of wastewater per year. The existing plant currently has primary treatment. The project is in the Silicon Valley Power's service territory, and the selected electricity provider emission factor is for the year 2026 (224 lb CO_2e per MWh) (Q). The example measure emission reduction is calculated below.

$$B = \left(100\times10^6 \text{ liters} \times \frac{0.26417 \text{ gal}}{\text{liter}} \times 0.01 \frac{\text{ft}^3}{\text{gal}} \times 0.65 \times \frac{1{,}028 \text{ BTU}}{\text{ft}^3 \text{ CH4}} \times \frac{0.000293 \text{ kWh}}{\text{BTU}} \times 0.85\right) = 43{,}962 \text{ kWh}$$

$$A1 = 100\times10^6 \text{ liters} \times \left[1.93\times10^{-6} \frac{\text{MT CH}_4}{\text{liter}} - \left(\frac{0.26417 \text{ gal}}{\text{liter}} \times 0.01 \frac{\text{ft}^3}{\text{gal}} \times 0.65 \times 662 \frac{\text{g CH}_4}{\text{m}^3 \text{ CH}_4} \times (1 - 0.99) \times \frac{0.02832 \text{ m}^3}{\text{ft}^3} \times \frac{10^{-6} \text{ MT}}{\text{g}} \times 25\right)\right] = 192 \text{ MT CO}_2\text{e}$$

$$A2 = 43{,}962 \text{ kWh} \times 0.001 \frac{\text{MWh}}{\text{kWh}} \times 224 \times 0.000454 \frac{\text{MT}}{\text{lb}} = 4 \text{ MT CO}_2\text{e}$$

$$A3 = 192 \text{ MT CO}_2\text{e} + 4 \text{ MT CO}_2\text{e} = 196 \text{ MT CO}_2\text{e}$$

$$A4 = \frac{196 \text{ MT CO}_2\text{e}}{100\times10^6 \text{ liters} \times 1.93 \times 10^{-6} \frac{\text{MT CO}_2\text{e}}{\text{liter}}} = 102\%$$

Quantified Co-Benefits

Successful implementation of this measure could achieve energy savings if the user's project includes CH_4-based energy generation infrastructure. This quantified co-benefit is derived in the steps above that are necessary to quantify GHG reductions.

Sources

- California Utilities. 2021. Excel database of GHG emission factors for delivered electricity, provided to the Sacramento Metropolitan Air Quality Management District and ICF. January through March 2021.
- International Council for Local Environmental Initiatives (ICLEI). 2013. *U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions. Appendix F: Wastewater and Water Emission Activities and Sources*. Available: https://icleiusa.org/publications/us-community-protocol/. Accessed: January 19, 2021.
- Intergovernmental Panel on Climate Change (IPCC). 2007. *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp. Available: https://www.ipcc.ch/report/ar4/wg1/. Accessed: January 2021.
- U.S. Environmental Protection Agency (U.S. EPA). 2020. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2018 – Chapter 7. Waste*. Available: https://www.epa.gov/sites/production/files/2020-04/documents/us-ghg-inventory-2020-chapter-7-waste.pdf. Accessed: January 19, 2021.

E-21. Install Cool Pavement

GHG Mitigation Potential

Potentially small reduction in GHG emissions from energy demand

Co-Benefits (icon key on pg. 34)

Climate Resilience

Cool pavement absorbs less heat, reducing the urban heat island effect and building both individual and community-wide resilience to high temperatures.

Health and Equity Considerations

Cool pavements should be prioritized in vulnerable and sensitive communities that experience urban heat island effects, have large amounts of paved areas, and lack sufficient shade. Any disbenefits from cool pavement installation projects such as glare should be addressed during the project's planning phase.

Measure Description

This measure involves installing cool pavement in place of dark pavement. Cool pavement helps to lower ambient outdoor air temperatures when compared to dark-colored, heat-absorbent pavement such as asphalt. This reduces the electricity needed to provide cooling, thereby reducing associated GHG emissions, depending on the project parameters (e.g., climate, carbon intensity of local utility).

Scale of Application

Project/Site and Plan/Community

Implementation Requirements

This measure is only applicable in areas where research is available on the energy savings from cool pavement (see GHG Calculation Variables). Implementation of this measure may result in limited or no GHG reductions for highly developed areas with tall buildings or in urban canyons, such as in a downtown or commercial area, or areas with extensive tree canopy cover. Tall buildings and tree canopies restrict the amount of sunlight reaching the street surface, and thus limited additional cooling would be achieved by the pavement surface.

Furthermore, installing cool pavements in areas with tall buildings or in urban canyons may result in an increased heating demand during the cooler months. Cool pavement installation should be prioritized in paved areas in open spaces with high urban heat island effects, such as major freeways, highways, arterial roads, and parking lots (Altostratus Inc. 2020).

Cost Considerations

The cost of applying cool pavement versus conventional paving materials will vary by region, contractor, time of year, materials chosen, accessibility of the site, local availability of materials, underlying soils, size of the project, traffic conditions, and desired lifetime of the pavement.

Expanded Mitigation Options

Pair with Measures C-1-A , *Use Electric or Hybrid Powered Equipment*, C-1-B, *Use Cleaner-Fuel Equipment*, and C-2, *Limit Heavy-Duty Diesel Vehicle Idling*¸ to ensure that the construction equipment used during the installation of cool pavement use less fuel, thereby further reducing GHG emissions.

GHG Reduction Formula

$$A_C = -\left(\frac{B_c \times D}{E}\right) \times J$$

$$K_H = \left(\frac{B_H \times I}{E}\right) \times M$$

$$L = \left(\frac{((A_c \times F) + (K_H \times G))}{N}\right)$$

GHG Calculation Variables

ID	Parameter	Value	Unit	Source
Output				
A	Reduction in electricity demand from the installation of cool pavement	[ ]	MWh/year	calculated
K	Increase in natural gas demand from the installation of cool pavement	[ ]	MMBtu/year	calculated
L	GHG emission reductions from the installation of cool pavement	[ ]	MT CO_2e/year	calculated
User Inputs				
B	Amount of cool pavement that is being constructed	[ ]	ft^2	user input
Constants, Assumptions, and Available Defaults				
C	Electricity Demand Forecast Zone – electric component (Zones 4, 5, 7, 11, 12 ,16, 17 or 18)	Figure E-1.1 Table E-1.1	integer	CEC 2017
H	Electricity Demand Forecast Zone – natural gas component (Zones 5 or 16)	Figure E-1.1 Table E-1.1	integer	CEC 2017
D	Cool pavement maximum energy saving per year	Table E-21.1	kWh/year/m^2	Lawrence Berkely National Laboratory 2017a, 2017b
E	Converting square feet to square meters	10.76	ft^2/m^2	conversion
F	Carbon intensity of local electricity provider	Tables E-4.3 and E-4.4	lbs CO_2e/MWh	CA Utilities 2021
G	Natural Gas Emission Factors	Table E-4.5	lbs CO_2e/MMBTu	U.S. EPA 2020
I	Cool pavement maximum heating savings per year	EDFZ 5 = -0.00829 EDFZ 16 = -0.0054	Therms/year/m^2	Lawrence Berkely National Laboratory 2017b

ID	Parameter	Value	Unit	Source
J	Converting kilowatt hours to megawatt hours	0.001	MWh/kWh	conversion
M	Converting therms to MMBTU	0.1	MMBTU/therms	conversion
N	Converting pounds to metric tons	2,204.62	lbs/MT	conversion

Further explanation of key variables:

- (B) – The amount of cool pavement that is being constructed.
- (C, H) – Climate zones are specific geographic areas of similar climatic characteristics, including temperature, weather, and other factors that affect building energy use. The CEC has specified numerous EDFZs in California, which are referenced in CEC's California Commercial End-Use Survey and Residential Appliance Saturation Study. This measure would only be applicable to certain EDFZs where research was done on calculating energy savings from the installation of cool pavement.
- (D) – The maximum electricity savings (kWh) per year per meter of installed cool pavement. This would only be applicable to eight EDFZs where electricity savings were quantified. The electricity savings and the EDFZs are provided in Table E-21.1.
- (F, G) – GHG intensity factors for major California utilities within the supported EDFZs are provided in Tables E-4.3 through E-4.5 in Appendix C. If the project study area is not serviced by a listed utility, or the user is able to provide a project-specific value (i.e., for the future year not referenced in the tables), users should use that specific value in the GHG calculation formula. If the utility is not known, users may elect to use the statewide grid average carbon intensity.
- (I) – The maximum additional heating requirements (therms) per year per meter of installed cool pavement. This would only be applicable to EDFZ 5 and EDFZ 16 because these areas were the only two included in the research paper that describes the additional heating requirement from cool pavement. For other areas, users could conservatively use the higher value from EDFZ 16 to estimate the additional heating requirement.

GHG Calculation Caps or Maximums

The maximum GHG emission reductions from this measure are tied to the total amount of area that cool pavement can be installed within a a supported EDFZ jurisdiction and the GHG intensity factors from the local utilities supporting that jurisdiction.

Example GHG Reduction Quantification

A city within EDFZ 16 is working on a pilot program that will install cool pavement on a 5-mile, 4-lane stretch of an arterial roadway. The total area of this roadway that would be covered is 1,267,200 square feet (BC, BH). Following the formulas above, this pilot program would result in a reduction of 3.27 $MTCO_2e$/yr in energy savings.

The following default values from tables in Appendix C are used.

- (D) – The cooling savings of 0.182 kWh/m^2/yr (Table E-21.1 in Appendix C) for EDFZ 16.
- (I) – The heating savings of -0.00554 therms/m^2/yr for EDFZ 16.

- (F) – The Los Angeles Department of Water & Power carbon intensity of electricity of 694 lbs CO_2e per MWh (EFEGHG) (Table E-4.3).

  (G) – The natural gas emission factor of 117.32 lbs CO_2e per MMBtu for residential uses (Table E-4.5).

$$A_C = -\left(\frac{1{,}267{,}200\ ft^2 \times 0.182\ kWh/m^2/yr}{10.76\ ft^2/m^2}\right) \times 0.001 MWh/kWH$$

A_C = -21.43 MWh/yr

$$K_H = \left(\frac{1{,}267{,}200\ ft^2 \times 0.00554\ therms/m^2/yr}{10.76\ ft^2/m^2}\right) \times 0.1\ MMBtu/therms$$

K_H = 65.24 MMBtu/yr

$$L = \left(\frac{((-21.43\ MWh/yr \times 694\ lbs\ CO_2e/MWh) + (65.24\ MMBtu/yr \times 117.32\ lbs\ CO_2e/MMBtu)}{2{,}204.62\ lbs/MT}\right)$$

L = -3.27 $MTCO_2e$/yr

Quantified Co-Benefits

Energy and Fuel Savings

Successful implementation of this measure would achieve electricity savings due to the cooling effects of the pavement.

$$A_C = -\left(\frac{B_c \times D}{E}\right) \times J$$

Worsened Air Quality

While the measure would achieve electricity savings, it can increase natural gas consumption (K_H) during colder months and potentially worsen ambient air quality (U) from natural gas combustion.

Criteria Pollutant Emission Increase Formula

$$K_H = \left(\frac{B_H \times I}{E}\right) \times M$$

$$U = \left(\frac{(|K_H| \times G)}{X}\right)$$

Criteria Pollutant Emissions Increase Calculation Variables

ID	Parameter	Value	Unit	Source
Output				
U	Increase in criteria pollutant emissions from building energy	[ ]	tons per year	calculated
User Inputs				

K	Increase in natural gas demand from the installation of cool pavement	[ ]	MMBtu/year	calculated
Constants, Assumptions, and Available Defaults				
H	Electricity Demand Forecast Zone – natural gas component (Zones 5 or 16)	Figure E-1.1 and Table E-1.1	integer	CEC 2017
G	Criteria pollutant emission factors of natural gas	Table E-4.5	lbs/MMBtu	U.S. EPA 1998
X	Converting pounds to short tons	2,000	lbs/tons	conversion

Further explanation of key variables:

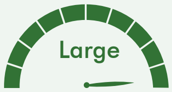
- (K_H) – Because K_H is a negative value in the above equation, the absolute value is used to calculate the positive increase in criteria pollutant emissions.
- (G) – Natural gas GHG emission factors for residential and non-residential uses are found in Table E-4.5 in Appendix C. When choosing between residential or non-residential, it is recommended that users use the emission factor representing the most prominent land use near the cool pavement that is being constructed.

Sources

- Altostratus Inc. 2020. *Capital Region Heat Pollution Reduction: Atmospheric Modeling for the Development of a Regional Heat Pollution Reduction Plan*. February 26. Available: https://www.airquality.org/LandUseTransportation/Documents/Altostratus_Final_Report.pdf. Accessed: January 2023.
- California Energy Commission (CEC). 2017. *California Electricity Demand Forecast Zones*. Available: https://cecgis-caenergy.opendata.arcgis.com/datasets/86fef50f6f344fabbe545e58aec83edd_0/data?geometry=-165.327%2C31.004%2C-72.427%2C43.220. Accessed: June 2021.
- California Utilities. 2021. Excel database of GHG emission factors for delivered electricity, provided to the Sacramento Metropolitan Air Quality Management District and ICF. January through March 2021.
- Lawrence Berkely National Laboratory. 2017a. *Are Cooler Surfaces a Cost-Effect Mitigation of Urban Heat Islands?*. April. Available: https://eta-publications.lbl.gov/sites/default/files/cooler_surfaces.pdf. Accessed: August 2023.
- Lawrence Berkely National Laboratory. 2017b. *Energy and Environmental Consequences of a Cool Pavement Campaign* May. Available: Microsoft Word - E&B Cool pavement campaign LBL_06 pre-print-FINAL.docx. Accessed: August 2023.
- U.S. Environmental Protection Agency (U.S. EPA). 1998. *AP 42, Fifth Edition, Volume I. Chapter 1: External Combustion Sources. 1.4, Natural Gas Combustion*. July. Available: https://www3.epa.gov/ttnchie1/ap42/ch01/final/c01s04.pdf. Accessed: January 2021
- U.S. Environmental Protection Agency (U.S. EPA). 2020. *Emission Factors for Greenhouse Gas Inventories*. March. Available: https://www.epa.gov/sites/production/files/2020-04/documents/ghg-emission-factors-hub.pdf. Accessed: March 2021

E-26. Biomass Energy

GHG Mitigation Potential



Potentially large reduction from electricity generation

Co-Benefits (icon key on pg. 34)

Climate Resilience

Increasing biomass energy generation enhances energy resilience and diversifies fuel supply chains if extreme weather events result in widespread power outages.

Health and Equity Considerations

New biomass processing facilities should be planned in consultation with local members of vulnerable or sensitive communities to ensure that impacts or disbenefits from biomass production and processing are addressed before installation. Non-combustion biomass energy projects, including those that create clean hydrogen, should also be considered.

Measure Description

This measure requires installing new biomass or biofuel electricity generation (or cogeneration). Although the direct combustion emissions for biofuels are generally on-par with other forms of fossil fuel energy, biofuels have a lower life-cycle carbon intensity due to the uptake of carbon from plants used to produce that fuel. A reasonable reference point for this carbon intensity would be the average carbon intensity of the electricity in the utility that would receive power from this new biomass plant.

Subsector

Renewable Energy Generation

Scale of Application

Project/Site or Plan/Community

Implementation Requirements

See measure description.

Cost Considerations

Installation costs for biofuel power generation infrastructure vary greatly depending on the type of biomass or feedstock (i.e., the raw materials needed to produce biofuels), the technology used, and the size of the installation. Overall, installation costs can be high, but initial costs can be partially offset by credits or rebates meant to encourage renewable energy generation. In the long term, using biofuels to generate electricity may result in cost savings due to reduced operational costs and more stable fuel pricing than fossil fuel energy.

Expanded Mitigation Options

Best practice is to site biofuel electricity generation infrastructure in areas where sustainable feedstock is available and can be obtained efficiently. By installing biomass energy generation locally, the carbon intensity of the electricity supply would decrease, reducing GHG emissions from local electricity consumption.

GHG Reduction Formula

A=**B**×C×D×[E-F]×G

GHG Calculation Variables

ID	Parameter	Value	Unit	Source
Output				
A	Annual emissions reduction from biomass plant generation	[ ]	MT CO_2e	calculated
User Inputs				
B	Rated peak generation power	[ ]	MW	user input
Constants, Assumptions, and Available Defaults				
C	Hours in a year	8,760	hours	conversion
D	Capacity factor of generation type	Table E-26.1	%	U.S. EIA 2023
E	Lifecycle carbon intensity of biomass sources	Table E-26.2	lb CO_2e per MWh	EPRI 2013
F	Lifecycle carbon intensity of CA electricity	642.9	lb CO_2e per MWh	CARB 2022
G	Conversion from lb to MT	0.000454	MT per lb	conversion

Further explanation of key variables:

- (B) – This is the rated peak power output of the generators used by the power plant. This is often referred to as the nameplate value.
- (C) – This is the number of hours per year for which the utility intends to operate, not including normal operational breaks, such as maintenance.
- (D) – The capacity factor corrects for the fact that power plants do not always operate at their rated peak power due to a variety of operational and economic factors in order to estimate the actual amount of electricity generation at a utility-scale power plant.
- (E) – The lifecycle carbon intensity of each biomass power source may be available using data from the Low Carbon Fuel Standard program. For generic projects with known fuels, this can be found using the data provided from the Electric Power Research Institute report provided.
- (F) – This value represents the carbon intensity of electricity displaced by the biomass power plant.

GHG Calculation Caps or Maximums

None.

Example GHG Reduction Quantification

In this example, a user installs a new 1-MW (B) biomass plant which burns dedicated woody crops that they intend to operate year-round. In 2023, the lifecycle carbon intensity of power for California is estimated to be 642.9 lb CO_2e/ MWh (F). The new plant, because it will burn wood, is estimated to have a capacity factor of 59 percent (D) and a mean carbon intensity of 189.6 lb CO_2e/MWh (E).

$$A = 1\ MW \times 8{,}760\ hrs \times 59\% \times \left[189.6\ \frac{lb\ CO_2e}{MWh} - 642.9\ \frac{lb\ CO_2e}{MWh}\right] \times 0.000454\ \frac{MT}{lb} = -1{,}063.6\ \frac{MT\ CO_2e}{year}$$

Quantified Co-Benefits

Energy and Fuel Savings

The energy savings of traditional fossil fuels (H) can be calculated as follows.

Natural Gas Reduction Formula

$$H = \frac{-B \times C \times D \times I}{J}$$

Electricity Reduction Calculation Variables

ID	Parameter	Value	Unit	Source
Output				
H	Natural gas saved	[ ]	therms	Calculated
Constants, Assumptions, and Available Defaults				
I	Heat Rate	7,728,000	BTU/MWh	CEC 2020
J	Conversion from BTU to therms	100,000	BTU/therm	Conversion

Further explanation of key variables:

- (I) – This value represents the average amount of energy needed to produce a MWh of electricity across all natural gas power plants in the state of California as of 2019.

Sources

- California Air Resources Board (CARB). 2022. 2023 Carbon Intensity Values for California Average Grid Electricity Used as a Transportation Fuel in California and Electricity Supplied Under the Smart Charging or Smart Electrolysis Provision. Available: https://ww2.arb.ca.gov/sites/default/files/classic/fuels/lcfs/fuelpathways/comments/tier2/2023_elec_update.pdf. Accessed: December 2023.
- California Energy Commission (CEC). 2020. Thermal Efficiency of Natural Gas-Fired Generation in California: 2019 Update. Available: https://efiling.energy.ca.gov/getdocument.aspx?tn=233380 Accessed: December 2020.

- Electric Power Research Institute (EPRI). 2013. Literature Review and Sensitivity Analysis of Biopower Life-Cycle Assessments and Greenhouse Gas Emission. Available: https://www.epri.com/research/products/000000000001026852. Accessed: August 2023.
- U.S. Energy Information Administration (U.S. EIA). 2023. Capacity Factors for Utility Scale Generators Primarily Using Non-Fossil Fuels. Electric Power Monthly. Available: https://www.eia.gov/electricity/monthly/ Accessed: August 2023.

Water

Energy used to pump, treat, and convey water generates GHG emissions and is the primary source of GHG emissions within the water sector. The amount of energy required depends on both the volume of water and energy intensity associated with the water source. For example, it generally takes less energy to pump and convey water from a local source than to transport water across long distances. California's water supply is diverse and comprised of groundwater, surface water, and reservoirs, with some water transport occurring over long distances and over varied terrain. Treating water so that it is potable for human use and processing wastewater also generates GHG emissions.

Indirect GHG emissions associated with water use can be decreased by reducing water demand and/or by using a less energy-intensive water source. A project can reduce its indoor water demand by installing low-flow and high-efficiency water fixtures and appliances, such as toilets, showerheads, faucets, clothes washers, and dishwashers. A reduction in outdoor water demand can be achieved by designing water-efficient landscapes that include plants with relatively low watering needs; minimizing areas of water-intensive turf; and installing smart irrigation systems to avoid excessive water use. These and other strategies could be combined into a water conservation strategy with a water reduction performance target. Less energy-intensive water sources include reclaimed and grey water, as well as locally sourced water (e.g., nearby groundwater basins, nearby surface water, and gravity-dominated systems).

Emission reductions achieved by reduced water demand will be directly proportional to the decrease in demand. Use of less energy-intensive water sources will decrease energy-related emissions, but these systems may also require energy to successfully operate. Resources and methods to quantify emissions reductions from measures that reduce water demand and/or target use of a less energy-intensive water source are described in this section. Use the graphic on the right to click on an individual measure to navigate directly to the measure's factsheet.

Water

- W-1. Use Reclaimed Non-Potable Water
- W-2. Use Grey Water
- W-3. Use Locally Sourced Water Supply
- W-4. Require Low-Flow Water Fixtures
- W-5. Design Water-Efficient Landscapes
- W-6. Reduce Turf in Landscapes and Lawns
- W-7. Adopt a Water Conservation Strategy

W-1. Use Reclaimed Non-Potable Water

GHG Mitigation Potential

Small

Potentially small reduction in GHG emissions from outdoor water use

Co-Benefits (icon key on pg. 34)

Climate Resilience

Using reclaimed non-potable water conserves water resources, which will become more strained under climate change, and provides a backup water source should extreme events disrupt current sources. This could also reduce costs associated with obtaining fresh potable water from distant sources.

Health and Equity Considerations

The project will provide appropriate education on non-potable water for project residents/employee.

Measure Description

This measure requires use of reclaimed water for outdoor uses. Reclaimed water is water reused for non-potable uses (e.g., landscape irrigation) after wastewater treatment instead of returning the water to the environment (i.e., discharging into rivers and other bodies of water). Using water after it has been treated requires substantially less energy to deliver it to users than fresh water from distant sources and, therefore, reduces GHG emissions. The use of reclaimed water is typically designated for non-potable uses, such as landscaping and other outdoor uses.

Although wastewater treatment processes have improved, there has been limited implementation of reclaimed water projects for household or potable uses. Furthermore, the treatment of wastewater to produce potable water (often through reverse osmosis) is usually energy-intensive and thus may not result in reduction in energy consumption and associated GHG emissions.

Scale of Application

Project/Site

Implementation Requirements

See measure description.

Cost Considerations

Initial costs of altering a system, whether it is irrigation, plumbing, or cleaning, to use reclaimed non-potable water will vary with the source of the water and the use; however, all applications will have costs associated with installing water collection and distribution infrastructure.

Expanded Mitigation Options

This measure does not include treatment of wastewater for potable uses, although the approach to assessing the potential change in GHG emissions would be the same.

GHG Reduction Formula

$A1 = C1 \times (D - E)$ (Energy savings)

$B1 = A1 \times F \times G \times H$ (Emissions reduction)

$B2 = C2 \times \frac{D-E}{D}$ (Percent emissions reduction)

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A1	Energy savings from using reclaimed water	[ ]	kWh	calculated
B1	GHG reduction from using reclaimed water	[ ]	MT CO_2e	calculated
B2	% GHG reduction from outdoor water use	[ ]	%	calculated
User Inputs				
C1	Amount of water to be used from reclaimed sources	[ ]	acre-feet (AF)	user input
C2	Percentage of water from reclaimed water (relative to total outdoor water demand)	[ ]	%	user input
Constants, Assumptions, and Available Defaults				
D	Electricity for municipally provided water	Table W-1.1	kWh per AF	CPUC 2016
E	Fraction of electricity for reclaimed water	Table W-1.1	kWh per AF	CPUC 2016
F	Conversion from kWh to MWh	0.001	MWh per kWh	conversion
G	Carbon intensity of electricity provider	Tables E-4.3 and E-4.4	lb CO_2e per MWh	CA Utilities 2021
H	Conversion from pounds (lb) to MT	0.000454	MT per lb	conversion

Further explanation of key variables:

- (C1) – The amount of water to be used from reclaimed water must be provided by the user.
- (D, E) – The water energy-intensity factors are derived from the most recent version of the California Public Utilities Commission (CPUC) Water Energy Calculator and are provided in Table W-1.1 in Appendix C, *Emission Factors and Data Tables* (CPUC 2016). The energy intensity factors rely on region-wide average values for the California Department of Water Resources' (DWR) 10 hydrologic regions. Following wastewater treatment, reclaimed water would be pre-treated (to meet standards) and distributed back to an end use (e.g., city park). Accordingly, the fraction of energy required to provide reclaimed water can be determined by consulting Table W-1.1 and identifying the columns for pre-treatment and water distribution (omit the column for extraction and conveyance).
- (G) – GHG intensity factors for major utilities in California are provided in Tables E-4.3 and E-4.4 in Appendix C. If the project study area is not serviced by the listed electricity provider, or the user is able to provide a project-specific value (i.e., for the future year in which the reclaimed water system would be established), the user should replace these defaults in the electricity consumption GHG calculation formula.

GHG Calculation Caps or Maximums

None.

Example GHG Reduction Quantification

The user reduces GHG emissions from water-related electricity by using reclaimed water for non-potable uses in place of fresh water. In this example, the project is in the San Joaquin River hydrologic region and includes the use of 31 AF per year of reclaimed water (C1), which represents 80 percent of the project's total outdoor water demand (C2). The electricity provider for the project area is Turlock Irrigation District and the analysis year is 2027. The carbon intensity of electricity is therefore 296 lb CO_2e per MWh (G).

$$A1 = \mathbf{31\ AF} \times \left(252\frac{\text{kWh}}{\text{AF}} - 163\frac{\text{kWh}}{\text{AF}}\right) = 2{,}759\ \text{kWh}$$

$$B1 = 2{,}759\ \text{kWh} \times 0.001\frac{\text{MWh}}{\text{kWh}} \times 296\frac{\text{lb } CO_2e}{\text{MWh}} \times 0.000454\frac{\text{MT}}{\text{lb}} = 0.4\ \text{MT } CO_2e$$

$$B2 = \mathbf{80\%} \times \frac{\left(252\frac{\text{kWh}}{\text{AF}} - 163\frac{\text{kWh}}{\text{AF}}\right)}{252\frac{\text{kWh}}{\text{AF}}} = 28\%$$

Quantified Co-Benefits

Energy and Fuel Savings

Energy savings (A1) are derived in the steps above that are necessary to quantify GHG reductions.

Water Conservation

This measure would not necessarily change water consumption, but it would result in conservation of fresh water sources by using reclaimed water. This quantity of freshwater savings is equal to the amount of reclaimed water (C1).

Sources

- California Public Utilities Commission (CPUC). 2016. Water-Energy Calculator–Draft Version 1.05. Available: https://www.cpuc.ca.gov/nexus_calculator/. Accessed: January 2021.
- California Utilities. 2021. Excel database of GHG emission factors for delivered electricity, provided to the Sacramento Metropolitan Air Quality Management District and ICF. January through March 2021.

W-2. Use Grey Water

GHG Mitigation Potential

Small

Potentially small reduction in GHG emissions from outdoor water use

Co-Benefits (icon key on pg. 34)

Climate Resilience

Using grey water conserves water resources, which will become more strained under climate change, and provides a backup water source should extreme events disrupt current sources. This could also reduce costs associated with obtaining fresh potable water from distant sources.

Health and Equity Considerations

The project should provide appropriate education on grey water for project residents and employees.

Measure Description

This measure requires the use of grey water for outdoor uses. *Grey water* is water from sinks, showers, tubs, and washing machines that has not contacted biological pathogens. Grey water offsets freshwater that would need to be extracted or sourced for the same demand, resulting in water and GHG emissions savings. The energy associated with grey water use is essentially negligible as it is used on site for a second time and does not require major pumping equipment or further treatment.

Scale of Application

Project/Site

Implementation Requirements

Grey water should only be used for non-potable applications, such as landscaping and other outdoor uses, because grey water does not undergo water treatment before being used for the second time.

Cost Considerations

Initial costs of altering the plumbing of a property to use grey water will vary with the property type; however, all applications will have costs associated with installing water collection, storage, and distribution infrastructure. These costs would be offset by reductions in freshwater use, as well as reduce energy requirements for water treatment and waste management.

Expanded Mitigation Options

For grey water sourced from sinks, it is best practice not to use water with greasy and oily substances, such as runoff from kitchen sinks with leftover oils, meat scraps, and dairy products.

GHG Reduction Formula

A1 = (**D** × E + **D** × F) × G × H (Water savings, if not known by user)

B = A1 × ((I + J) – K) (Energy savings)

C1 = B × L × M × N (Emissions reduction)

C2 = **A2** (Percent emissions reduction)

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A1	Outdoor water savings from using grey water	[ ]	AF	calculated
B	Energy savings from using grey water	[ ]	kWh	calculated
C1	GHG reduction from using grey water	[ ]	MT CO_2e	calculated
C2	% GHG reduction from outdoor water use	[ ]	%	calculated
User Inputs				
A2	Percentage of water from grey water sources (relative to total outdoor water demand)	[ ]	%	user input
D	Number of residents in homes with grey water systems	[ ]	occupants	user input
Constants, Assumptions, and Available Defaults				
E	Gal per day per occupant from showers, bathtubs, and lavatories	25	gal per day per occupant	CA Code 2019
F	Gal per day per occupant for laundry	15	gal per day per occupant	CA Code 2019
G	Days per year	365	days per year	conversion
H	Conversion from gal to AF	3.07×10^{-6}	AF per gal	conversion
I	Electricity required for municipally provided water	Table W-1.1	kWh per AF	CPUC 2016
J	Electricity required for wastewater treatment following municipal use	418	kWh per AF	CPUC 2016
K	Fraction of electricity for grey water	0	kWh per AF	assumption
L	Conversion from kWh to MWh	0.001	MWh per kWh	conversion
M	Carbon intensity of local electricity provider	Tables E-4.3 and E-4.4	lb CO_2e per MWh	CA Utilities 2021
N	Conversion from lb to MT	0.000454	MT per lb	conversion

Further explanation of key variables:

- (A1) – If the user knows how much grey water will be used for their project, that amount should be used to determine GHG reductions. If it is not known, however, the formula for A1 can be used to estimate the volume of grey water at residential uses, based on the 2019 California Plumbing Code.
- (I, K, J) – The water energy-intensity factors are derived from the most recent version of the CPUC Water Energy Calculator and are provided in Table W-1.1 in Appendix C (CPUC 2016). The energy intensity factors rely on region-wide average values for DWR's 10 hydrologic regions. Because grey water is reused on site, it avoids energy after initial water consumption for at least once use cycle (i.e., wastewater treatment and extraction, conveyance, pre-treatment, and distribution energy for an equivalent volume of water).
- (M) – GHG intensity factors for major utilities in California are provided in Tables E-4.3 and E-4.4 in Appendix C. If the project study area is not serviced by the listed electricity provider, or the user is able to provide a project-specific value (i.e., for the future year in which the grey water system would be established), the user should replace these defaults in the electricity consumption GHG calculation formula.

GHG Calculation Caps or Maximums

None.

Example GHG Reduction Quantification

The user reduces GHG emissions from water-related electricity by using grey water for non-potable uses in place of fresh water. In this example, the project in the South Coast hydrologic region and includes 300 residents. These residents would produce about 13.4 AF of water, which the user has determined is equal to 20 percent of the project's total water demand (A2). The electricity provider for the project area is City of Riverside and the analysis year is 2024. The carbon intensity of electricity is therefore 789 lb CO_2e per MWh (L).

$$A1 = \left(\mathbf{300} \times 25\frac{\text{gal}}{\text{day·resident}} + \mathbf{300} \times 15\frac{\text{gal}}{\text{day·resident}}\right) \times 365\frac{\text{days}}{\text{year}} \times \left(3.07\times10^{-6}\frac{\text{AF}}{\text{gal}}\right) = 13.4\ \text{AF}$$

$$B = 13.4\ \text{AF} \times \left(\left(1{,}898\frac{\text{kWh}}{\text{AF}} + 418\frac{\text{kWh}}{\text{AF}}\right) - 0\frac{\text{kWh}}{\text{AF}}\right) = 31{,}034\ \text{kWh}$$

$$C1 = 31{,}034\ \text{kWh} \times 0.001\frac{\text{MWh}}{\text{kWh}} \times 789\ \frac{\text{lb CO}_2\text{e}}{\text{MWh}} \times 0.000454\frac{\text{MT}}{\text{lb}} = 11.1\ \text{MT CO}_2\text{e}$$

$$C2 = \mathbf{20\%}$$

Quantified Co-Benefits

Energy and Fuel Savings

Energy savings (B) are derived in the steps above that are necessary to quantify GHG reductions.

Water Conservation

This measure would not necessarily change water consumption, but it would result in conservation of fresh water sources by using grey water. This quantity of freshwater savings is equal to the amount of grey water (A1).

Sources

- California Plumbing Code. 2019 (CA Code). *Chapter 15 Alternate Water Sources for Nonpotable Applications.* https://up.codes/viewer/california/ca-plumbing-code-2019/chapter/15/alternate-water-sources-for-nonpotable-applications#15. Accessed: January 2021.
- California Public Utilities Commission (CPUC). 2016. Water-Energy Calculator–Draft Version 1.05. Available: *https://www.cpuc.ca.gov/nexus_calculator/.* Accessed: January 2021.
- California Utilities. 2021. Excel database of GHG emission factors for delivered electricity, provided to the Sacramento Metropolitan Air Quality Management District and ICF. January through March 2021.

W-3. Use Locally Sourced Water Supply

GHG Mitigation Potential

Potentially moderate reduction in GHG emissions from water use

Co-Benefits (icon key on pg. 34)

Climate Resilience

Using locally sourced water provides fewer opportunities for extreme events to disrupt the water source due to shorter traveling times. This could also reduce costs associated with obtaining fresh potable water from distant sources.

Health and Equity Considerations

Locally sourced water may have more contaminants than imported options. For potable uses, carefully consider the water quality of the proposed source.

Measure Description

This measure requires use of local water supplies instead of more distant water supplies. Locally sourced water is typically less energy intensive because it does not need to be moved across long distances (unless locally sourced water requires extensive pretreatment to address water quality concerns). Using locally sourced water can thus avoids the higher GHG emissions from energy consumed to pump and move water through larger infrastructure systems, such as the State Water Project.

Scale of Application

Plan/Community

Implementation Requirements

See measure description.

Cost Considerations

Prioritizing locally sourced water reduces costs associated with the transportation of water to the use location. However, regions that are not already large-scale water producers will most likely require significant investment in water extraction, processing, management, and potentially reuse in order to meet demand.

Expanded Mitigation Options

Install onsite water collection systems, such as a rain barrels or cisterns, for even more local water supply, reducing the associated energy and GHG emissions from water transmission.

GHG Reduction Formula

$A1 = C1 \times (D - E)$ (Energy savings)

$B1 = A1 \times F \times G \times H$ (Emissions reduction)

$B2 = C2 \times \frac{D-E}{D}$ (Percent emissions reduction)

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A1	Energy savings from using local water	[ ]	kWh	calculated
B1	GHG reduction from using local water	[ ]	MT CO_2e	calculated
B2	% GHG reduction from outdoor water use	[ ]	%	calculated
User Inputs				
C1	Amount of water to be obtained from local sources	[ ]	AF	user input
C2	Percentage of water from local sources (relative to total water demand)	[ ]	%	user input
E	Electricity required to treat and distribute local water	[ ]	kWh/AF	user input
Constants, Assumptions, and Available Defaults				
D	Electricity for municipally provided water	Table W-1.1	kWh per AF	CPUC 2016
F	Conversion from kWh to MWh	0.001	MWh per kWh	conversion
G	Carbon intensity of local electricity provider	Tables E-4.3 and E-4.4	lb CO_2e per MWh	CA Utilities 2021
H	Conversion from lb to MT	0.000454	MT per lb	conversion

Further explanation of key variables:

- (E) – The water energy-intensity factor for the local water source must be defined by the user.
- (D) – The water energy-intensity factors are derived from the most recent version of the CPUC Water Energy Calculator and are provided in Table W-1.1 in Appendix C (CPUC 2016). The energy intensity factors rely on region-wide average values for DWR's 10 hydrologic regions.
- (G) – GHG intensity factors for major utilities in California are provided in Tables E-4.3 and E-4.4 in Appendix C. If the project study area is not serviced by the listed electricity provider, or the user is able to provide a project-specific value (i.e., for the future year in which the project begins local water use), the user should replace these defaults in the electricity consumption GHG calculation formula.

GHG Calculation Caps or Maximums

None.

Example GHG Reduction Quantification

The user reduces GHG emissions from water-related electricity by using locally sourced water. In this example, the project is in the South Coast hydrologic region and uses 46 AF per year of water. The user chooses to supply 100 percent of the water for the project (C1, C2) from an alternative local source that has a water energy-intensity of 1,200 kWh per AF (E). The electricity provider for the project area is Burbank Water and Power and the analysis year is 2029. The carbon intensity of electricity is therefore 218 lbs CO_2e per MWh (G).

$$A1 = \mathbf{46\ AF} \times \left(1{,}898 \frac{kWh}{AF} - \mathbf{1{,}200\ \frac{kWh}{AF}}\right) = 32{,}108\ kWh$$

$$B1 = 32{,}108\ kWh \times 0.001 \frac{MWh}{kWh} \times 218\ \frac{lb\ CO_2e}{MWh} \times 0.000454 \frac{MT}{lbs} = 3.2\ MTCO_2e$$

$$B2 = \mathbf{100\%} \times \frac{1{,}898 \frac{kWh}{AF} - \mathbf{1{,}200 \frac{kWh}{AF}}}{1{,}898 \frac{kWh}{AF}} = 37\%$$

Quantified Co-Benefits

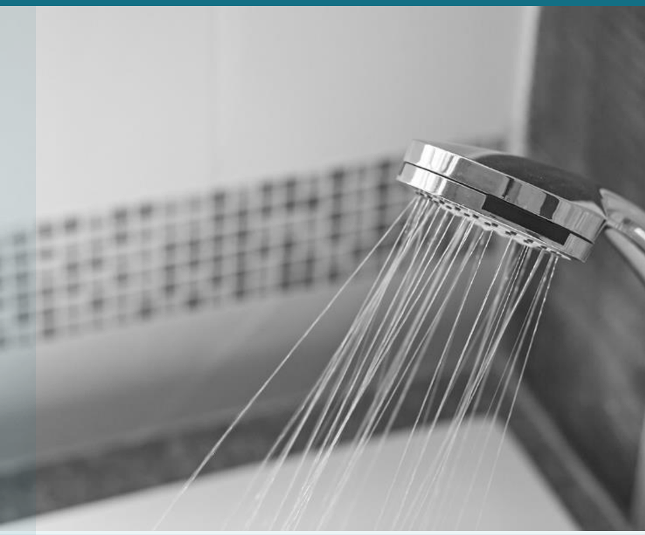
Energy and Fuel Savings

Energy savings (A1) are derived in the steps above that are necessary to quantify GHG reductions.

Sources

- California Public Utilities Commission (CPUC). 2016. Water-Energy Calculator–Draft Version 1.05. Available: https://www.cpuc.ca.gov/nexus_calculator/. Accessed: January 2021.
- California Utilities. 2021. Excel database of GHG emission factors for delivered electricity, provided to the Sacramento Metropolitan Air Quality Management District and ICF. January through March 2021.

W-4. Require Low-Flow Water Fixtures



GHG Mitigation Potential

Small

Potentially small reduction in GHG emissions from indoor water use

Co-Benefits (icon key on pg. 34)

Climate Resilience

Using low-flow water fixtures conserves water resources, which will become more strained under climate change.

Health and Equity Considerations

Low-flow and high-efficiency water fixtures can help to reduce water utility bill costs for project residents.

Measure Description

This measure requires use of low-flow or high-efficiency water fixtures in residential and non-residential buildings. Low-flow and high-efficiency fixtures may include toilets, urinals, showerheads, faucets, clothes washers, and dishwashers. These fixtures use less water than their traditional counterparts and, therefore, reduce energy and indirect GHG emissions that result from sourcing and transporting fresh water.

Scale of Application

Project/Site

Implementation Requirements

Install low-flow or high-efficiency fixtures that exceed state standards in any of the following: toilets, urinals, showerheads, faucets, clothes washers, and dishwashers.

Cost Considerations

Low-flow water fixtures tend to be slightly more expensive to purchase and install than less efficient models; however, these costs are almost immediately offset by large savings in water and energy consumption.

Expanded Mitigation Options

Install low-flow or high-efficiency water fixtures that perform better than the minimum efficiency standard established by ENERGY STAR, reducing the associated energy use and GHG emissions.

GHG Reduction Formula

$$A1 = \sum \left(D1 \times Ez \times \frac{Fz-Gz}{Fz}\right) \text{ or } = \sum (D1 \times Hz)$$ (Water savings)

$$A2 = \frac{A1}{D1} \text{ or } = \frac{D1-D2}{D1}$$ (Percent emissions reduction)

$$B = A1 \times I \times (J + K)$$ (Energy savings)

$$C = B \times L \times M \times N$$ (Emissions reduction)

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A1	Indoor water savings with low-flow fixtures	[ ]	AF	calculated
A2	% reduction in indoor water, energy, and GHG emissions with low-flow fixtures	[ ]	%	calculated
B	Energy savings with low-flow fixtures	[ ]	kWh	calculated
C	GHG reduction with low-flow fixtures	[ ]	MT CO_2e	calculated
User Inputs				
D1	Existing indoor water use	[ ]	gal	user input
D2	Mitigated indoor water use	[ ]	gal	user input (if known)
Hz	% savings of water for end use z	1–100	%	user input (if known)
Constants, Assumptions, and Available Defaults				
Ez	% of indoor water used for end use z	Table W-4.1 Table W-4.2	%	Pacific Institute 2003 and Water Research Foundation 2016
Fz	Current state standard water flow rate for end use z	Table W-4.3 Table W-4.4	variable units	EnergyStar 2021a, 2021b, 2021c, 2021d and CA Green Building Code
Gz	Reduced flow rate for end use z	Table W-4.3 Table W-4.4	variable units	EnergyStar 2021a, 2021b, 2021c, 2021d and CA Green Building Code
I	Conversion from gal to AF	3.07×10^{-6}	AF per gal	conversion

ID	Variable	Value	Unit	Source
J	Electricity for municipally provided water	Table W-1.1	kWh per AF	CPUC 2016
K	Electricity required for wastewater treatment following municipal use	418	kWh per AF	CPUC 2016
L	Conversion from kWh to MWh	0.001	MWh per kWh	conversion
M	Carbon intensity of local electricity provider	Tables E-4.3 and E-4.4	lb CO_2e per MWh	CA Utilities 2021
N	Conversion from lb to MT	0.000454	MT per lb	conversion
z	End use or type of fixture	N/A	-	-

Further explanation of key variables:

- (Ez) – For residential uses, the percentages of indoor water that is typically used for the most common end uses are shown in Table W-4.1 in Appendix C. For non-residential uses, the percentages of total and indoor water that is typically used for the most common end uses are shown in Table W-4.2 in Appendix C. To calculate the water savings for this measure relative to total or indoor use, the user should multiply the savings rate from a given fixture (e.g., kitchen faucet) by the percentage of water that is used in kitchen faucets for a typical residential or non-residential use.
- (Fz) – The current (2019) California Plumbing Code water use flow rates for common fixtures are provided in Table W-4.3 (for residential uses) and Table W-4.4 (for non-residential uses) in Appendix C. The user can use a specific existing flow rate if the flow rate for the end use or fixture differs from the 2019 code.
- (Gz) – The reduced water use flow rate for common fixtures in provided in Table W-4.3 (for residential uses) and Table W-4.4 (for non-residential uses). These reduced rates assume implementation of voluntary measures from the 2019 California Green Building Code or EnergyStar certification, which goes beyond the current (2019) California Plumbing Code. The user can use a specific reduced flow rate if the flow rate for the end use or fixture differs from the rates shown in Tables W-4.3 or W-4.4.
- (Hz) – This variable is the percent water savings from using a fixture with improved water efficiency, relative to the existing rate for that fixture. If the user knows what the percent savings is for their fixtures, the equation above with variable Hz can be used.
- (J) – The water energy-intensity factors are derived from the most recent version of the CPUC Water Energy Calculator and are provided in Table W-1.1 in Appendix C (CPUC 2016). The energy intensity factors assume that all water is treated to potable standards and rely upon region-wide average values for DWR's 10 hydrologic regions.
- (K) – For this measure, water conservation would affect indoor water consumption. Because indoor water is sent to wastewater treatment plants, it is necessary to account for the energy that would be avoided at the wastewater treatment plant. The value of 418 kWh/AF is based on the CPUC Water Energy Calculator (CPUC 2016).
- (M) – GHG intensity factors for major utilities in California are provided in Tables E-4.3 and E-4.4 in Appendix C. If the project study area is not serviced by the listed electricity provider, or the user is able to provide a project-specific value, the user should replace these defaults in the electricity consumption GHG calculation formula.

GHG Calculation Caps or Maximums

None.

Example GHG Reduction Quantification

The user reduces GHG emissions from water-related electricity by requiring low-flow fixtures. In this example, the project is a non-residential office use located in Central Coast hydrologic region with a total indoor water demand of 10 million gal per year (D1). The user is proposing to upgrade the toilets and bathroom faucets per the 2019 California Green Building Code Voluntary Measures. Accordingly, the following assumptions are obtained from Tables W-4.2 and W-4.4 in Appendix C:

- Percent of indoor water used for toilets (Ez) = 48 percent.
- Percent of indoor water used for bathroom faucets (Ez) = 3 percent.
- Current state standard water flow rate for toilets (Fz) = 1.28 gal per flush.
- Current state standard water flow rate for toilets (Fz) = 0.5 gal per minute.
- Reduced water flow rate for toilets (Fz) = 1.12 gal per flush.
- Reduced water flow rate for toilets (Fz) = 0.35 gal per minute.

The project is in the San Francisco Bay hydrologic region, the electricity provider is My Choice Energy (MCE), and the analysis year is 2026. The carbon intensity of electricity is therefore 184 lb CO_2e per MWh (G).

$$A1 = \left[\left(10\times10^6 \text{ gal} \times 48\%(\text{toilet}) \times \frac{1.28(\text{toilet}) - 1.12(\text{toilet})}{1.28(\text{toilet})}\right) + \left(10\times10^6 \text{ gal} \times 3\%(\text{bathroom faucet}) \times \frac{0.5(\text{bathroom faucet}) - 0.35(\text{bathroom faucet})}{0.5(\text{bathroom faucet})}\right)\right] = 690{,}000 \text{ gal}$$

$$A2 = \frac{690{,}000 \text{ gal}}{10\times10^6 \text{ gal}} = 7\%$$

$$B = 690{,}000 \text{ gal} \times \left(3.07\times10^{-6} \frac{\text{AF}}{\text{gal}}\right) \times \left(695 \frac{\text{kWh}}{\text{AF}} + 418 \frac{\text{kWh}}{\text{AF}}\right) = 2{,}358 \text{ kWh}$$

$$C = 2{,}358 \text{ kWh} \times 0.001 \frac{\text{MWh}}{\text{kWh}} \times 184 \frac{\text{lb } CO_2e}{\text{MWh}} \times 0.000454 \frac{\text{MT}}{\text{lb}} = 0.2 \text{ MT } CO_2e$$

Quantified Co-Benefits

Energy and Fuel Savings

Energy savings (B) are derived in the steps above that are necessary to quantify GHG reductions.

Water Conservation

Water savings (A1) are derived in the steps above that are necessary to quantify GHG reductions.

Sources

- California Plumbing Code. 2019 (CA Code). *Chapter 15 Alternate Water Sources for Nonpotable Applications.* https://up.codes/viewer/california/ca-plumbing-code-2019/chapter/15/alternate-water-sources-for-nonpotable-applications#15. Accessed: January 2021.
- California Public Utilities Commission (CPUC). 2016. Water-Energy Calculator–Draft Version 1.05. Available: https://www.cpuc.ca.gov/nexus_calculator/. Accessed: January 2021.
- California Utilities. 2021. Excel database of GHG emission factors for delivered electricity, provided to the Sacramento Metropolitan Air Quality Management District and ICF. January through March 2021.
- EnergyStar. 2021a. Clothes Washers Key Product Criteria. Available: https://www.energystar.gov/products/appliances/clothes_washers/key_product_criteria. Accessed: January 2021.
- EnergyStar. 2021b. Commercial Dishwashers Key Product Criteria. Available: https://www.energystar.gov/products/commercial_food_service_equipment/commercial_dishwashers/key_product_criteria. Accessed: January 2021.
- EnergyStar. 2021c. Commercial Kitchen Equipment Calculator. Available: http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx. Accessed: January 2021.
- EnergyStar. 2021d. Dishwashers Key Product Criteria. Available: https://www.energystar.gov/products/appliances/dishwashers/key_product_criteria. Accessed: January 2021.
- Pacific Institute. 2003. Waste Not, Want Not: The Potential for Urban Water Conservation in California. November. Available: https://pacinst.org/wp-content/uploads/2013/02/waste_not_want_not_full_report3.pdf. Accessed: January 2021.The Water Research Foundation. 2016. Residential End Uses of Water, Version 2. Available: https://www.waterrf.org/research/projects/residential-end-uses-water-version-2. Accessed: January 2021.

W-5. Design Water-Efficient Landscapes

GHG Mitigation Potential

Potentially small reduction in GHG emissions from outdoor water use

Co-Benefits (icon key on pg. 34)

Climate Resilience

Designing water-efficient landscapes conserves water resources, which will become more strained under climate change. In addition, native landscaping can help to support biodiversity and pollinators.

Health and Equity Considerations

Water-efficient landscaping can lower utility costs for project residents, and reduce pesticide and fertilizer run-off, which can affect water quality.

Measure Description

This measure requires the use of landscapes that are water efficient, with lower water demands than required by the DWR 2015 Model Water Efficient Landscape Ordinance (MWELO) (California Code of Regulations [C.C.R.], Title 23, Division 2, Chapter 2.7). Designing water-efficient landscapes for a project site or throughout a community reduces water consumption and thus the corresponding energy and indirect GHG emissions that result from sourcing and transporting fresh water.

Scale of Application

Project/Site and Plan/Community

Implementation Requirements

Relative to the maximum allowable water use under the MWELO, users can achieve water savings by reducing lawn sizes, planting vegetation with minimal water needs (e.g., California native species), choosing vegetation appropriate for the climate of the project site or community, or choosing complementary plants that have similar water needs or that can provide shade and/or water to each other.

Cost Considerations

Water-efficient landscapes save money not only through reduced requirements for irrigation, but also require fewer inputs like fertilizer and pesticides and less use of landscaping equipment. Depending on the area of the landscape and the cost of designing it for water efficiency, these cost savings usually recoup the cost of installation and design.

Expanded Mitigation Options

Pair with Measure W-6 for increased outdoor water conservation and GHG reductions. Encourage application of biochar to improve soil quality and enhance carbon sequestration. Incorporate low-impact development practices in the landscape and surrounding area.

GHG Reduction Formula

$$A1 = ([(D \times E) + ((1 - D) \times F)] - (\frac{G}{H} \times E)) \times I \times J$$ (Water savings)

$$A2 = 1 - A1/[((D \times E) + ((1 - D) \times F)) \times I \times J]$$ (Percent emissions reduction)

$$B = A1 \times K \times L$$ (Energy savings)

$$C = B \times M \times N \times O$$ (Emissions reduction)

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A1	Outdoor water savings with water-efficient landscapes	[ ]	gal	Calculated
A2	% reduction in outdoor water, energy & GHG emissions with water-efficient landscapes	[ ]	%	Calculated
B	Energy savings with water-efficient landscapes	[ ]	kWh	Calculated
C	GHG reduction with water-efficient landscapes	[ ]	MT CO_2e	Calculated
User Inputs				
D	Evapotranspiration adjustment factor for maximum allowable water use	0.55 or 0.45	unitless	user input
E	Landscape area	[ ]	sf	user input
F	Special landscape area	[ ]	sf	user input
Constants, Assumptions, and Available Defaults				
G	Plant factor	0 to 1.0	unitless	UC Davis 2021a
H	Irrigation efficiency	0.75 or 0.81	unitless	23 C.C.R. Appendix A
I	Evapotranspiration rate	[ ]	Inches per year	23 C.C.R. Appendix A
J	Conversion from acre-inches/acre to gal/sf	0.62	(gal per sf) per (acre-inch per acre)	conversion
K	Conversion from gal to AF	3.07×10^{-6}	AF per gal	conversion
L	Electricity for municipally provided water	Table W-1.1	kWh per AF	CPUC 2016
M	Conversion from kWh to MWh	0.001	MWh per kWh	conversion

ID	Variable	Value	Unit	Source
N	Carbon intensity of local electricity provider	Tables E-4.3 and E-4.4	lb CO_2e per MWh	CA Utilities 2021
O	Conversion from lb to MT	0.000454	MT per lb	conversion

Further explanation of key variables:

- (A1) – The methodology for calculating water reductions is based on the MWELO. It combines calculations for maximum allowable water use (known as MAWA per the MWELO) and estimated total water use (known as ETWU per the MWELO) into one formula for quantifying water savings.
- (D) – The evapotranspiration adjustment factor for maximum allowable water use is dependent on the project or land use type and is 0.55 for residential uses and 0.45 for non-residential uses.
- (F) – Special landscape area is an area of the landscape dedicated solely to edible plants, recreational areas, areas irrigated with recycled water, or water features using recycled water.
- (G) – In the calculation for water savings, the plant factor is the primary determinant of the magnitude of water savings. The plant factor should be taken from the University of California Davis' Water Use Classification of Landscape Species (WUCOLS) or other professional associations that are approved by DWR. The plant factor ranges from 0 to 0.1 for very low water plants; 0.1 to 0.3 for low water plants; from 0.4 to 0.6 for moderate water use plants; and from 0.7 to 1.0 for high water use plants. The water demands of a particular plant species can vary, depending on the region where the project is located. The region categorizations and plant factors can be found from the WUCOLS plant database (UC Davis 2021a, 2021b).
- (H) – The irrigation efficiency factor depends on the type of irrigation that will be used for the landscape and is 0.75 for spray head irrigation and 0.81 for drip irrigation.
- (I) – The evapotranspiration rate corresponding to the user's location affects how much water savings are achieved. Users can look-up location-dependent evapotranspiration rates from Appendix A of the MWELO (23 C.C.R. Appendix A).
- (L) – The water energy-intensity factors are derived from the most recent version of the CPUC Water Energy Calculator and are provided in Table W-1.1 in Appendix C (CPUC 2016). The energy intensity factors rely on region-wide average values for DWR's 10 hydrologic regions.
- (N) – GHG intensity factors for major utilities in California are provided in Tables E-4.3 and E-4.4 in Appendix C. If the project study area is not serviced by the listed electricity provider, or the user is able to provide a project-specific value, the user should replace these defaults in the electricity consumption GHG calculation formula.

GHG Calculation Caps or Maximums

None.

Example GHG Reduction Quantification

The user reduces GHG emissions from water-related electricity by requiring water efficient landscaping. In this example, the project is a residential use in Crescent City (North Coast hydrologic region). As a residential project, the evapotranspiration adjustment factor is 0.55 (D). Per MWELO, the evapotranspiration rate for Crescent City is 27.7 inches per year (I). The project includes a landscaped area of 1,500 sf (E), which will be landscaped with coyote mint (a low water use plant with plant factor equal to 0.1 [G]) and irrigated with a drip system (H). The project does not include special landscaping area (F). The electricity provider for the project area is PacificCorp, and the analysis year is 2022. The carbon intensity of electricity is, therefore, 1,228 lb CO_2e per MWh (N).

$$A1 = ([(\mathbf{0.55} \times \mathbf{1{,}500\ sf}) + ((1 - \mathbf{0.55}) \times \mathbf{0\ sf})] - (\frac{0.1}{0.81} \times \mathbf{1{,}500\ sf})) \times 27.7\frac{\text{inch}}{\text{yr}} \times 0.62\frac{\left(\frac{\text{gal}}{\text{sf}}\right)}{\left(\frac{\text{acre}\cdot\text{in}}{\text{acre}}\right)} = 10{,}988\ \frac{\text{gal}}{\text{yr}}$$

$$A2 = 1 - 10{,}988\frac{\text{gal}}{\text{yr}} / [((\mathbf{0.55} \times \mathbf{1{,}500\ sf}) + ((1 - \mathbf{0.55}) \times \mathbf{0\ sf})) \times 27.7\frac{\text{inch}}{\text{yr}} \times 0.62\frac{\frac{\text{gal}}{\text{sf}}}{\frac{\text{acre}\cdot\text{inch}}{\text{acre}}}] = 22\%$$

$$B = 10{,}988\frac{\text{gal}}{\text{yr}} \times \left(3.07\times10^{-6}\frac{\text{AF}}{\text{gal}}\right) \times 362\frac{\text{kWh}}{\text{AF}} = 12\frac{\text{kWh}}{\text{yr}}$$

$$C = 12\frac{\text{kWh}}{\text{yr}} \times 0.001\frac{\text{MWh}}{\text{kWh}} \times 1{,}228\ \frac{\text{lb } CO_2e}{\text{MWh}} \times 0.000454\frac{\text{MT}}{\text{lb}} = 0.007\frac{\text{MT } CO_2e}{\text{yr}}$$

Quantified Co-Benefits

Energy and Fuel Savings

Energy savings (B) are derived in the steps above that are necessary to quantify GHG reductions.

Water Conservation

Water savings (A1) are derived in the steps above that are necessary to quantify GHG reductions.

Sources

- California Public Utilities Commission (CPUC). 2016. Water-Energy Calculator–Draft Version 1.05. Available: https://www.cpuc.ca.gov/nexus_calculator/. Accessed: January 2021.
- California Utilities. 2021. Excel database of GHG emission factors for delivered electricity, provided to the Sacramento Metropolitan Air Quality Management District and ICF. January through March 2021.
- University of California, Davis (UC Davis). 2021a. *WUCOLS IV Water Use Classification of Landscape Species*. Plant Search Database. Available: https://ucanr.edu/sites/WUCOLS/Plant_Search/. Accessed: January 2021.
- University of California, Davis (UC Davis). 2021b. *WUCOLS IV Water Use Classification of Landscape Species*. Regions. Available: https://ucanr.edu/sites/WUCOLS/WUCOLS_IV_User_Manual/Regions/. Accessed: January 2021.

W-6. Reduce Turf in Landscapes and Lawns

GHG Mitigation Potential

Large

Potentially large reduction in GHG emissions from outdoor water use

Co-Benefits (icon key on pg. 34)

Climate Resilience

Reducing turf conserves water resources, which will become more strained under climate change.

Health and Equity Considerations

Turf is often used for play. For residential or school projects, include play opportunities, build additional public parks nearby, and/or increase access to existing parks or playgrounds. However, turf often requires use of fertilizer (which can be derived from fossil fuels) and herbicides, both of which can affect water quality, and the removal of turf can reduce runoff effects.

Measure Description

This measure would remove or avoid turf grass. Turf grass (i.e., lawn grass) has relatively high-water needs compared to most other types of vegetation. Lowering landscaping water demands by reducing turf size would reduce water consumption and thus the corresponding energy and indirect GHG emissions that result from sourcing and transporting fresh water. Water agencies in California have instituted turf removal programs that provide rebates for residents who reduce the turf area at their homes.

Scale of Application

Project/Site

Implementation Requirements

See measure description.

Cost Considerations

Turf maintenance in landscape and lawns has always been significantly more expensive than a lawn filled with hardier species that are native to the region. As turf requires constant input to be maintained, the cost of transitioning turf to a more sustainable landscape is relatively inexpensive, and both a short- and long-term cost savings may be realized.

Expanded Mitigation Options

Additional GHG emissions savings may be achieved through reduced fertilizer use. The methods to calculate these reductions are not included in the quantification method.

GHG Reduction Formula

$A1 = D \times E \times F \times G \times H$ (Water savings)

$A2 = \frac{F}{I}$ (Percent emissions reduction)

$B = A1 \times J \times K$ (Energy savings)

$C = B \times L \times M \times N$ (Emissions reduction)

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A1	Outdoor water savings from turf reduction	[ ]	gal	calculated
A2	% reduction in GHG emissions from outdoor water use	[ ]	%	calculated
B	Energy savings from turf reduction	[ ]	kWh	calculated
C	GHG emissions reduction from turf reduction	[ ]	MT CO_2e	calculated
User Inputs				
F	Area of turf to be removed	[ ]	sf	user input
I	Total turf area	[ ]	sf	user input
Constants, Assumptions, and Available Defaults				
D	Crop coefficient	0.6 or 0.8 (cool- or warm-season grasses)	unitless	UC Davis 2021a, 2021b
E	Evapotranspiration rate	[ ]	inches per year	MWELO
G	Conversion factor acre-inches/acre to gal/sf	0.62	(gal per sf) per (acre-inch per acre)	conversion
H	Days per year	365	days per year	conversion
J	Conversion from gal to AF	$3.07x10^{-6}$	AF per gal	conversion
K	Electricity required for municipally provided water	Table W-1.1	kWh per AF	CPUC 2016
L	Conversion from kWh to MWh	0.001	MWh per kWh	conversion
M	Carbon intensity of local electricity provider	Tables E-4.3 and E-4.4	lb CO_2e per MWh	CA Utilities 2021
N	Conversion from lb to MT	0.000454	MT per lb	conversion

Further explanation of key variables:

- (D) – The crop coefficient for turf grasses is represented by two values, one for cool-season grasses (0.6) and one for warm-season grasses (0.8).
- (E) – The evapotranspiration rate corresponding to the user's location affects how much water savings are achieved. Users can look-up location-dependent evapotranspiration rates from Appendix A of the MWELO (23 CCR Appendix A).
- (H) – The water energy-intensity factors are derived from the most recent version of the CPUC Water Energy Calculator and are provided in Table W-1.1 in Appendix C (CPUC 2016). The energy intensity factors rely on region-wide average values for DWR's 10 hydrologic regions.
- (M) – GHG intensity factors for major utilities in California are provided in Tables E-4.3 and E-4.4 in Appendix C. If the project study area is not serviced by the listed electricity provider, or the user is able to provide a project-specific value, the user should replace these defaults in the electricity consumption GHG calculation formula.

GHG Calculation Caps or Maximums

None.

Example GHG Reduction Quantification

The user reduces GHG emissions from water-related electricity by reducing turf grass. In this example, the project is in Lancaster (South Coast hydrologic region), which has evapotranspiration rate of 44.2 inches per day (E). The project will remove 800 sf of turf (F) with warm-season grasses (D). The project's entire turf area is 1,200 sf (I). The electricity provider for the project is Lancaster Choice Energy, and the analysis year is 2022. The carbon intensity of electricity is, therefore, 600 lb CO_2e per MWh (M).

$$A1 = 0.8 \times 44.2\,\frac{\text{inch}}{\text{yr}} \times \mathbf{800\ sf} \times 0.62\,\frac{\left(\frac{\text{gal}}{\text{sf}}\right)}{\frac{\text{acre}\cdot\text{inch}}{\text{acre}}} = 17{,}539\,\frac{\text{gal}}{\text{yr}}$$

$$A2 = \frac{\mathbf{800\ sf}}{\mathbf{1{,}200\ sf}} = 67\%$$

$$B = 17{,}539\ \text{gal} \times \left(3.07\times10^{-6}\,\frac{\text{AF}}{\text{gal}}\right) \times 1{,}898\,\frac{\text{kWh}}{\text{AF}} = 102\ \text{kWh}$$

$$C = 102\ \text{kWh} \times 0.001\,\frac{\text{MWh}}{\text{kWh}} \times 600\,\frac{\text{lb CO}_2\text{e}}{\text{MWh}} \times 0.000454\,\frac{\text{MT}}{\text{lb}} = 0.03\ \text{MT CO}_2\text{e}$$

Quantified Co-Benefits

Energy and Fuel Savings

Energy savings (B) are derived in the steps above that are necessary to quantify GHG reductions.

Water Conservation

Water savings (A1) are derived in the steps above that are necessary to quantify GHG reductions.

Sources

- California Public Utilities Commission (CPUC). 2016. Water-Energy Calculator–Draft Version 1.05. Available: https://www.cpuc.ca.gov/nexus_calculator/. Accessed: January 2021.
- California Utilities. 2021. Excel database of GHG emission factors for delivered electricity, provided to the Sacramento Metropolitan Air Quality Management District and ICF. January through March 2021.
- University of California, Davis (UC Davis). 2021a. *Turfgrass Crop Coefficients*. Available: https://ucanr.edu/sites/UrbanHort/Water_Use_of_Turfgrass_and_Landscape_Plant_Materials/Turfgrass_Crop_Coefficients_Kc/. Accessed: January 2021.
- University of California, Davis (UC Davis). 2021b. *Water Requirements for Turfgrasses*. Available: https://ucanr.edu/sites/WUCOLS/Water_Requirements_for_Turfgrasses/. Accessed: January 2021.

W-7. Adopt a Water Conservation Strategy

GHG Mitigation Potential

Varies

Variable reduction in GHG emissions from water use

Co-Benefits (icon key on pg. 34)

Climate Resilience

Conserving water reduces the strain on water resources, which is expected to increase under climate change.

Health and Equity Considerations

Ensure strategy includes enough water for outdoor use to maintain and enhance urban tree canopy as much as possible. Water conservation can also help to lower utility costs for project residents.

Measure Description

This measure will establish a water conservation strategy to achieve a reduction in water consumption. The water reduction performance standard is flexible to the users' needs, and in this measure is set as a percent reduction in water consumption relative to a reference condition (e.g., existing conditions, historic year).

Scale of Application

Project/Site and Plan/Community

Implementation Requirements

The strategy should clearly identify the actions that will be undertaken to achieve the performance standard. These actions could include any of the measures presented in this Handbook (Measures W-1 through W-6) or others developed by the user; for example, low-impact development practices to enhance onsite water infiltration and improve stormwater management.

Cost Considerations

A water conservation strategy is a low-cost way to encourage using less water and energy, which in turns saves money. Costs from developing and implementing the strategy are primarily related to staff time and document production. Costs and savings achieved by actions undertaken because of the strategy would vary depending on the action.

Expanded Mitigation Options

Non-applicable

GHG Reduction Formula

A = (B × C) × D × E × F × G

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	GHG reduction from strategy	[ ]	MT CO_2e	calculated
User Inputs				
B	Water consumption for the reference year	[ ]	AF	user input
C	Performance standard for conservation strategy	[ ]	%	user input
Constants, Assumptions, and Available Defaults				
D	Electricity required for municipally provided water	Table W-1.1	kWh per AF	CPUC 2016
E	Conversion from kWh to MWh	0.001	MWh per kWh	conversion
F	Carbon intensity of local electricity provider	Tables E-4.3 and E-4.4	lb CO_2e per MWh	CA Utilities 2021
G	Conversion from lb to MT	0.000454	MT per lb	conversion

Further explanation of key variables:

- (B) – Water consumption for the project or community for the reference year must be defined by the user.
- (C) – The percent reduction in water consumption relative to the reference condition.
- (D) – The water energy-intensity factors are derived from the most recent version of the CPUC Water Energy Calculator and are provided in Table W-1.1 in Appendix C (CPUC 2016). The energy intensity factors rely on region-wide average values for DWR's 10 hydrologic regions.
- (F) – GHG intensity factors for major utilities in California are provided in Tables E-4.3 and E-4.4 in Appendix C. If the project study area is not serviced by the listed electricity provider, or the user is able to provide a project-specific value, the user should replace these defaults in the electricity consumption GHG calculation formula.

GHG Calculation Caps or Maximums

None.

Example GHG Reduction Quantification

The user reduces GHG emissions by adopting and implementing a water conservation strategy. In this example, the performance standard for the strategy is a 10 percent reduction in existing (2020) water consumption by 2030. Existing water consumption is 1,000 AF, and the project is in the Sacramento River hydrologic region (D) and SMUD service territory. The carbon intensity of electricity is, therefore, 224 lb CO_2e per MWh (F).

$$A = \left(1{,}000 \frac{AF}{yr} \times 10\%\right) \times 207 \frac{kWh}{AF} \times 0.001 \frac{MWh}{kWh} \times 224 \frac{lb\ CO_2e}{MWh} \times 0.000454 \frac{MT}{lb} = 2.11 \frac{MT\ CO_2e}{yr}$$

Quantified Co-Benefits

The co-benefits that are quantifiable (energy and fuel savings, water conservation) are calculated as part of the GHG reduction formula. The abbreviated formulas are also shown below.

Energy and Fuel Savings Formula

$$\frac{MWh}{year} = (B \times C) \times D \times E$$

Water Conservation Formula

$$\frac{AF}{year} = B \times C$$

Sources

- California Public Utilities Commission (CPUC). 2016. Water-Energy Calculator–Draft Version 1.05. https://www.cpuc.ca.gov/nexus_calculator/. Accessed: January 2021.
- California Utilities. 2021. Excel database of GHG emission factors for delivered electricity, provided to the Sacramento Metropolitan Air Quality Management District and ICF. January through March 2021.

Lawn and Landscaping

Landscaping equipment is the primary source of direct GHG emissions in the lawn and landscaping sector. Landscaping equipment traditionally uses gasoline fuel and releases emissions based on the amount of fuel combusted and emission factor of the engine. Equipment emissions can be reduced by requiring use of zero-emission landscaping equipment (including battery-powered and corded electric equipment) over conventional gasoline-fueled counterparts. The exclusive use of grid electricity to power the equipment eliminates onsite gasoline emissions but increases indirect emissions from electricity generation. However, grid-based emissions are typically less than the emissions from the gasoline-fueled equipment (depending on the source of grid power).

Emissions reductions achieved by zero-emission equipment are determined by finding the difference in emissions between those generated by the replacement power source and those generated by conventional gasoline engines. Emissions for the mitigated scenario may consist of direct emissions from combustion fuel use, and/or indirect emissions from grid electricity. Resources and methods to quantify emissions reductions from a measure requiring zero-emission landscaping equipment are described in this section.

Additional measures that can be undertaken to reduce emissions within the lawn and landscaping sector include ensuring electric yard equipment compatibility and implementing a yard equipment exchange program. Electric yard equipment compatibility is a supporting action for successful implementation of a measure that restricts gasoline landscaping equipment in favor of zero-emission equipment. A yard equipment exchange program would help facilitate community-scale equipment turnover and engine replacement. Please refer to the *Supporting or Non-Quantified GHG Reduction Measures* section at the end of Chapter 3 for additional information.

LL-1. Replace Gas-Powered Landscape Equipment with Zero-Emission Landscape Equipment

GHG Mitigation Potential

Large

Potentially large reduction in GHG emissions from landscaping equipment

Co-Benefits (icon key on pg. 34)

Climate Resilience

Replacing gas-powered landscape equipment with zero-emission landscape equipment can reduce sensitivity to fuel price shocks or scarcity.

Health and Equity Considerations

Consider implementing programs to help disadvantaged business enterprises convert to electric equipment. Reduction or replacement of gasoline-powered equipment reduces localized air pollution.

Measure Description

This measure requires use of zero-emission landscaping equipment over conventional gasoline-fueled counterparts. Equipment types historically powered by gasoline engines covered by this measure include chainsaws, chippers, lawn mowers, leaf blowers/vacuums, riding mowers, tillers, and trimmers (CARB 2020). Replacing gasoline-powered equipment with zero-emission equipment reduces fossil fuel combustion and thus GHG emissions. However, electric equipment results in GHG emissions from the electricity used to charge the equipment. The indirect GHG emissions increase from electricity must be calculated in addition to the GHG emissions reduction from displaced fossil fuel combustion to estimate the total net GHG emissions reduction achieved by this measure.

Scale of Application

Project/Site

Implementation Requirements

For this measure to be successfully implemented, it is helpful for electrical outlets on the exterior of buildings to be accessible so that the corded electric landscaping equipment can be more easily used in different areas, and batteries can be charged if indoor charging is not available. Measure LL-3, *Electric Yard Equipment Compatibility,* in Table 3-2 should, therefore, be considered as a supporting action to this measure.

Cost Considerations

Although the environmental benefits of replacing gas powered landscape equipment are high, so too are the costs. Zero-emission equipment is usually more expensive than conventional gasoline-powered equipment. Once the equipment is purchased, however, there are long-term cost savings in avoided fuel inputs and maintenance.

Expanded Mitigation Options

Users may consider an exchange program to expand penetration of this measure, as outlined in Measure LL-2, *Implement Yard Equipment Exchange Program*, in Table 3-2.

GHG Reduction Formula

A = [**B** × C × (D × E) × F1 × G] – [**B** × C × D × **F2** × H]

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	GHG reduction from using plug-in or battery electric equipment	[ ]	MT CO_2e	calculated
User Inputs				
B	Hours of equipment operation	[ ]	hours	user input
F2	Carbon intensity of gasoline equipment	[ ]	g CO_2e per hp-hour	CARB 2020
Constants, Assumptions, and Available Defaults				
C	Load factor of equipment	Table LL-1.1	unitless	CARB 2020
D	Horsepower (hp) of equipment	Table LL-1.1	hp	CARB 2020
E	Conversion from horsepower to MW	0.0007457	MW per hp	conversion
F1	Carbon intensity of local electricity provider	Tables E-4.3 and E-4.4	lb CO_2e per MWh	CA Utilities 2021
G	Conversion from lb to MT	0.000454	MT per lb	conversion
H	Conversion from grams (g) to MT	1×10^{-6}	MT per g	conversion

Further explanation of key variables:

- (C) – The load factor is the average operational level of an engine as a fraction or percentage of the engine manufacturer's maximum rated horsepower (hp). Average load factors of various landscaping equipment are provided in Table LL-1.1 in Appendix C, *Emission Factors and Data Tables* (CARB 2020). If the user can provide an equipment-specific load factor, they should replace the default in the GHG calculation formula.
- (D) – Average hp of various landscaping equipment are provided in Table LL-1.1 in Appendix C (CARB 2020). If the user can provide an equipment-specific hp, the user should replace the default in the GHG calculation formula.
- (E) – Conversion factor assumes that energy requirements and losses are the same for both a fuel-powered engine and a piece of electric equipment.
- (F1) – GHG intensity factors for major California electricity providers are provided in Tables E-4.3 and E-4.4 in Appendix C. If the project study area is not serviced by a listed electricity provider, or the user is able to provide a project-specific value (i.e., for the future year not referenced in Appendix C), the user should replace the default in the GHG calculation formula. If the electricity provider is not known, users may elect to use the statewide grid average carbon intensity.
- (F2) – GHG intensity factors for various landscaping equipment can be obtained from CARB's (2020) SORE2020 model.

GHG Calculation Caps or Maximums

None.

Example GHG Reduction Quantification

The user reduces lawn and landscaping emissions by replacing fossil fuel combustion with electricity consumption, which generates fewer GHG emissions per unit of activity. In this example, a 5-hp residential gasoline 4-stroke leaf blower (D) that is used 8 hours per day (B) is replaced by an electric-powered equivalent. The average load factor for a 5-hp leaf blower is 0.94 (C). The electricity provider for the project area is CleanPower SF and the analysis year is 2025. The carbon intensity of electricity is, therefore, 80 lb CO_2e per MWh (F1).

$$A = \left(8\ \frac{\text{hours}}{\text{day}} \times 0.94 \times \left[5\ \text{hp} \times 0.0007457\ \frac{\text{MW}}{\text{hp}}\right] \times 80\ \frac{\text{lb CO}_2\text{e}}{\text{MWh}} \times 0.000454\frac{\text{MT}}{\text{lb}}\right) - \left(8\ \frac{\text{hours}}{\text{day}} \times 0.94 \times 5\ \text{hp} \times 635\frac{\text{g CO}_2\text{e}}{\text{hp-hour}} \times 1e^{-6}\frac{\text{MT}}{\text{g}}\right) = -0.02\frac{\text{MT CO}_2\text{e}}{\text{day}}$$

Measure Co-Benefits

Improved Air Quality

Reducing gasoline combustion will also reduce local criteria pollutants. Emission savings can be calculated using the same formula used to quantify GHG reductions (A). Criteria pollutant intensity factors for various landscaping equipment can be obtained from CARB's (2020) SORE2020 model.

Electricity supplied by statewide fossil-fueled or bioenergy power plants will generate criteria pollutants. However, because these power plants are located throughout the state, electricity consumption from equipment charging will not generate localized criteria pollutant emissions. Consequently, for the quantification of criteria pollutant emission reductions, either the electricity portion of the equation can be removed, or the electricity intensity (F1) can be set to zero.

Energy and Fuel Savings

Fossil fuel (gasoline) savings are a product of the equipment fuel efficiency (gal consumed per hour) and the equipment operating time (hours). Fuel intensity factors for various landscaping equipment can be obtained from CARB's (2020) SORE2020 model . Users should multiply the fuel intensity by the equipment operating hours to quantify fuel savings. Increased electricity consumption is calculated as part of the GHG reduction formula. The abbreviated formula is also shown below.

$$\text{MWh} = [B \times C \times (D \times E)]$$

Sources

- California Air Resources Board (CARB). 2020. 2020 Emissions Model for Small Off-Road Engines—SORE2020. Version 1.1. September. Available: https://ww2.arb.ca.gov/our-work/programs/mobile-source-emissions-inventory/msei-announcements. Database queried by Ramboll and provided electronically to ICF. September 2021.
- California Utilities. 2021. Excel database of GHG emission factors for delivered electricity, provided to the Sacramento Metropolitan Air Quality Management District and ICF. January through March 2021.

Solid Waste

CH_4 emissions are generated through the decomposition of organic waste disposed in a landfill. CO_2 is also generated as materials degrade, but these emissions are considered part of the natural carbon cycle of growth and decomposition. The transportation of waste to a landfilling facility also generates emissions from the combustion of fuel to operate the waste-hauling vehicle. In some cases, organic materials that are landfilled do not completely decompose, allowing for biogenic carbon storage that otherwise would not have occurred. In addition, landfills may capture some of the CH_4 generated by organic materials and combust it to generate electricity, thereby avoiding emissions that otherwise would have been emitted to generate electricity (U.S. EPA 2020).

Emissions associated with landfilling can be avoided through the diversion of waste. Alternate waste management pathways include recycling and composting.

- Recycling is the separation and collection of wastes, their subsequent transformation or remanufacture into usable or marketable products or materials, and the purchase of products made from recyclable materials (U.S. EPA 2020). During recycling, emissions are generated from the transportation of waste to recycling facilities and the operation of machinery to process these materials into new, recycled products. Other emissions may be generated during the recycling process through the purification chemicals or agents. At the same time, recycling offsets emissions associated with the virgin production of materials.
- Composting involves bacterial decomposition of organic matter into compost. Emissions result from the transportation and processing of waste at the compost facility, as well as from the decomposition process. At the same time, compost application can help reduce the use of synthetic fertilizers and increase soil carbon storage.

The methodology used in this Handbook to quantify emission reductions from diverting waste from landfills is based on a lifecycle approach that accounts for upstream and downstream emissions associated with the waste management pathways with and without the measure. This is consistent with the methodology developed by the U.S. Environmental Protection Agency (U.S. EPA) (2020). Additionally, Measure S-3 accounts for up-stream emissions in the food supply chain, such as production- and transportation-related emissions. As a result, users are cautioned in how these reductions are compared to operational emissions inventories, which may not include lifecycle emissions. Additionally, the methodology assumes that all disposed waste will be diverted from the landfill. In reality, recycling and composting programs will likely only result in the diversion of a fraction of disposed waste. Users should consider this when calculating the benefits of implementation of waste diversion programs.

Solid Waste

- S-1. Institute or Extend Recycling Services
- S-2. Implement Organics Diversion Program
- S-3. Require Edible Food Recovery Program Partnerships with Food Generators

Use the graphic to click on an individual measure to navigate directly to the measure's factsheet.

S-1. Institute or Extend Recycling Services

GHG Mitigation Potential

Small

Potentially small reduction in GHG emissions from waste management pathways

Co-Benefits (icon key on pg. 34)

Climate Resilience

Recycling can reduce upstream material extraction and product manufacturing, preserving resources and reducing energy use.

Health and Equity Considerations

Any new recycling facilities should not be constructed near vulnerable or underserved communities.

Measure Description

This measure will institute or extend recycling services to reduce the volume of landfilled waste. Decomposition of certain types of landfilled waste produces CH_4. Increasing waste diversion from landfills therefore reduces GHG emissions. The recycling process generates some emissions, but also reduces upstream emissions from the manufacturing and production of new raw materials and goods.

Scale of Application

Project/Site and Plan/Community

Implementation Requirements

See measure description.

Cost Considerations

Expanding recycling services generates costs of collection, processing, and management of the materials to be recycled, and can include the construction of new facilities to process a certain type of material, or transportation for the materials to reach a plant that can accommodate them. However, expanded recycling also reduces costs associated with new material production, waste processing, landfill management, pollution control, and waste-stream GHG emissions.

Expanded Mitigation Options

Waste reduction is as important, if not more so, as waste diversion. Work with building tenants to audit waste streams to identify opportunities for material reduction. For example, organizations may reduce single-use disposal at large events (e.g., concerts) and venues (e.g., stadiums) through partnerships with organizations that provide reusable cups and dishes.

GHG Reduction Formula

A = [E1 or E2] × D

$B_Z = A \times F_Z$

C = Input B_Z into U.S. EPA WARM

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Waste disposed by building type	[ ]	tons	calculated
B	Waste disposed by material type	[ ]	tons	calculated
C	GHG reduction from recycling vs. landfilling waste	[ ]	MT CO_2e	calculated using U.S. EPA WARM
User Inputs				
D	Population	[ ]	resident or employee	user input
Constants, Assumptions, and Available Defaults				
E1	Annual residential waste disposal rates by location	Table S-1.1	tons per resident per year	CalRecycle n.d.(a)
E2	Annual statewide non-residential waste disposal rates by business type	Table S-1.2	tons per employee per year	CalRecycle n.d.(b)
F	Percentage of material z in waste stream	Table S-1.3	%	CalRecycle n.d.(c), 2020
z	Material type (e.g., glass)	N/A	-	-

Further explanation of key variables:

- (C) – U.S. EPA's (2020) Waste Reduction Model (WARM) calculates GHG emissions associated with various waste management practices, including recycling and landfilling. To estimate the GHG benefit of recycling over landfilling, users input the tonnage of waste by material type into the Tons Landfilled column under the "baseline" scenario. The user then inputs the tonnage of waste by material type into the Tons Recycled column under the "alternative management" scenario. If a material type cannot be recycled, the used should input the tonnage for that material into the Tons Landfilled column under the alternative management scenario. The model calculates emissions under the baseline and alternative management scenarios of manufacturing, transportation, and end-of-life landfilling or recycling of waste and shows the net GHG savings in MT CO_2e.
- (E1) – Annual solid waste disposal rates for multi-family and single-family homes are provided in Table S-1.1 in Appendix C, *Emission Factors and Data Tables*.
- (E2) – Annual non-residential waste disposal rates by business type are provided in Table S-1.2 in Appendix C.

- (F) – The composition of disposed waste by material type for residential and non-residential buildings is provided in Table S-1.3 in Appendix C.

GHG Calculation Caps or Maximums

None.

Example GHG Reduction Quantification

The user reduces GHG emissions by diverting waste from a landfill to a recycling center. In this example, the project is an Arts, Entertainment, & Recreation business with 100 employees (D).

$$A = 1.94\ \frac{\text{tons}}{\text{yr·employee}} \times \textbf{100 employees} = 194\ \frac{\text{tons}}{\text{yr}}$$

$$B_{\text{paper}} = 194\frac{\text{tons}}{\text{yr}} \times 21\% = 40.7\frac{\text{tons}}{\text{yr}}$$

$$B_{\text{glass}} = 194\frac{\text{tons}}{\text{yr}} \times 3\% = 5.8\frac{\text{tons}}{\text{yr}}$$

$$B_{\text{metals}} = 194\frac{\text{tons}}{\text{yr}} \times 2\% = 3.9\frac{\text{tons}}{\text{yr}}$$

$$B_{\text{plastic}} = 194\frac{\text{tons}}{\text{yr}} \times 14\% = 27.2\frac{\text{tons}}{\text{yr}}$$

$$B_{\text{food}} = 194\frac{\text{tons}}{\text{yr}} \times 34\% = 66.0\frac{\text{tons}}{\text{yr}}$$

$$B_{\text{yard trimmings}} = 194\frac{\text{tons}}{\text{yr}} \times 12\% = 23.3\frac{\text{tons}}{\text{yr}}$$

$$B_{\text{mixed organics}} = 194\frac{\text{tons}}{\text{yr}} \times 6\% = 11.6\frac{\text{tons}}{\text{yr}}$$

$$B_{\text{carpet}} = 194\frac{\text{tons}}{\text{yr}} \times 1\% = 1.9\frac{\text{tons}}{\text{yr}}$$

$$B_{\text{concrete}} = 194\frac{\text{tons}}{\text{yr}} \times 2\% = 3.9\frac{\text{tons}}{\text{yr}}$$

$$B_{\text{dimensonal lumber}} = 194\frac{\text{tons}}{\text{yr}} \times 1\% = 1.9\frac{\text{tons}}{\text{yr}}$$

$$B_{\text{fly ash}} = 194\frac{\text{tons}}{\text{yr}} \times 1\% = 1.9\frac{\text{tons}}{\text{yr}}$$

The user inputs the tons of waste by material type (B) into U.S. EPA's WARM in the Tons Landfilled column. The project will recycle all paper (B_{paper}), glass (B_{glass}), and plastic (B_{plastic}), which is assumed in the alternative management scenario. Based on WARM, the project would mitigate up to 202 MT CO_2e by diverting its waste from a landfill to a recycling facility.

Quantified Co-Benefits

None.

Sources

- CalRecycle. n.d.(a) *Residential Waste Stream by Material Type*. Available: https://www2.calrecycle.ca.gov/WasteCharacterization/ResidentialStreams. Accessed: April 2021.
- CalRecycle. n.d.(b) *Disposal and Diversions Rates for Business Groups*. Available https://www2.calrecycle.ca.gov/WasteCharacterization/BusinessGroupRates. Accessed: January 2021.
- CalRecycle. n.d.(c) *Business Group Waste Stream Calculator*. Available https://www2.calrecycle.ca.gov/WasteCharacterization/BusinessGroupCalculator. Accessed: January 2021.
- CalRecycle. 2020. *2018 Facility-Based Characterization of Solid Waste in California.* Available https://www2.calrecycle.ca.gov/WasteCharacterization/Study. Accessed: January 2021.
- U.S. Environmental Protection Agency (U.S. EPA). 2020. *Waste Reduction Model (WARM), Version 15*. Available: https://www.epa.gov/warm. Accessed: January 2021.

S-2. Implement Organics Diversion Program

GHG Mitigation Potential

Small

Potentially small reduction in GHG emissions from management pathways

Co-Benefits (icon key on pg. 34)

Climate Resilience

Organics diversion programs can increase the amount of compost produced, which can go toward gardens and farms and help improve food and crop production. Compost can also help increase soil carbon storage, which can in turn improve biodiversity and groundwater storage.

Health and Equity Considerations

If possible, work with local food banks and shelters to ensure that edible food goes to people first.

Measure Description

This measure will implement an organics diversion program to reduce the volume of organic waste sent to landfills. An organics diversion program lowers the landfill disposal rate of food waste (both edible and non-edible), food soiled paper, yard waste, and non-hazardous wood waste. Decomposition of organic waste in landfills produces CH_4. Increasing organic waste diversion from landfills thus reduces GHG emissions.

Scale of Application

Project/Site and Plan/Community

Implementation Requirements

Waste management practices to support organics diversion may include construction and management of a composting facility (citywide scale), providing residential and business composting pickup services (citywide scale), community outreach (citywide scale and project scale), or providing clearly marked triple bin locations (waste, recycling, composting) (project scale).

Cost Considerations

Implementing organics diversion services, or utility scale composting, generates costs for collection, processing, and management of the materials to be composted, and can include the construction of new composting facilities or transportation for the materials to reach a plant that can accommodate them. However, expanded composting also reduces costs associated with waste processing, landfill management, pollution control, and waste-stream greenhouse gas emissions. The resulting compost can also take the place of fertilizer, saving costs on land management inputs and increasing agricultural yields.

Expanded Mitigation Options

Diversion of edible food to food banks is another viable organics diversion program but is not specifically captured by the current quantitative method for this measure.

GHG Reduction Formula

A = [E1 or E2] × D

$B_Z = A \times F_Z$

C = Input B_Z into U.S. EPA WARM

Composting can help reduce the use of nitrogen-based fertilizer, which results in GHG emissions during the manufacturing process (which involves use of natural gas) and release of nitrogen dioxide (NO_2) during use. These emissions are not quantified as part of this measure's methodology. Additional GHG reductions may be achieved if the diversion program reduces VMT and associated vehicle emissions. Refer to *Quantified Co-Benefits* below for further discussion.

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Waste disposed by building type	[ ]	tons	calculated
B	Waste disposed by material type	[ ]	Tons	calculated
C	GHG reduction from recycling vs. composting waste	[ ]	MT CO_2e	calculated using U.S. EPA WARM
User Inputs				
D	Population	[ ]	resident or employee	user input
Constants, Assumptions, and Available Defaults				
E1	Annual residential waste disposal rates by location	Table S-1.1	tons per resident per year	CalRecycle n.d.(a)
E2	Annual statewide non-residential waste disposal rates by business type	Table S-1.2	tons per employee per year	CalRecycle n.d.(b)
F	Percentage of material z in waste stream	Table S-1.3	%	CalRecycle n.d.(c), 2020
z	Material type (e.g., glass)	N/A	-	-

Further explanation of key variables:

- (C) – U.S. EPA's (2020) WARM calculates the GHG emission impacts associated with various waste management practices, including recycling and composting. To estimate the GHG benefit of composting over landfilling, users input the tonnage of organic waste by material type into the Tons Landfilled column under the "baseline" scenario. The user then inputs the tonnage of organic waste by material type into the Tons Composted column under the "alternative management" scenario. The model calculates emissions under the baseline and alternative management scenarios of manufacturing, transportation and end-of-life landfilling, or diversion of organic waste and shows the net GHG savings in MT CO_2e.

- (E1) – Annual solid waste disposal rates for multi-family and single-family homes are provided in Table S-1.1 in Appendix C.
- (E2) – Annual non-residential waste disposal rates by business type are provided in Table S-1.2 in Appendix C.
- (F) – The composition of disposed waste by material type for residential and non-residential buildings is provided in Table S-1.3 in Appendix C.

GHG Calculation Caps or Maximums

None.

Example GHG Reduction Quantification

The user reduces GHG emissions by diverting organic waste from a landfill. In this example, the project is an Arts, Entertainment, & Recreation business with 100 employees (D).

$$A = 1.94\ \frac{\text{tons}}{\text{yr} \cdot \text{employee}} \times \mathbf{100\ employees} = 194\ \frac{\text{tons}}{\text{yr}}$$

$$B_{food} = 194\frac{\text{tons}}{\text{yr}} \times 34\% = 66.0\ \frac{\text{tons}}{\text{yr}}$$

$$B_{yard\ trimmings} = 194\frac{\text{tons}}{\text{yr}} \times 12\% = 23.3\frac{\text{tons}}{\text{yr}}$$

$$B_{mixed\ organics} = 194\frac{\text{tons}}{\text{yr}} \times 6\% = 11.6\frac{\text{tons}}{\text{yr}}$$

The user inputs the tons of waste by material type (B) into U.S. EPA's WARM in the Tons Landfilled column. The project will compost all materials, which is assumed in the alternative management scenario. Based on WARM, this business can mitigate up to 40 MT CO_2e by diverting waste from a landfill to compost facility.

Quantified Co-Benefits

VMT Reductions

Organics diversion programs may reduce waste transfer vehicle VMT if the compost facility is closer to the waste generation source than the landfill. The VMT reduction may be calculated using the following formula.

$$G = (\mathbf{H} \times \mathbf{I}) - (\mathbf{J} \times \mathbf{K})$$

VMT Reduction Calculation Variables

ID	Variable	Value	Unit	Source
Output				
G	Reduction in waste transfer vehicle VMT	[ ]	miles/day	calculated
User Inputs				
H	Daily waste transfer trips without the organics diversion program	[ ]	trips/day	user input
I	Waste transfer trip distance without the organics diversion program	[ ]	miles/trip	user input
J	Daily waste transfer trips under the organics diversion program	[ ]	trips/day	user input
K	Waste transfer trip distance under the organics diversion program	[ ]	miles/trip	user input
Constants, Assumptions, and Available Defaults				
	None			

Further explanation of key variables:

- (H, J) – The user should take care to properly account for all vehicle trips directly affected by implementation of the measure. This value may be the same with and without the diversion program.
- (I, K) – The user should take care to properly account for the full trip distance of the waste transfer vehicle. Note that if the trip distance increases with implementation of the organics diversion program (i.e., K>I), this measure would result in a VMT increase.

Users may translate VMT reductions (or increases) (G) to GHG emissions using emission factors from CARB's (2021) EMFAC model. Users should multiply the VMT reductions (or increases) by the appropriate vehicle emission factors. If the organics diversion program also reduces (or increases) the number of vehicle trips (i.e., J<H or J>H), users should quantify the resulting changes in process emissions using EMFAC.

Improved Air Quality

Composting can produce volatile organic compound (VOC) emissions in and around the composting site. This may result in worsened regional air quality. Increases in VOC emissions may be offset if the organics diversion program reduces waste transfer vehicle VMT. Users may translate VMT reductions (or increases) (G) to criteria pollutant emissions using emission factors from CARB's (2021) EMFAC model. Users should multiply the VMT reductions (or increases) by the appropriate vehicle emission factors. If the organics diversion program also reduces (or increases) the number of vehicle trips (i.e., J<H or J>H), users should quantify the resulting changes in process emissions using EMFAC.

Sources

- California Air Resources Board (CARB). 2021. *EMFAC*. Available: https://arb.ca.gov/emfac/. Accessed: September 2021.
- CalRecycle. n.d.(a) *Residential Waste Stream by Material Type*. Available: https://www2.calrecycle.ca.gov/WasteCharacterization/ResidentialStreams. Accessed: April 2021.
- CalRecycle. n.d.(b) *Disposal and Diversions Rates for Business Groups*. Available https://www2.calrecycle.ca.gov/WasteCharacterization/BusinessGroupRates. Accessed: January 2021.
- CalRecycle. n.d.(c) *Business Group Waste Stream Calculator*. Available https://www2.calrecycle.ca.gov/WasteCharacterization/BusinessGroupCalculator. Accessed: January 2021.
- CalRecycle. 2020. *2018 Facility-Based Characterization of Solid Waste in California.* Available https://www2.calrecycle.ca.gov/WasteCharacterization/Study. Accessed: January 2021.
- U.S. Environmental Protection Agency (U.S. EPA). 2020. Waste Reduction Model (WARM), Version 15. Available https://www.epa.gov/warm. Accessed: January 2021.

S-3. Require Edible Food Recovery Program Partnerships with Food Generators

GHG Mitigation Potential

99%

Up to 99% of GHG emissions associated with edible food waste

Co-Benefits (icon key on pg. 34)

Climate Resilience

Food recovery programs can have health benefits and improve community resilience. Additionally, food recovery conserves resources, reduces waste, and lowers methane emissions.

Health and Equity Considerations

Edible foods diverted from landfills and redistributed for consumption can increase community food security and improve the nutritional status of vulnerable populations.

Measure Description

This measure requires that food service establishments, wholesale providers, and retail sources of edible food waste partner with food recovery programs. Food recovery programs collect edible foods, which would otherwise be landfilled or composted, from commercial production and distribution channels and redistribute the food for consumption by those in need. This measure avoids emissions from the decomposition of non-diverted organic material in landfills. This measure's reductions are lifecycle emissions, as it results in reductions in up-stream and down-stream emissions, such as production and transportation related emissions.

Scale of Application

All—Project/Site and Plan/Community

Implementation Requirements

Implementation of this measure requires having data on the following: (1) total edible food recovered, (2) vehicle(s) used for the food recovery and total VMT, and (3) total square footage of the refrigeration systems used and type of refrigerants used.

Cost Considerations

Establishing edible food recovery program partnerships with food generators can generate costs from the collection of edible food. Specifically, edible recovery requires the use of vehicles that have maintenance and fuel costs, electricity costs from the use of large refrigeration systems, costs from refrigerant leakages and recharges, and in some cases, labor costs. However, edible food recovery programs can reduce food costs for households within a community and improve food security.

Expanded Mitigation Options

Pair with Measure E-10, *Procure Electricity from Lower Carbon Intensity Power Supply*, to ensure that the energy supplied to power the electrified equipment has a lower carbon intensity than the local grid, thereby further reducing GHG emissions. Also pair with Measure R-1, *Use Alternative Refrigerants Instead of High-GWP Refrigerants*, to ensure that refrigeration systems are responsible for less emissions and increase the benefit of this measure.

GHG Reduction Formula

$$A=\sum_{E}\left[\left(\frac{G\times H}{L}\right)+\left(\frac{I\times J\times K}{M}\right)\right]$$

$$B=\sum_{F}\left[\left((N\times O+P)\times\left(\frac{Q}{R\times M}\right)\right)+\left(\frac{S\times T\times U}{M}\right)\right]$$

$$C=-\left(\frac{V}{W}\right)\times X$$

$$D= C+ A + B$$

GHG Calculation Variables

ID	Parameter	Value	Unit	Source
Output				
A	GHG emissions from transportation vehicles	[ ]	MT CO_2e/year	calculated
B	GHG emission from refrigeration equipment	[ ]	MT CO_2e/year	calculated
C	GHG emission reductions from recovery of edible food	[ ]	MT CO_2e/year	calculated
D	Net GHG emissions from the recovery of edible foods	[ ]	MT CO_2e/year	calculated
User Inputs				
E	Number and type of identical delivery vehicle(s)	[ ]	unitless	user input and Table S-3.1
F	Number and type and number of identical refrigeration unit(s)	[ ]	unitless	user input and Table S-3.1
H	Average miles per year for the delivery vehicle(s)	[ ]	miles/year	user input
I	Leakage rate of the Transportation Refrigeration Unit (TRU), if applicable	[ ]	%	user input
J	The TRU refrigerant charge size, if applicable	[ ]	lbs/year	user input
N	Volume of refrigeration compartment	[ ]	ft^3	user input

ID	Parameter	Value	Unit	Source
T	Refrigerant charge size, if known	[ ] or Table S-3.1 (Appendix A)	lbs	user input or CARB 2020a
V	Amount of edible food recovered per year	[ ]	lbs	user input
How Constants, Assumptions, and Available Defaults				
G	Delivery vehicle GHG emission factor	Table T-30.2	g CO_2e per mile	CARB 2020b, 2020c, 2020d; U.S. DOE 2021
L	Grams to metric ton conversion factor	1,000,000	g/MT	conversion
K	GWP of refrigerant (default of R-134A is assumed for TRU)	Table R-1.1; default value is 1,430	unitless	IPCC 2007 and WMO 2018
M	Pounds to metric ton conversion factor	2,204.62	lbs/MT	conversion
O	Electricity consumption of refrigeration unit per year per cubic feet	Table S-3.1	kWh/year per ft^3	CARB 2020e and 10 CFR 431.66
P	Constant electricity consumption of a refrigeration unit per year	Table S-3.1	kWh/year	CARB 2020e and 10 CFR 431.66
Q	Carbon intensity of local electricity provider	Table E-4.3 and Table E-4.4	lbs CO_2e per MWh	CA Utilities 2021
R	Converting MWh to kWh	1,000	kWh/MWh	conversion
S	Annual Average Leakage rate per year of the refrigeration unit	Table S-3.1	%	CARB 2020e
U	GWP of refrigerant	Table R-1.1	unitless	IPCC 2007 and WMO 2018
W	Pounds to short ton conversion factor	2,000	lbs/ton	Conversion
X	Edible food waste recovery emission reduction factor (Landfill or Composting)	1.78 (Landfill) 1.49 (Composting)	MT CO_2e/ton	CARB 2020f and Venkat 2012

Further explanation of key variables:

- (E) – The type of delivery vehicles that are supported for this measure are provided in Table S-3.1 in Appendix A. The user will need to specify how many of the individual delivery vehicle types are being used and run different calculations for each different type of delivery vehicle. The equation cannot be run without specifying (1) the delivery vehicle from Table S-3.1, and (2) the number of delivery vehicles.
- (F) – The type of refrigeration units that are supported for this measure are provided in Table S-3.1 in Appendix A. The user will need to specify how many of the individual refrigeration unit types are being used and run different calculations for each different

type of refrigeration unit. The equation cannot be run without specifying the (1) type of refrigeration unit from Table S-3.1, and (2) the number of refrigeration units.

- (G) – This value is used to calculate the emissions generated by delivery vehicles transporting the recovered food. Delivery vehicle GHG emission factors (grams CO_2e per mile) are provided in Table T-30.2 in Appendix C.
- (H) – This input represents the number of miles traveled by the delivery vehicle(s) used to transport the recovered food.
- (I) – This value represents the rate at which refrigerants leak from the transportation refrigeration unit in the delivery vehicle.
- (J) – This value represents the quantity of refrigerants used in the delivery vehicles.
- (K) – This value is the GWP for the refrigerants used in the delivery vehicles. GWP values are provided in Table R-1.1 in Appendix C.
- (N) – This value represents the volume of the refrigeration compartment used to store the recovered food.
- (O) – This value is used to calculate the emissions generated by refrigeration units where the recovered food is stored. The electricity consumption of the refrigeration unit per year per cubic feet are provided in Table S-3.1 in Appendix A.
- (P) – This value is used to calculate the quantity of energy consumed in the refrigeration units. The constant electricity consumption of a refrigeration unit per year are provided in Table S-3.1 in Appendix A.
- (Q) – Electricity GHG emission factors for the different utilities inCalifornia are provided in Tables E-4.3 and Table E-4.4 in Appendix C.
- (S) – This value represents the rate at which refrigerants leak from the refrigeration unit.
- (T) – This value represents the quantity of refrigerants used to store the recovered food.
- (U) – This value is the GWP for the refrigerants used in the refrigeration storage units. GWP values are provided in Table R-1.1 in Appendix C.
- (X) – This value represents the lifecycle GHG emissions that are reduced from one short ton of recovered food from a landfill or from a composting facility.

GHG Calculation Caps or Maximums

Measure Maximum

None. However, it is possible that the GHG emissions from transportation and refrigeration use exceed the emission reduction from the edible food recovery, resulting in a disbenefit for this measure.

Example GHG Reduction Quantification

A food bank located in the City of Los Angeles with a 960 cubic feet commercial walk-in refrigerator with solid doors (F, N) is recovering edible food waste from local restaurants. Based on the collection in 2023, the food bank is estimating that it will be able to recover and donate approximately 25,000 pounds of edible food in 2025 from the local restaurants (V). The food bank will be using a gasoline refrigerated van (E) to recover the edible food. The food bank is anticipating that the total distance traveled per day is approximately 20 miles, or approximately 7,300 miles per year (H). Following the equations above, the recovery of the 25,000 pounds of edible food would result in a reduction of 5.98 $MTCO_2e$/year.

The following default values from tables in Appendix C are used.

- Carbon intensity of 556.3 grams CO_2e per mile for the gasoline refrigerated van (G).
- The average yearly leakage rate of 24 percent (RLeak), which is modeled as a percentage in the formula (i.e., 0.24).
- The average yearly refrigerant charge size of 4 lbs (J).
- The global warming potential (GWP) of 1,430 for R-134A (K).
- The electricity consumption per year per cubic foot of 36.5 kWh/year/ft^3 for the commercial refrigerator with solid doors (O).
- The yearly constant electricity consumption of 744.6 kWh/year (P).
- The Los Angeles Department of Water & Power carbon intensity of electricity of 694 lbs CO_2e per MWh (Q).
- The leakage rate of 15 percent for commercial refrigerators (S).
- The average yearly refrigerant charge size of 31.4 pounds (T).
- The GWP of 150 for refrigeration unit refrigerants (U) was assumed.
- The edible food waste recovery emission reduction factor of 1.78 MT CO_2e /ton (X).

$$A=\sum_{1}\left[\left(\frac{556.3 \text{ g } CO_2e/\text{mi} \times \mathbf{7{,}300 \text{ mi/year}}}{1{,}000{,}000 \text{ g/MT}}\right)+\left(\frac{\mathbf{0.24} \times \mathbf{4 \text{ lbs/yr}} \times 1{,}430}{2{,}204.62 \text{ lbs/MT}}\right)\right]$$

$A = 4.68\ MTCO_2e/yr$

$$B=\sum_{1}\left[\left(\left((\mathbf{960ft^3} \times 36.5 \text{ kWh/year/ft}^3)+744.6 \text{ kWh/year}\right) \times \left(\frac{694 \text{ lbs } CO_2e/\text{MWh}}{2{,}204.62\frac{\text{lbs}}{\text{MT}} \times 1{,}000 \text{ kWh/MWh}}\right)\right)+\left(\frac{0.15 \times \mathbf{31.4 \text{ lbs/year}} \times 150}{2{,}204.62 \text{ lbs/MT}}\right)\right]$$

$B = 11.59\ MTCO_2e/year$

$$C=-\left(\frac{\mathbf{25{,}000 \text{ lbs}}}{2{,}000 \text{ lbs/ton}}\right) \times 1.78$$

$C = -22.25\ MTCO_2e/year$

$D = -22.25\ MTCO_2e/year + 4.68\ MTCO_2e/year + 11.59\ MTCO_2e/year$

$D = -5.98\ MTCO_2e/year$

Quantified Co-Benefits

Improved Air Quality

Edible food recovery may improve air quality emissions by reducing the total amount of organic waste that would be flared at a local landfill, by reducing electricity demand, and by reducing transportation emissions from collecting food waste and transporting waste to a landfill.

Criteria Pollutant Emission Reduction Formula

$$A2=\sum_{E}\left[\left(\frac{G\times H}{I}\right)\right]$$

$$B2=\sum_{F}((J\times K+L)\times M)$$

$$C2=-\left(\left(\frac{N}{O}\right)\times P\right)+\left(\left(\frac{N}{O}\right)\times Q\right)$$

$$D2=C2+A2+B2$$

Criteria Pollutant Emissions Increase Calculation Variables

ID	Parameter	Value	Unit	Source
Output				
A2	Air quality emissions from transportation vehicles	[ ]	lbs/year	calculated
B2	Air quality emission from refrigeration equipment	[ ]	lbs/year	calculated
C2	Air quality emission reductions from recovery of edible food	[ ]	lbs/year	calculated
D2	Air quality emissions from the recovery of edible foods	[ ]	lbs/year	calculated
User Inputs				
E	Number and type of identical delivery vehicle(s)	[ ]	unitless	user input and Table S-3.1
F	Number and type of identical refrigeration unit(s)	[ ]	unitless	user input and Table S-3.1
H	Average miles per year for the delivery vehicle(s)	[ ]	miles/year	user input
J	Volume of refrigeration compartment	[ ]	ft^3	user input
N	Amount of edible food rescued	[ ]	lbs	user input
How Constants, Assumptions, and Available Defaults				
G	ROG, NOX, PM2.5, and diesel PM10 exhaust emission factors	EMFAC2021	g/miles	CARB 2023
I	Grams to pounds conversion factor	453.6	g/lbs	conversion
F2	Type of refrigeration units	Table S-3.1	unitless	CARB 2020b
K	Electricity consumption of refrigeration unit per year per feet	Table S-3.1	kWh/year per ft^3	CARB 2020b
L	Constant electricity consumption of a refrigeration unit per year	Table S-3.1	kWh/Year	CARB 2020b
M	Electricity air quality emission factor	Table S-3.2	lbs/kWh	CAPCOA 2021
O	Pounds to short ton conversion factor	2,000	lbs/ton	conversion
P	Avoided transportation for food waste emissions reduction factor	Table S-3.2	lbs/ton	CARB 2020b
Q	Avoided landfill flare emission reduction factor	Table S-3.2	lbs/ton	CARB 2020b

Sources

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Natural and Working Lands

Natural and working lands may be a GHG sink or source of GHG emissions. For example, trees and other vegetation incorporate carbon into their biomass during their growth phase and thereby can remove a finite amount of carbon from the atmosphere. Carbon can also be stored in soils. These types of natural lands are considered GHG sinks. Other types of lands, on the other hand, such as certain types of agriculture and animal operations, can emit GHGs from a variety of sources and activities.

Measures within the natural and working lands sector aim to enhance the sequestration capacity of the land, reduce the intensity of emissions from GHG sources, or reduce emissions associated with the use of off-road equipment on agricultural land. A project can increase the area available for vegetation by converting previously developed land into vegetated open space. Conversions from one type of vegetated land to another may increase or decrease carbon sequestration, depending on the relative sequestration capacities of the land types. Additional ways to increase sequestration may include planting new trees on either developed or undeveloped land. GHG emission from working lands can be reduced through climate-smart farming practices, some of which may increase below- and above-ground carbon storage. For users in wildfire-prone areas, projects can reduce GHG emissions from wildfire events by managing forested areas in specific ways to lessen the potential for severe wildfire activity. Finally, emissions from equipment used on agricultural lands can be reduced by replacing diesel-powered equipment with electric or hybrid-electric equipment.

Natural and Working Lands

- N-1. Create New Vegetated Open Space
- N-2. Expand Urban Tree Planting
- N-3. Implement Management Practices to Improve the Health and Function of Natural and Working Lands
- N-4. Require Best Management Practices for Manure Management
- N-7. Wildfire Resilience and Management
- N-8. Agricultural Equipment Efficiency

Methods to quantify GHG reductions from natural and working lands measures are inherently complex given the dynamic variables that influence GHG emissions. These methods do not lend to a simplified quantification approach that can be presented in a few pages. Therefore, it is advised users rely on existing tools to quantify GHG reductions as referenced in this section. Additional measures that can be undertaken to reduce emissions within the natural and working lands sector include establishing a local farmer's market or community garden. Please refer to *Supporting or Non-Quantified GHG Reduction Measures* for additional information on these measures.

Use the below graphic to click on an individual measure to navigate directly to the measure's factsheet.

N-1. Create New Vegetated Open Space

Photo Credit: Doug Donaldson, March 2017

GHG Mitigation Potential

Varies

Variable reduction in GHG emissions from vegetated open spaces

Co-Benefits (icon key on pg. 34)

Climate Resilience

Creating new vegetated open spaces can reduce the urban heat island effect, mitigate flooding, and improve water quality, as well as provide recreational spaces that improve health and community resilience. Vegetated open space can also provide wildlife habitat and corridors for wildlife migration in the face of increasing temperatures and changing precipitation patterns.

Health and Equity Considerations

Prioritize open space creation in communities that have the lowest level of access to parks, gardens, and open spaces.

Measure Description

This measure would convert previously developed areas to vegetated open spaces. By creating new vegetated areas from previously settled land, the project would sequester CO_2 that would not have been captured without the land conversion. Trees and other vegetation also incorporate carbon into their biomass during their growth phase (stored carbon).

Scale of Application

Project/Site and Plan/Community

Implementation Requirements

Implementation must involve conversion of cleared areas to vegetated open spaces. This measure does not give any GHG reduction for the preservation of existing lands.

Cost Considerations

Upfront costs of creating more green spaces will depend on how the land is currently being used and how much construction is required to make it suitable. However, vegetated open spaces can achieve cost savings from improved storm water management, and can also reduce the incidence and cost of heat exposure and pollution-related illnesses.

Expanded Mitigation Options

A best practice for creating new open spaces is to ensure the habitat type(s) are native or will thrive in the local climate.

GHG Reduction Formula

RePlan

Users are directed to the California Strategic Growth Council's (2021) *RePlan: Regional Conservation and Development Planning Tool* (RePlan). RePlan provides an estimate of total stored carbon throughout California. The tool was developed using CARB's Natural and Working Lands (NWL) inventory method. Users can identify total stored carbon across five geographic scales: statewide, ecoregion, county, watershed, and user-drawn polygon for a specific area. Based on the scale selected, RePlan returns the metric tons (equivalent to megagrams, as used by RePlan) of stored carbon per hectare (ha). The carbon storage value is representative of current conditions, per CARB's inventory and the analysis conducted by the Strategic Growth Council. The result is not an annual accumulation value or sequestration rate.

Users converting previously developed areas to vegetated open spaces can use RePlan to obtain estimated total ecosystem carbon storage on parcels within the same general area of the project that contain similar land cover types. RePlan can also be used to estimate existing stored carbon (if any) on the project site that will be converted to the new land cover type. Existing stored carbon on the project site should be subtracted from the estimated carbon storage of the future land use type.

Alternative Quantification Method

RePlan integrates the latest planning and environmental data to support robust quantification of carbon storage throughout the state. The tool is aligned with California's conservation, resource management, and development objectives. While RePlan is recommended as the primary quantification tool for this measure, users may consult the below equation and method to generate a high-level estimate of stored soil carbon plus above and belowground biomass carbon pools, which can serve as an estimate of total CO_2 stored.

$$A = [(B_C \times C_C) + (B_S \times C_S \times D)] \times E$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	CO_2 benefit from new land cover type (soil and above and belowground carbon storage)	[ ]	MT CO_2e per year (over accumulation period)	calculated
User Inputs				
B_C	Hectare (Ha) of land-by-land cover type	[ ]	ha	user input
B_S	Ha of land by soil type	[ ]	ha	user input
Constants, Assumptions, and Available Defaults				
C_C	Annual above and belowground biomass carbon accumulation by land cover type	Table N-1.1	MT carbon per ha per year	CARB 2021a
C_S	Annual soil carbon accumulation by soil type and land use type	Table N-1.2	MT carbon per ha per year	CARB 2020a

ID	Variable	Value	Unit	Source
D	Soil carbon gain from conversion from settlements to vegetated land	30	%	CARB 2020a
E	Molecular weight ratio of CO_2 to carbon	44/12	MT CO_2 to MT carbon	assumed

Further explanation of key variables:

- (A) – If the existing land use type currently generates CO_2e or includes soil carbon plus above or belowground stored carbon, those emissions should be added or removed, respectively, from the CO_2e reduction quantified under this measure.
- (B_C) – The land cover types are based on those defined in CARB's NWL inventory.
- (B_S) – The soil types and land use types are based on those defined in CARB's *Benefits Calculator Tool for Agricultural Lands Conservation* (CARB 2020a). The soil type for the project area can be obtained from UC Davis' SoilWeb (UC Davis n.d.). CARB's *Agricultural Lands Conservation Easement Quantification Methodology* provides detailed instructions for using this tool (CARB 2020b).
- (C_C) – Average annual above or belowground stored carbon accumulation rates per ha of land cover type and air basin are provided in Table N-1.1 in Appendix C, *Emissions Factors and Data Tables*. These rates include above and belowground carbon storage in biomass pools. They were developed by CARB (2021a) from their NWL inventory. The rates have been annualized over the following accumulation periods.
  - Forest = 60 years. This is the median project duration under the California Climate Investments Forest Health Quantification Method for the California Department of Forestry and Fire Protection's Forest Health Program. The median project duration represents one stand rotation, which is the typical time to harvest (CARB 2021b).
  - Grasslands = 20 years. This represents the typical amount of time for restored grasslands on former agricultural sites to accumulate the same amount of biomass carbon as native grasslands (Matamala et al. 2008).
  - Shrublands = 35 years. This rate represents the average frequency of wildfires in Southern California Chaparral systems (Luo et al. 2007).
- (C_S) – Average annual soil carbon accumulation rates per ha of land use type are provided in Table N-1.2 in Appendix C (CARB 2020a). The rates have been annualized over a 20-year accumulation period, consistent with IPCC's (2006) GHG inventory framework.

GHG Calculation Caps or Maximums

None. If the existing land use cover currently includes stored carbon, and that value exceeds that of the new land cover type, this measure may result in a GHG emissions increase.

Example GHG Reduction Quantification

The user reduces GHG emissions by converting 20 ha of developed area to Broadleaf Forest (B_C) with a Spodosols (B_S) soil type. The project is in the Lake Tahoe Air Basin where the resulting annual average above and belowground biomass carbon accumulation per ha is 1.69 MT (C_C). The annual average carbon stock per ha is 5.89 MT (C_S). The resulting CO_2e reduction is 254 MT per year.

$$A = \left[\left(\mathbf{20\ ha} \times 1.69\ \frac{\text{MT carbon}}{\text{ha}\cdot\text{yr}}\right) + \left(\mathbf{20\ ha} \times 5.89\ \frac{\text{MT carbon}}{\text{ha}\cdot\text{yr}} \times 30\%\right)\right] \times \frac{44}{12}\frac{\text{MT CO}_2}{\text{MT carbon}} = 254\ \frac{\text{MT CO}_2\text{e}}{\text{yr}}$$

Quantified Co-Benefits

None quantified. Depending on the land cover type created, successful implementation of this measure could achieve improved air quality, improved public health, and improved ecosystem health.

Sources

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N-2. Expand Urban Tree Planting

GHG Mitigation Potential

Varies

Variable reduction in GHG emissions from urban tree planting

Co-Benefits (icon key on pg. 34)

Climate Resilience

Planting trees provides more shade, reducing the urban heat island effect and localized health impacts of higher temperatures. Trees can also help to improve stormwater management and air quality and support mental health and social resilience.

Health and Equity Considerations

Tree planting should be prioritized in areas that have lower levels of existing canopy. Tree-planting programs should be designed in collaboration with residents. This ensures not only that community preferences are considered, but that the community feels ownership over the trees and is more likely to participate in long-term tree care. Trees should be selected according to local preferences, such as avoiding high-pollen trees that may exacerbate allergies.

Measure Description

This measure requires tree planting in urban areas. Planting trees sequesters CO_2 while the trees are actively growing, thereby reducing GHGs. The amount of CO_2 sequestered depends on the type of tree and the duration of the active growing period. Urban trees may also provide shade, which can reduce the urban heat island effect and building cooling demands. Buildings that use less electricity for air conditioning reduce energy consumption and associated indirect GHG emission.

Given many parts of California are in dry climates, the selection of tree type is critical to minimize the use of additional water. Trees that have high water demands that are met through GHG-intensive water (such as water transported over long distances) can impact the amount of GHG reductions achieved by this measure. Nonetheless, even during times of drought, trees help to provide multiple benefits to communities, and state agencies as well as natural resource organizations have emphasized repeatedly the importance of watering and maintaining trees during droughts.

Scale of Application

Project/Site and Plan/Community

Implementation Requirements

See measure description.

Cost Considerations

Upfront costs of planting more urban trees will depend on how the land is currently being used and how much maintenance and assistance in growing the trees will need to be successful. However, urban trees can reduce the incidence and cost of heat exposure and pollution-related illnesses by reducing the urban heat island effect and filtering pollutants from the air and soil.

Expanded Mitigation Options

Best practices for urban tree planting programs include selecting native tree species that require minimal water and maintenance, planting low-biogenic VOC emitting and low-allergen trees, and appropriately distancing trees from buildings, especially in high fire areas.

GHG Reduction Formula

Users are directed to the U.S. Forest Service (USFS) (2021) i-Tree Planting tool. The i-Tree Planting tool quantifies increased carbon sequestration from urban tree planting using species-based biomass equations that account for user defined site-specific variables and tree growth rates. The tool also quantifies GHG reductions from energy savings (e.g., kWh), if applicable.

While simplified quantification methods for increased carbon sequestration resulting from urban tree planting have been used in the past, this Handbook does not recommend their application given the number and dynamic nature of variables that can influence the amount of CO_2 reduced. Tools like i-Tree Planting comprehensively account for these variables, enabling users easily to calculate the approximate benefits from individual trees.

The i-Tree Planting tool is available at: https://planting.itreetools.org/.

Depending on the scale of the project, users may also wish to consult other i-Tree tools, including i-Tree Design (https://design.itreetools.org/), i-Tree Canopy (https://canopy.itreetools.org/), and i-Tree County (https://county.itreetools.org/). Users may consult the Climate Action Reserves' *Urban Tree Planting Project Protocol* (CAR 2014) or CARB's *Quantification Methodology for Urban and Community Forestry Program* (CARB 2020).

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	CO_2 sequestered over project lifetime	[ ]	lb CO_2	calculated
B	CO_2 reduced from building energy savings over project lifetime	[ ]	lb CO_2	calculated
User Inputs				
C	Project state/province	[ ]	address	user input
D	Project county/division	[ ]	Text	user input
E	Project city	[ ]	Text	user input
F	Project lifetime	1–99	Years	user input
G	Tree mortality over project lifetime	0–100	%	user input
H	Tree species planted by the project	[ ]	species name	user input*
I	Diameter breast height of each tree	[ ]	Inches	user input*
J	Distance to the nearest building	[ ]	Feet	user input*
K	Direction of tree from the building	[ ]	degrees	user input*
L	Building vintage	[ ]	Text	user input*
M	Building climate controls	[ ]	Text	user input*
N	Tree condition	[ ]	Text	user input*
O	Tree exposure to sunlight	[ ]	Text	user input*
Constants, Assumptions, and Available Defaults				
Q	Carbon intensity of local electricity provider	Table E-4.3 Table E-4.4	lb CO_2e per MWh	CA Utilities 2021
R	Carbon intensity of natural gas	117	lb CO_2e per MMBtu	TCR 2020

* Inputs provided through a drop-down menu.

Further explanation of key variables:

- (A and B) – The GHG reductions are presented over the project lifetime. If users are seeking an annualized value, they will need to divide this result by the assumed project lifetime (F).
- (F) – Trees sequester CO_2 while the trees are actively growing. The i-Tree Planting tool will project the benefits for up to 99 years into the future. The tool defaults to 40 years.
- (G) – The i-Tree Planting tool will incorporate tree mortality into the projected benefits.
- (I) – The diameter of the trunk measured at 4.5 feet above the ground.
- (J) – For trees that will be planted to shade buildings, enter the distance class to the nearest building (0–19 feet, 20–39 feet, 40–59 feet, > 60 feet). Note that this could be a building on an adjacent site. The i-Tree tool will not calculate shade benefits (i.e., energy savings) for trees more than 60 feet away from the building.
- (K) – General direction of the tree from the building (e.g., north 0 degrees). This input can be ignored if the tree is more than 60 feet from the building.
- (L) – The age of the building affects its energy efficiency and therefore the potential benefits the trees can bring. Available inputs are built after 1980, built 1950–1980, and built before 1950. If the specific age of the building in unknown, the user can input the typical age of buildings for the area where the user is working. This input can be ignored if the tree is more than 60 feet from the building.
- (M) – Trees can only have an impact on energy use in buildings where energy is used to heat or cool. Available inputs are heating and air conditioning (A/C), heat only, A/C only, and none. If the climate controls of the building are unknown, the user can input the option that is most common for the area where the user is working. This input can be ignored if the tree is more than 60 feet from the building.
- (N) – The condition of the trees will affect how well they grow and thus future benefits. Available inputs are excellent, good, fair, poor, critical, dying, and dead. New plantings are likely to be excellent.
- (O) – The exposure to sunlight affects both how the trees grow and the degree to which a new tree adds shade to a building. Available inputs are full sun, partial shade, and full shade.
- (Q) – GHG intensity factors for major California utilities are provided in Tables E-4.3 and E-4.4 in Appendix C. If the project study area is not serviced by a listed electricity provider, or the user is able to provide a project-specific value (i.e., for a future year not referenced in Tables E-4.3 or E-4.4), the user should use that specific value. If the electricity provider is not known, the user may elect to use the statewide grid average carbon intensity or rely on the i-Tree Planting default.
- (R) – The carbon intensity of natural gas was calculated in terms of CO_2e by multiplying the U.S. natural gas combustion emission factors for CO_2, CH_4, and N_2O (TCR 2020) by the corresponding 100-year GWP values from the IPCC's Fourth Assessment Report (IPCC 2007). See Table E-4.5 in Appendix C for more natural gas emission factors.

GHG Calculation Caps or Maximums

None.

Example GHG Reduction Quantification

The user reduces emissions by planting shade trees at a new home site. In this example, the project is in the City of Sacramento (E)/Sacramento County (D)/California (C). The electricity provider for the project area is SMUD, and the analysis year is 2022. The carbon intensity of electricity is, therefore, 344 lb CO_2e per megawatt-hour (Q). The project lifetime is 40 years (F) and expected tree morality 10 percent (G). The project will plant two (P) live oaks (H) with a diameter breast height of 4 inches (I). The trees are 0 to 19 feet from the nearest building (J) and oriented east 90 degrees (K). The building was built between 1950 and 1980 (L) and includes heat and A/C (M). The tree condition is excellent (N) and has full sunlight (O). Based on these inputs to the i-Tree Planting tool, over the project lifetime, the trees would sequester 16,045 lb of CO_2 and reduce 6,787 lb of CO_2 from building energy savings. This totals 22,832 pounds of CO_2, or 571 pounds CO_2 per year (based on 40-year project lifetime).

Quantified Co-Benefits

The i-Tree tool outputs electricity savings (kWh), fuel savings (MMBtu), avoided runoff (gallons), and criteria pollutant emissions reductions (pounds). All values are over the project lifetime. Note that depending on user inputs, the measure may result in increased fuel consumption (MMBtu) from building shading in the winter.

Sources

- California Air Resources Board (CARB). 2020. *Quantification Methodology for Urban and Community Forestry Program*. California Climate Investments. Version 2.0. January. Available: https://ww2.arb.ca.gov/sites/default/files/classic//cc/capandtrade/auctionproceeds/calfire_ucf_finalqm_012820.pdf?_ga=2.67722641.1011230202.1624305360-1883459709.1621467679. Accessed: June 2021.
- California Utilities. 2021. Excel database of GHG emission factors for delivered electricity, provided to the Sacramento Metropolitan Air Quality Management District and ICF. January through March 2021.
- Climate Action Reserve. 2014. *Urban Tree Planting Project Protocol*. Version 2.0 June. Available: https://www.climateactionreserve.org/wp-content/uploads/2014/07/Urban_Tree_Planting_Project_Protocol_V2.0.pdf. Accessed: June 2021.
- Intergovernmental Panel on Climate Change (IPCC). 2007. *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp. Available: https://www.ipcc.ch/report/ar4/wg1/. Accessed: January 2021.
- The Climate Registry (TCR). 2020. *2020 Default Emission Factor Document*. April. Available: https://www.theclimateregistry.org/wp-content/uploads/2020/04/The-Climate-Registry-2020-Default-Emission-Factor-Document.pdf. Accessed: January 2021.
- U.S. Forest Service (USFS). 2021. i-Tree Planting Calculator. Available: https://planting.itreetools.org/. Accessed: January 201.

N-3. Implement Management Practices to Improve the Health and Function of Natural and Working Lands

GHG Mitigation Potential

Varies

Variable reduction in GHG emissions from natural and working lands

Co-Benefits (icon key on pg. 34)

Climate Resilience

Improving the health and function of natural and working islands can reduce the urban heat island effect and flooding and improve water quality, as well as provide recreational spaces that improve health and community resilience. Improving natural and working lands can also provide habitat in which wildlife can live and through which it can migrate in the face of increasing temperatures and changing precipitation patterns.

Health and Equity Considerations

Some management practices can reduce the use of pesticides and herbicides, which can reduce exposure to farmworkers and their families.

Measure Description

This measure covers a broad range of management strategies aimed at improving the overall health and functionality of natural and working lands as a mechanism for increasing carbon sequestration and reducing GHG emissions. Management practices may include those that change ecosystem carbon exchange rates (e.g., cultivated land soil conservation, use of biochar) and those that involve land cover changes.

Scale of Application

Plan/Community

Implementation Requirements

Note that this measure is only applicable to users with land management authority.

Cost Considerations

Overall, improved land management reduces net expenses drastically. Practices designed for maximum land health reduce costs related to inputs, irrigation, and damage from extreme weather, and preserve ecosystems and animal life.

Expanded Mitigation Options

See the *GHG Reduction Formula* section below for online tools to quantify GHG reductions from various conservation practices and management strategies. For agricultural applications, consider developing a Carbon Farm Plan to comprehensively evaluate all elements of your land management strategy.

GHG Reduction Formula

Users are directed to the U.S. Department of Agriculture (2021) COMET-Planner Tool (COMET-Planner) and USFS (2021) Forest Vegetation Simulator (FVS). COMET-Planner is a California-specific tool that was developed for the California Department of Food and Agriculture Heathy Soils Program. COMET-Planner should be used to quantify GHG reductions from conservation practices on cropland, orchard and vineyards, and grazing land. The FVS should be used to quantify GHG reductions from forest management.

GHG Calculation Caps or Maximums

None.

Example GHG Reduction Quantification

The user reduces emissions by implementing grazing management to improve irrigated pasture conditions. The user consults COMET-Planner to quantify the estimated reductions. The project is in Napa County. The user selects "Grazing" for the agricultural system, "Prescribed Grazing" for the conservation practice standard, and "Grazing Management to Improve Irrigated Pasture Condition" for the conservation practice implementation. The practice would be applied to 25 acres. Based on these inputs, the user will reduce GHG emissions by 2 MT CO_2e per year (USDA 2021).

Quantified Co-Benefits

None quantified. Depending on the management strategy, successful implementation of this measure could achieve improved air quality, water conservation, improved public health, and improved ecosystem health.

Sources

- U.S. Department of Agriculture (USDA). 2021. COMET-Planner. Available: http://www.comet-planner-cdfahsp.com/. Accessed: March 2021.
- U.S. Forest Service Forest (USFS). 2021. Forest Vegetation Simulator (FVS). Available: https://www.fs.fed.us/fvs/index.shtml. Accessed: March 2021.

N-4. Require Best Management Practices for Manure Management

GHG Mitigation Potential

Varies

Variable reduction in GHG emissions from manure management practices

Co-Benefits (icon key on pg. 34)

Climate Resilience

Improving manure management can improve water and air quality, thereby improving community health and resilience. Depending on the alternative management practice, it can also increase the amount of compost produced, which can go toward gardens and farms and help improve soil health as well as food and crop production.

Health and Equity Considerations

Fertilizer and manure are major causes of groundwater contamination in California, especially in the Central Valley. Improved manure management can help to improve water quality for rural and vulnerable communities.

Measure Description

This measure will require best management practices for the management of manure from livestock. Well-managed pasture systems and aerobic dry composting systems tend to have lower emissions, while anaerobic wet handling systems generate more CH_4. This measure is thus intended for manure collection systems that are currently managed by anaerobic decomposition of manure volatile solids stored in a lagoon or other predominantly liquid anaerobic environment. Utilizing alternative practices to manage manure results in reduced agriculture emissions from livestock by decreasing the amount of volatile manure solids that are stored in wet, anaerobic conditions.

Scale of Application

Project/Site and Plan/Community

Implementation Requirements

Emission reductions can only be quantified for projects with existing manure management practices that include the anaerobic decomposition of manure volatile solids stored in a lagoon or other predominantly liquid anaerobic environment.

Cost Considerations

Incorporating best practices for manure management may entail initial costs to build the related storage and processing ability. Cost savings come in the form of reduced need for inputs like fertilizer if the manure is used on site and avoided water pollution and greenhouse gas emissions.

Expanded Mitigation Options

See the *GHG Reduction Formula* section below for tools to quantify GHG reductions from various alternative manure management practices.

GHG Reduction Formula

Users are directed to CARB's (2021) *Benefits Calculator Tool for the Alternative Manure Management Program* (AMMP tool). The AMMP tool quantifies GHG reductions from livestock manure management based on user-entered parameters, including the livestock type, number of cattle, the type of existing manure collection system, and the user's chosen alternative type of manure collection system. The AMMP tool is only applicable to users who have existing manure management practices that include the anaerobic decomposition of manure volatile solids stored in a lagoon or other predominantly liquid anaerobic environment.

The user can choose from many alternative manure management practices, such as pasture-based management, and various methods of solid separation and scrape conversion. The tool also quantifies GHG reductions from energy savings (e.g., MWh, diesel fuel gallons), if applicable.

Because of the wide range of manure management practices, which corresponds to GHG calculations that have many user-entered variables that influence the amount of GHGs reduced, this Handbook recommends that users use the AMMP tool directly. Tools like AMMP comprehensively account for these variables, enabling users easily to calculate the approximate benefits that each manure management practice will achieve.

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	GHGs reduced from alternative manure management	[ ]	MT CO_2e	calculated
User Inputs				
B	Project county	[ ]	text	user input
C	Type of alternative manure management practice to be adopted	[ ]	text	user input
D	Existing livestock by category	[ ]	text & number of livestock	user input
E	Existing manure collection practices	[ ]	text	user input
F	Existing number of months livestock spend at pasture	0–12	months	user input
G	Existing solid-separation and secondary solid separation	[ ]	text	user input
H	Existing storage/treatment practice for separated solids	[ ]	text	user input
I	Specification of milk produced, if applicable	[ ]	%	user input
J	Existing electricity consumption from manure management activities	[ ]	MWh per year	user input
K	Existing diesel fuel consumption from manure management activities	[ ]	gallons per year	user input
L	Alternative number of months livestock spend at pasture	0–12	months	user input

ID	Variable	Value	Unit	Source
M	Alternative solid-separation and secondary solid separation	[ ]	text	user input
N	Estimated alternative electricity consumption from alternative manure management activities	[ ]	MWh per year	user input
O	Estimated alternative diesel fuel consumption from alternative manure management activities	[ ]	gallons per year	user input
P	List of stationary and mobile sources associated with manure management activities	[ ]	text	user input
Constants, Assumptions, and Available Defaults				
	None			

Further explanation of key variables:

- (A) – The GHG reductions achieved by the implementation of alternative manure management practices are calculated by the AMMP tool. On the GHG Summary tab of the AMMP tool, the GHG reduction is given for a 5-year period. Thus, if the user would like to know the annual number of reductions, that value can be found on the For Technical Reviewers tab of the tool, or by simply dividing the 5-year reduction by 5.

  For more information on the inputs for the AMMP tool, users should refer to the AMMP tool user guide, which provides technical details on the input parameters of the tool (CARB 2019).

GHG Calculation Caps or Maximums

None.

Example GHG Reduction Quantification

The user's livestock operation in Sonoma County (B) currently has 400 lactating dairy cows in freestalls, 100 dry cows, and 100 grazing heifers (D). The current manure management technique has a flush system for freestalls and milking parlors (E), and all cattle are at pasture for 9 months per year (F, L). There is no solid separation currently, and this will not change for the alternative practices (G, H, M). The current energy consumption is 200 MWh per year of electricity (J) and 600 gallons per year of diesel fuel (K). The average milk production is 55 lbs per day per cow, with 3.75 percent milk fat, 3 percent true protein, and 4.9 percent lactose (I). The alternative manure management practice will involve the installation of a new compost bedded pack barn (C). With the alternative manure management practices, electricity consumption will be reduced to 150 MWh per year (N), and diesel consumption will increase to 1,200 gallons per year (O). Based on these inputs, the user will reduce GHG emissions by 2,720 MT CO_2e for five years, or 544 MT CO_2e per year. This example is taken from the AMMP tool user guide (CARB 2019).

Quantified Co-Benefits

The AMMP tool calculates criteria pollutant reductions (lb), fuel savings (gallons of diesel), and soil health benefits (tons of compost production). All values are over a 5-year project life.

Sources

- California Air Resources Board (CARB). 2019. *User Guide–California Department of Food and Agriculture Alternative Manure Management Program*. Available: https://ww2.arb.ca.gov/sites/default/files/classic//cc/capandtrade/auctionproceeds/cdfa_ammp_final userguide_2-8-19.pdf. Accessed: January 2021.
- California Air Resources Board (CARB). 2021. CCI Quantification, Benefits, and Reporting Materials. Available: https://ww2.arb.ca.gov/resources/documents/cci-quantification-benefits-and-reporting-materials. Accessed: January 2021.

N-7. Wildfire Resilience and Management

GHG Mitigation Potential

Varies

Variable reduction in GHG emissions from natural and working lands

Co-Benefits (icon key on pg. 34)

Climate Resilience

Wildfire resilience and management techniques can reduce wildfire risk, enhance post-wildfire recovery, and improve air quality. This measure could also improve the health and function of natural lands, which reduces the urban heat island effect and flooding, improves water quality, and provides recreational spaces that improve health and community resilience. Increasing wildfire resilience and management can also protect wildlife habitat and migration corridors in the face of increasing temperatures and changing precipitation patterns.

Health and Equity Considerations

Programs to reduce wildfire smoke exposure should consider and address any impacts on vulnerable populations, including outdoor workers and the unhoused, who are disproportionately exposed to wildfire smoke.

Expanding Indigenous cultural burns across forested lands could promote sustainable forest growth and make forests more resilient.

Measure Description

This measure involves implementing fuel treatments in forested areas to minimize the likelihood of severe or catastrophic wildfire behavior, thereby minimizing pyrogenic carbon emissions during a wildfire event. The vast majority of carbon emissions from wildfire events originate from live tree biomass that primarily exists in the overstory canopy. Implementing fuel treatments has the short-term effect of releasing more carbon emissions as understory, ladder fuels, and forest fuel loads are burned. However, in the long term, treated stands produce fewer emissions compared to untreated stands because treated stands produce low to moderate fire severity that does not disturb the carbon stock in the overstory canopy. Untreated stands are far more likely to experience severe behavior that ignites the canopy and releases the stored carbon in the overstory.

Scale of Application

Project/Site and Plan/Community

Implementation Requirements

See measure description.

Cost Considerations

The costs of implementing fuel treatment applications in forested woodlands varies widely based on the size and accessibility of the treatment area, the amount and type of surface fuels, the specific treatment method(s) employed and underlying topographic characteristics. While costs associated with fuel treatment implementation can be significant, particularly for large scale projects, they may be offset by a variety of grant funding available at the federal and state levels for managing surface fuels to minimize wildfire hazards.

Expanded Mitigation Options

This measure can be paired with Measure N-3, *Implement Management Practices to Improve the Health and Function of Natural and Working Lands,* to comprehensively improve the health of natural and working lands. In some cases, this measure could be paired with Measure E-26, *Biomass Energy,* because some types of fuel removed from the understory during measure implementation could provide biomass energy fuel, if facilities are in close proximity.

GHG Reduction Formula

Although this measure is quantifiable, the methods to quantify the measure are complex and require a substantial amount of computation that cannot reasonably be completed manually. For these reasons, no GHG reduction methods are included here, but users can use CalEEMod to quantify reductions associated with the measure.

Quantified Co-Benefits

None quantified. Successful implementation of this measure could achieve improved air quality, improved public health, and improved ecosystem health.

Sources

- Fargione, J. E., Bassett, S., Boucher, T., Bridgham, S. D., Conant, R. T., Cook-Patton, S. C., et al. (2018). Natural climate solutions for the United States. Sci. Adv. 4, eaat1869. Available: Natural climate solutions for the United States | Science Advances.
- C. Wiedinmyer, M. D. Hurteau, Prescribed fire as a means of reducing forest carbon emissions in the western United States. Environ. Sci. Technol. 44, 1926–1932 (2010). Available: Prescribed Fire As a Means of Reducing Forest Carbon Emissions in the Western United States | Environmental Science & Technology (acs.org).

N-8. Agricultural Equipment Efficiency

GHG Mitigation Potential

Large

Potentially large reduction in GHG emissions from agricultural equipment

Co-Benefits (icon key on pg. 34)

Climate Resilience

Improving agricultural equipment efficiency through use of electric- or hybrid-powered equipment can reduce sensitivity to fuel price shocks or scarcity in conventional fuels. However, using all-electric equipment may decrease resilience if it is the only option available during a power outage.

Health and Equity Considerations

Replacing diesel and gas-powered equipment with cleaner-fuel or electric equipment reduces the risk of pollutant-related health conditions and effects related to noise pollution for the user and surrounding communities.

Measure Description

This measure requires use of electric- or hybrid-powered, off-road agricultural equipment over conventional diesel-fueled counterparts during agricultural activities. Replacing diesel-powered, off-road agricultural equipment with electric or hybrid-electric equipment reduces fossil fuel combustion and thus GHG emissions. However, all-electric equipment results in GHG emissions from the electricity used to charge the equipment. The indirect GHG emissions increase from electricity must be calculated in addition to the GHG emissions reduction from displaced fossil fuel combustion to estimate the total net GHG emissions reduction achieved by this measure if using all electric-powered equipment. Variations of this measure are described in Measure C-1-A, *Use Electric or Hybrid Powered Equipment*, Measure M-6, *Off-Road Equipment Efficiency*, and Measure C-1-B, *Use Cleaner-Fuel Equipment*.

Scale of Application

Project/Site and Plan/Community

Implementation Requirements

Note that while this measure discusses off-road equipment used for agricultural purposes, this measure can also be implemented for other off-road equipment applications (e.g., construction, general purposes).

Cost Considerations

Electric- or hybrid-powered equipment tends to be more expensive to purchase and install than conventional models powered by fossil fuels. These costs may be offset by savings in fuel use and maintenance.

Expanded Mitigation Options

Pair with Measure E-10, *Procure Electricity from Lower Carbon Intensity Power Supply*, to ensure that the energy supplied to power the electrified equipment has a lower carbon intensity than the local grid, thereby further reducing GHG emissions. Consider using portable batteries to support and extend implementation of this measure at more remote sites.

GHG Reduction Formula

$A1=(C\times D\times F\times G1\times H)-(C\times D\times \mathbf{G2_B}\times I)$

$A2=(C\times D\times E\times \mathbf{G2_B}\times I)$

GHG Calculation Variables

ID	Parameter	Value	Unit	Source
Output				
A1	GHG reduction from using electric off-road agricultural equipment	[ ]	MT CO_2e	calculated
A2	GHG reduction from using hybrid off-road agricultural equipment	[ ]	MT CO_2e	calculated
User Inputs				
B	Fuel type of existing equipment	[ ]	text	user input
C	Hours of equipment operation	[ ]	hours	user input
G2	Carbon intensity of fossil fuel off-road equipment	[ ]	g CO_2e per hp-hour	CARB 2021; CAPCOA 2023
Constants, Assumptions, and Available Defaults				
D	Horsepower of electric or hybrid off-road equipment	[ ]	hp	user input; CARB 2023; CA CORE 2023
E	Percent fuel reduction of hybrid equipment compared to fossil fuel equipment	10	%	Holian and Pyeon 2017
F	Conversion from horsepower to MW	0.0007457	MW per hp	conversion
G1	Carbon intensity of local utility provider	Tables E-4.3 and E-4.4	lbs CO_2e per MWh	CA Utilities 2021
H	Conversion from lbs to MT	0.000454	MT per lb	conversion
I	Conversion from grams to MT	1 e^{-6}	MT per gram	conversion

Further explanation of key variables:

- (B) – The fuel type of the existing equipment is used to obtain the carbon intensity of the equipment (G2) from OFFROAD.
- (C) – This input represents the hours of operation that the equipment will be used over a user-specified time period.
- (D) – The horsepower of the electric agricultural equipment that is electric will need to be provided by the user.
- (E) – The percent fuel reduction is used in this formula as a proxy for the percent activity reduction that would be expected with hybrid, off-road, heavy-duty equipment. Based

on a survey of 12 models of off-road, heavy-duty equipment from 10 different manufacturers, hybrid off-road equipment reduced fuel use by 10 to 45 percent, with an average of 28 percent (Holian and Pyeon 2017). To be conservative, the low end of the range is cited. If the user can provide an equipment-specific hp, the user should replace the default in the GHG calculation formula. If the user knows the make and model of the agricultural equipment, the user should replace the default in the GHG calculation formula.

- (F) – Conversion factor assumes that energy requirements and losses are the same for both a fuel-powered engine and an electrically-charged engine.
- (G1) – GHG intensity factors for major California utilities are provided in Tables T-13.1 and T-13.2 in Appendix C. If the project study area is not serviced by a listed utility, or the user is able to provide a project-specific value (i.e., for the future year not referenced in Appendix C), the user should replace the default in the GHG calculation formula. If the utility is not known, the user may elect to use the statewide grid average carbon intensity.
- (G2) – GHG intensity factors for various off-road equipment can be obtained from CARB's (2021) OFFROAD model. Note that the OFFROAD emissions rates are inclusive of equipment load. Therefore, the GHG reduction equation does not include a multiplier for load factor. In addition, GHG intensity factors for various off-road equipment can be obtained from the User Guide for CalEEMod: Appendix G.

GHG Calculation Caps or Maximums

None.

Example GHG Reduction Quantification

The user reduces agricultural equipment emissions by replacing fossil-fuel combustion with electricity consumption, which generates fewer GHG emissions per unit of activity. In this example, an agricultural farm is replacing a 2020 model year 70-hp diesel tractor (D) that is used 8 hours per day (C) with an electric-powered equivalent (CARB 2023; CA CORE 2023). A 2020 model year 70-hp diesel tractor has an approximate carbon intensity of 530 grams CO_2e per hp-hour (G2). The electric utility for the project area is Pacific Gas & Electric Company, and the analysis year is 2025. The carbon intensity of electricity is, therefore, 206 lbs CO_2e per megawatt-hour (G1).

$$A=\left(8\ \frac{\text{hours}}{\text{day}}\times 70\ \text{hp}\times 0.0007457\ \frac{\text{MW}}{\text{hp}}\times 206\ \frac{\text{lbs } CO_2e}{\text{MWh}}\times 0.000454\frac{\text{MT}}{\text{lb}}\right)-\left(8\ \frac{\text{hours}}{\text{day}}\times 70\ \text{hp}\times 530\ \frac{\text{g } CO_2e}{\text{hp-hour}}\times 1\text{x}10^{-6}\frac{\text{MT}}{\text{g}}\right)=-0.26\ \frac{\text{MT } CO_2e}{\text{day}}$$

Quantified Co-Benefits

Improved Air Quality

Reducing fossil-fuel combustion will also reduce local criteria pollutants. Emission savings can be calculated using the same formula used to quantify GHG reductions (A1 and A2). Criteria pollutant intensity factors for various off-road equipment can be obtained from CARB's (2021) OFFROAD model.

Electricity supplied by statewide fossil-fueled power plants will generate criteria pollutants. However, because these power plants are located throughout the state, electricity consumption from equipment charging will not generate localized criteria pollutant emissions at the equipment source. Consequently, for the quantification of criteria pollutant emission reductions, either the electricity portion of the equation can be removed or the electricity intensity (G1) can be set to zero.

Energy and Fuel Savings

Fossil fuel savings are a product of the equipment fuel efficiency (gallons consumed per hour) and the equipment operating time (hours). Fuel intensity factors for various off-road equipment can be obtained from CARB's (2021) OFFROAD model. Users should multiply the fuel intensity by the equipment operating hours to quantify fuel savings.

Increased electricity consumption for electric equipment is calculated as part of the GHG reduction formula (A). The abbreviated formula is also shown below.

$$MWh = C \times D \times F$$

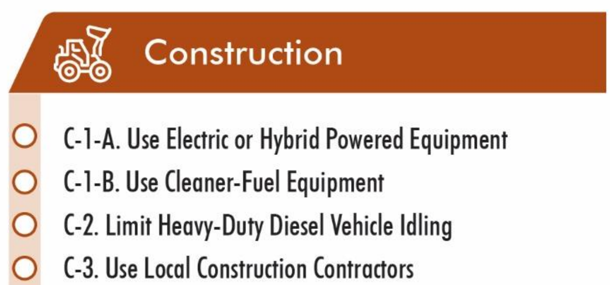
Sources

- California Air Pollution Control Officer's Association (CAPCOA). 2023. User Guide for CalEEMod Version 2022.1: Appendix G, Default Data Tables Available: https://caleemod.com/user-guide. Accessed: January 2024.
- California Air Resources Board (CARB). 2021. OFFROAD2021–ORION. Available: https://arb.ca.gov/emfac/emissions-inventory. Accessed: December 2023.
- California Air Resources Board (CARB). 2023. CARB Advanced Clean Off-road Equipment List Fact Sheet. August. Available: https://ww2.arb.ca.gov/sites/default/files/classic/ZEE/2023%20ZEE%20List%2008182023%20CORE%20TRL%20No%20Hybrid.pdf. Accessed: December 2023.
- California Utilities. 2021. Excel database of GHG emission factors for delivered electricity, provided to the Sacramento Metropolitan Air Quality Management District and ICF. January through March 2021.
- Clean Off-Road Equipment Voucher Incentive Project (CA CORE). 2023. Eligible Equipment Catalog. Available: https://californiacore.org/equipmentcatalog/. Accessed: December 2023.
- Holian, M., and J. Pyeon. 2017. Analyzing the Potential of Hybrid and Electric Off-Road Equipment in Reducing Carbon Emissions from Construction Industries. Mineta Transportation Institute. September. Available: https://transweb.sjsu.edu/research/Analyzing-Potential-Hybrid-and-Electric-Road-Equipment-Reducing-Carbon-Emissions-Construction-Industries. Accessed: December 2023.

Construction

Equipment and vehicles are the primary sources of GHG emissions in the construction sector. Construction equipment typically operates on construction sites and includes off-road sources like cranes, bulldozers, forklifts, and tractors. Vehicles are used for personnel, material, and equipment transport, as well as onsite material supply movement. Construction equipment and vehicles traditionally use diesel or gasoline fuel and release emissions based on the amount of fuel combusted and the emission certification level of the engine.

Equipment and vehicle emissions can be reduced by using engines that emit fewer pollutants for the same amount of work. This is typically equipment and vehicles powered by electricity or cleaner fuels (e.g., compressed natural gas, renewable diesel). The exclusive use of grid electricity by electric equipment and vehicles eliminates the diesel emissions at the site but increases indirect electricity emissions. However, grid-based emissions are typically less than the emissions from the diesel-fueled equipment (depending on the source of grid power). Hybrid-powered equipment and vehicles would decrease but not eliminate fuel use. The electricity for hybrid engines is self-generated, so it would not increase grid-based electrical generation and the associated emissions unless the equipment has plug-in capability. Likewise, depending on the fuel type, cleaner-fuel equipment and vehicles would decrease but not eliminate combustion emissions.



Emissions reductions achieved by electric-powered and cleaner-fuel equipment and vehicles are determined by finding the difference in emissions between those generated by the replacement power source and those generated by conventional fossil-fueled engines. Emissions for the mitigated scenario may consist of direct emissions from combustion fuel use, and/or indirect emissions from grid electricity. Resources and methods to quantify emissions reductions from measures that target cleaner-fuel equipment are described in this section. Measures that reduce vehicle fuel consumption through idling restrictions and local contractor provisions are also discussed. Use the below graphic to click on an individual measure to navigate directly to the measure's factsheet.

C-1-A. Use Electric or Hybrid Powered Equipment

Photo Credit: Granite Construction, March 2019

GHG Mitigation Potential

Large

Potentially large reduction in GHG emissions from construction equipment

Co-Benefits (icon key on pg. 34)

Climate Resilience

Using electric- or hybrid-powered equipment can reduce sensitivity to fuel price shocks or scarcity. However, using all-electric equipment may decrease resilience if they are the only option available during a power outage.

Health and Equity Considerations

This measure will not only reduce air pollution for surrounding communities but also for onsite workers.

Measure Description

This measure requires use of electric- or hybrid-powered construction equipment over conventional diesel-fueled counterparts. Replacing diesel-powered equipment with electric or hybrid-electric equipment reduces fossil fuel combustion and thus GHG emissions. However, all-electric equipment results in GHG emissions from the electricity used to charge the equipment. The indirect GHG emissions increase from electricity must be calculated in addition to the GHG emissions reduction from displaced fossil fuel combustion to estimate the total net GHG emissions reduction achieved by this measure if using all-electric equipment. A variation of this measure is described in Measure C-1-B, *Use Cleaner-Fuel Equipment*. Additionally, similar measures are included in the Handbook for other types of equipment, such as agricultural equipment (see Measure N-8) and general off-road equipment (see Measure M-6).

Scale of Application

Project/Site and Plan/Community

Implementation Requirements

Note that while this measure discusses offroad equipment used for construction, this measure can also be implemented for other offroad equipment applications (e.g., agriculture, industrial).

Cost Considerations

Electric- or hybrid-powered equipment tends to be more expensive to purchase and install than conventional models powered by fossil fuels. These costs may be offset by savings in fuel use and maintenance.

Expanded Mitigation Options

Pair with Measure E-10, *Procure Electricity from Lower Carbon Intensity Power Supply*, to ensure that the energy supplied to power the electrified equipment has a lower carbon intensity than the local grid, thereby further reducing GHG emissions. Consider using portable batteries to support and extend implementation of this measure at more remote sites.

GHG Reduction Formula

A1 = (**C** × D × F × G1 × H) – (**C** × D × **G2** × I)

A2 = **C** × D × E × **G2** × I

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A1	GHG reduction from using electric equipment	[ ]	MT CO_2e	calculated
A2	GHG reduction from using hybrid equipment	[ ]	MT CO_2e	calculated
User Inputs				
B	Fuel type of existing equipment	[ ]	text	user input
C	Hours of equipment operation	[ ]	hours	user input
G2	Carbon intensity of fossil-fueled equipment	[ ]	g CO_2e per hp-hour	CARB 2021
Constants, Assumptions, and Available Defaults				
D	Horsepower of equipment	Table C-1-B.1	hp	CARB 2021
E	Percent fuel reduction of hybrid equipment compared to conventional equipment	10	%	Holian and Pyeon 2017
F	Conversion from horsepower to MW	0.0007457	MW per hp	conversion
G1	Carbon intensity of local electricity provider	Tables E-4.3 and E-4.4	lb CO_2e per MWh	CA Utilities 2021
H	Conversion from lb to MT	0.000454	MT per lb	conversion
I	Conversion from g to MT	1 e^{-6}	MT per g	conversion

Further explanation of key variables:

- (B) – The fuel type of the existing equipment is used to obtain the carbon intensity of the equipment (G2) from OFFROAD.
- (D) – Average hp of various construction equipment are provided in Table C-1-B.1 in Appendix C, *Emission Factors and Data Tables* (CARB 2021). If the user can provide an equipment-specific hp, they should replace the default in the GHG calculation formula.
- (E) – The percent fuel reduction is used in this formula as a proxy for the percent activity reduction that would be expected with hybrid construction equipment. Based on a survey of 12 models of heavy construction equipment from 10 different manufacturers, hybrid construction equipment reduced fuel use by 10 to 45 percent, with an average of 28 percent (Holian and Pyeon 2017). To be conservative, the low end of the range is cited. If the user can provide an equipment-specific hp, the user should replace the default in the GHG calculation formula. If the user knows the make and model of the construction equipment used, the user should replace the default in the GHG calculation formula.

- (F) – Conversion factor assumes that energy requirements and losses are the same for both a fuel-powered engine and an electrically-charged engine.
- (G1) – GHG intensity factors for major California utilities are provided in Tables E-4.3 and E-4.4 in Appendix C. If the project study area is not serviced by a listed electricity provider, or the user is able to provide a project-specific value (i.e., for the future year not referenced in Appendix C), the user should replace the default in the GHG calculation formula. If the electricity provider is not known, the user may elect to use the statewide grid average carbon intensity.
- (G2) – GHG intensity factors for various construction equipment can be obtained from CARB's (2021) OFFROAD model. Note that the OFFROAD emissions rates are inclusive of equipment load. Therefore, the GHG reduction equation does not include a multiplier for load factor.

GHG Calculation Caps or Maximums

None.

Example GHG Reduction Quantification

The user reduces construction equipment emissions by replacing fossil fuel combustion with electricity consumption, which generates fewer GHG emissions per unit of activity. In this example, a 158-hp diesel excavator (D) that is used 8 hours per day (C) is replaced by an electric-powered equivalent. A 158-hp excavator has a carbon intensity of 530 g CO_2e per hp-hour (G2). The electricity provider for the project area is Silicon Valley Clean Energy, and the analysis year is 2025. The carbon intensity of electricity is, therefore, 5 lb CO_2e per megawatt-hour (G1).

$$A1 = \left(8\ \frac{\textbf{hours}}{\textbf{day}} \times 158\ \text{hp} \times 0.0007457\ \frac{\text{MW}}{\text{hp}} \times 5\ \frac{\text{lb}\ CO_2e}{\text{MWh}} \times 0.000454\frac{\text{MT}}{\text{lb}}\right) - \left(8\ \frac{\textbf{hours}}{\textbf{day}} \times 158\ \text{hp} \times \textbf{530}\ \frac{\textbf{g}\ \boldsymbol{CO_2e}}{\textbf{hp-hour}} \times 1e^{-6}\frac{\text{MT}}{\text{g}}\right) = -0.7\frac{\text{MT}\ CO_2e}{\text{day}}$$

Quantified Co-Benefits

Improved Air Quality

Reducing fossil-fuel combustion will also reduce local criteria pollutants. Emission savings can be calculated using the same formula used to quantify GHG reductions (A1 and A2). Criteria pollutant intensity factors for various construction equipment can be obtained from CARB's (2021) OFFROAD model.

Electricity supplied by statewide fossil-fueled or bioenergy power plants will generate criteria pollutants. However, because these power plants are located throughout the state, electricity consumption from equipment charging will not generate localized criteria pollutant emissions at the equipment source. Consequently, for the quantification of criteria pollutant emission reductions, either the electricity portion of the equation can be removed, or the electricity intensity (G2) can be set to zero.

Energy and Fuel Savings

Fossil fuel savings are a product of the equipment fuel efficiency (gallons consumed per hour) and the equipment operating time (hours). Fuel intensity factors for various construction equipment can be obtained from CARB's OFFROAD model. Users should multiply the fuel intensity by the equipment operating hours to quantify fuel savings.

Increased electricity consumption for electric equipment is calculated as part of the GHG reduction formula (A1). The abbreviated formula is also shown below.

$$MWh = C \times D \times F$$

Sources

- California Air Resources Board (CARB). 2021. OFFROAD2017–ORION. Available: https://arb.ca.gov/emfac/emissions-inventory. Database queried by Ramboll and provided electronically to ICF. September 2021.
- California Utilities. 2021. Excel database of GHG emission factors for delivered electricity, provided to the Sacramento Metropolitan Air Quality Management District and ICF. January through March 2021.
- Holian, M., and J. Pyeon. 2017. *Analyzing the Potential of Hybrid and Electric Off-Road Equipment in Reducing Carbon Emissions from Construction Industries.* Mineta Transportation Institute. September. Available: https://transweb.sjsu.edu/sites/default/files/1533-analyzing-the-potential-of-hybrid-and-electric-off-road-equipment-in-reducing-carbon-emissions-from-construction-industries-research-brief.pdf. Accessed: January 2021.

C-1-B. Use Cleaner-Fuel Equipment

Photo Credit: TruckPR, April 2017

GHG Mitigation Potential

Small

Potentially small reduction in GHG emissions from construction equipment

Co-Benefits (icon key on pg. 34)

Climate Resilience

Using cleaner fuel equipment allows for fuel redundancy and can reduce sensitivity to price shocks or scarcity in conventional fuels.

Health and Equity Considerations

While most alternative fuels reduce both GHG and criteria pollutants, a few may increase criteria pollutant emissions. The most prominent example of this is biodiesel, which generally results in higher NOx emissions, but lower PM emissions compared to conventional diesel.

Measure Description

This measure requires use of cleaner-fueled construction equipment over conventional diesel- or gasoline-fueled counterparts. Depending on the fuel type, equipment type, and horsepower, equipment may emit fewer GHG for the same amount of work as equivalent diesel- or gasoline-fueled engines. A variation of this measure is described in Measure C-1-A, *Use Electric or Hybrid Powered Equipment*. Compressed natural gas (CNG) is specifically addressed in the quantification method for this measure, although users could expand to cover additional fuel types, such as renewable diesel.

Scale of Application

Project/Site and Plan/Community

Implementation Requirements

Note that while this measure discusses offroad equipment used for construction, this measure can also be implemented for other offroad equipment applications (e.g., agriculture, industrial).

Cost Considerations

Equipment powered by cleaner-fuels tend to be more expensive to purchase and install than less clean models. These costs may be offset by savings in fuel use and maintenance.

Expanded Mitigation Options

Other cleaner fuels available for use in construction equipment include renewable diesel, biodiesel, and hydrogen fuel cells. These fuels are not specifically captured by the current quantitative method for this measure.

GHG Reduction Formula

$A = ((C \times D \times E2) - (C \times D \times E1)) \times F$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	GHG reduction from using cleaner-fuel equipment	[ ]	MT CO_2e	calculated
User Inputs				
B	Fuel types of existing and cleaner-fuel equipment	[ ]	text	user input
C	Hours of equipment operation	[ ]	hours	user input
E1	Carbon intensity of existing equipment	[ ]	g CO_2e per hp-hour	CARB 2021
E2	Carbon intensity of cleaner-fuel equipment	[ ]	g CO_2e per hp-hour	CARB 2021
Constants, Assumptions, and Available Defaults				
D	Horsepower of equipment (diesel, gasoline, and CNG equipment)	Table C-1-B.1	hp	CARB 2021
F	Conversion from g to MT	1 e^{-6}	MT per g	conversion

Further explanation of key variables:

- (A) – Depending on the fuel type, equipment type, and horsepower, the cleaner-fuel equipment may emit more GHGs than an equivalent gasoline- or diesel-fueled engine. The user should take care to consider the potential criteria pollutant co-benefits against possible GHG increases from the use of a cleaner fuel.
- (B) – The fuel type of the existing and cleaner-fuel equipment is used to obtain the carbon intensity of the equipment (E1 and E2) from CARB's (2021) OFFROAD.
- (D) – Average hp of various construction equipment are provided in Table C-1-B.1 in Appendix C (CARB 2021). If the user can provide an equipment-specific hp, they should replace the default in the GHG calculation formula.
- (E1 and E2) – GHG intensity factors for various construction equipment by fuel type can be obtained from CARB's (2021) OFFROAD model. Note that the OFFROAD emissions rates are inclusive of equipment load. Therefore, the GHG reduction equation does not include a multiplier for load factor.

GHG Calculation Caps or Maximums

None. If the emissions rate for the cleaner-fuel equipment exceeds that of the diesel- or gasoline-powered counterpart, this measure may result in a GHG emissions increase.

Example GHG Reduction Quantification

The user reduces construction equipment emissions by replacing gasoline or diesel combustion with CNG or renewable diesel consumption, which may generate fewer GHG emissions per unit of activity, depending on the piece of equipment and horsepower. In this example, a fleet of 23-hp diesel aerial lifts (D) that are used 40 hours per day (C) in 2022 is replaced by CNG-fueled equivalents. A 23-hp diesel aerial lift has a carbon intensity of 851g CO_2e per hp-hour (E1). The CNG-fueled equivalent has a hp of 19 and carbon intensity of 675g CO_2e per hp-hour (E2).

$$A = \left(\left(40\,\frac{\text{hours}}{\text{day}} \times 19\text{ hp} \times 675\,\frac{\text{g CO}_2\text{e}}{\text{hp-hour}}\right) - \left(40\,\frac{\text{hours}}{\text{day}} \times 23\text{ hp} \times 851\,\frac{\text{g CO}_2\text{e}}{\text{hp-hour}}\right)\right) \times 1e^{-6}\,\frac{\text{MT}}{\text{g}} = -0.3\,\frac{\text{MT CO}_2\text{e}}{\text{day}}$$

Quantified Co-Benefits

Improved Air Quality

Depending on the fuel type, equipment type, and horsepower, the cleaner-fuel equipment may emit more criteria pollutants than an equivalent gasoline- or diesel-fueled engine. Emission changes can be calculated using the same formula used to quantify GHG reductions (A). The carbon intensity factors (E1 and E2) should be replaced in the formula with the corresponding criteria pollutant intensity factors, which can be obtained from CARB's OFFROAD model.

Energy and Fuel Savings

This measure would displace use of fossil fuel (gasoline or diesel) with a cleaner fuel type (CNG). Total fuel consumption is a product of the equipment fuel efficiency (gallons consumed per hour) and the equipment operating time (hours). Fuel intensity factors for various construction equipment can be obtained from CARB's OFFROAD model. Users should multiply the fuel intensity factor by the equipment operating hours to quantify fuel changes for the existing and cleaner-fuel equipment.

Sources

- California Air Resources Board (CARB). 2021. OFFROAD2017–ORION. Available: https://arb.ca.gov/emfac/emissions-inventory. Database queried by Ramboll and provided electronically to ICF. September 2021.

C-2. Limit Heavy-Duty Diesel Vehicle Idling

GHG Mitigation Potential

Small

Potentially small reduction in GHG emissions from construction vehicles

Co-Benefits (icon key on pg. 34)

Climate Resilience

Limiting vehicle idling saves fuels and can reduce sensitivity to price shocks or fuel scarcity.

Health and Equity Considerations

This measure will not only reduce air pollution for surrounding communities but also for onsite workers.

Measure Description

This measure limits heavy-duty vehicle idling beyond current regulatory restrictions. The Airborne Toxic Control Measure to Limit Diesel-Fueled Commercial Motor Vehicle Idling prohibits diesel-fueled commercial motor vehicles of more than 10,000 pounds from idling the vehicle's primary engine for 5 minutes at a single location (13 CCR Section 2485). There are some exceptions to the regulation, such as positioning or providing a power source for equipment or operations, such as lift, crane, pump, drill, hoist, or other auxiliary equipment. Reduction in idling time beyond the regulation would further reduce fuel consumption and thus emissions. Reducing idling benefits the health of construction workers as well as nearby residents and workers.

Scale of Application

Project/Site and Plan/Community

Implementation Requirements

The construction site manager should develop an enforceable mechanism that monitors the idling time to ensure compliance with this measure. Note that while this measure discusses heavy-duty vehicles used for construction, this measure can also be implemented for other vehicle applications (e.g., agriculture, industrial).

Cost Considerations

There are no initial costs associated with this measure. Restricting vehicle idling time beyond regulation will reduce fuel consumption, leading to long-term cost savings.

Expanded Mitigation Options

Pair with Measure T-30, *Use Cleaner-Fuel Vehicles,* to reduce the carbon intensity of fuels combusted during idling.

GHG Reduction Formula

$A = (B - D) \times C \times E \times F \times G \times H$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	GHG reduction from idling limit	[ ]	MT CO_2e	calculated
User Inputs				
B	Idle restriction with measure implementation	[ ]	minutes/period	user input
C	Vehicle trips	[ ]	trips	user input
Constants, Assumptions, and Available Defaults				
D	Idle limit without the measure	5	minutes/period	13 CCR Section 2485
E	Idle periods per trip	2	period/trip	assumption
F	Vehicle idling emission factor	[ ]	g/idle hours	CARB 2021
G	Conversion from minutes to hour	0.0167	hours per minute	conversion
H	Conversion from g to MT	$1\ e^{-6}$	MT per g	conversion

Further explanation of key variables:

- (A) – Emissions reductions are quantified per vehicle idling period. Daily emissions reductions can be quantified if the number of idling periods per day is known.
- (B) – The measure-imposed idle restriction must exceed the idle limit without the measure (D).
- (C) – Idle restrictions are imposed on vehicles idling at a single location. Vehicles may make multiple trips to that location or make trips to different locations but still be subject to the idling limit. Users should define the number of trips the vehicle will make for the analysis period (e.g., per day, per year).
- (D) – The Airborne Toxic Control Measure to Limit Diesel-Fueled Commercial Motor Vehicle Idling limits diesel-fueled commercial motor vehicle idling time to 5 minutes at a single location, with exceptions for some vehicles with auxiliary equipment powered by the primary engine. The user should determine the appropriate idling limit without the measure for such exempted vehicles.
- (E) – The quantification method assumes the vehicle will idle twice per trip at a single location: once during vehicle shutdown from the inbound trip and once during vehicle warmup for the outbound trip. Users should apply a different factor if the number of idle periods per trip is known.
- (F) – GHG intensity factors for diesel-fueled heavy vehicle idling can be obtained from CARB's (2021) EMFAC model.

GHG Calculation Caps or Maximums

None.

Example GHG Reduction Quantification

The user reduces vehicle idling emissions by enforcing an idling period of 3 minutes (B). In this example, a heavy-duty truck is regulated under the Airborne Toxic Control Measure to Limit Diesel-Fueled Commercial Motor Vehicle Idling. The idling limit without the measure is therefore 5 minutes at a single location (D). The vehicle has a gross vehicle weight of 35,000 pounds and will operate at a construction site in Los Angeles County in 2023. The vehicle will make 10 trips to the construction site per day (C). The idling carbon intensity is 6,375 g CO_2e per idle hour (F).

$$A = \left(3\ \frac{\text{idle min}}{\text{period}} - 5\ \frac{\text{idle min}}{\text{period}}\right) \times 10\ \frac{\text{trips}}{\text{day}} \times 2\ \frac{\text{period}}{\text{trip}} \times 6{,}375\ \frac{\text{g}}{\text{idle}\cdot\text{hr}}$$

$$\times\ 0.0167\ \frac{\text{hr}}{\text{min}} \times 1\text{e}^{-6}\ \frac{\text{MT}}{\text{g}} = <\text{-}0.1\ \frac{\text{MT CO}_2\text{e}}{\text{day}}$$

Quantified Co-Benefits

Improved Air Quality

Reducing fossil-fuel combustion from idling restrictions will also reduce local criteria pollutants. The reduction in criteria pollutant emissions can be calculated using the GHG reduction formula, where (F) represents the criteria pollutant intensity factors obtained from CARB's (2021) EMFAC model.

Sources

- California Air Resources Board (CARB). 2021. *EMFAC*. Available: https://arb.ca.gov/emfac/. Accessed: September 2021.

C-3. Use Local Construction Contractors

GHG Mitigation Potential

Varies

Variable reduction in GHG emissions from construction worker vehicles

Co-Benefits (icon key on pg. 34)

Climate Resilience

Reducing worker commute trip lengths saves fuels and can reduce sensitivity to price shocks or fuel scarcity.

Health and Equity Considerations

Refer to Measure IEP-1, *Local Labor and Apprenticeships (Construction)*, in Chapter 5.

Measure Description

This measure requires use of local construction contractors. Contracting construction work with a local company reduces VMT associated with construction employee commute distances and, therefore, reduces emissions from vehicle fuel combustion. Local hire provisions may cover the entire workforce or a percentage of the workforce based on the project size or employment type.

Scale of Application

Project/Site and Plan/Community

Implementation Requirements

Local hiring requirements should be expressed in the contractor bid specifications. Note that this measure is specific to local hire provisions for employees reporting to the construction site. Measure C-4, *Use Local and Sustainable Building Materials*, requires use of local building materials, which can reduce VMT and emissions from vendor and delivery trips.

Cost Considerations

Local and skilled workforce provisions can promote economic development, channeling some of the economic value of development directly to the community in which it is building. Decreased worker commute times and fuel savings may generate additional discretionary funds. Reduced car use may decrease the need for infrastructure spending on road maintenance.

Expanded Mitigation Options

Local workforce provisions may increase the likelihood of employee commute trips by transit, walking, or biking. Potential GHG reductions from mode shift are not reflected in the quantification methodology. Partner with local transit agencies to provide discounted transit passes to further incentivize alternative transportation.

Consider additional provisions for workforce training to bolster development of skilled trades and further economic growth. Requirements may include workers who have graduated from a Joint Labor Management apprenticeship training program approved by the State of California or who have at least as many hours of on-the-job experience in the appliable craft or are registered in an apprenticeship training program.

GHG Reduction Formula

A = (B – D) × C × E × F × G

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	GHG reduction from using local construction contractors	[ ]	MT CO_2e	calculated
User Inputs				
B	Distance provision of local hiring requirement	[ ]	miles/one-way trip	user input
C	Number of employees	[ ]	employees	user input
Constants, Assumptions, and Available Defaults				
D	Countywide average one-way employee commute trip distance	Table C-3.1	miles/one-way trip	2015 CSTMD
E	Employee trips per day	2	trips per employee	assumption
F	Vehicle emission factor	[ ]	g CO_2e per mile	CARB 2021
G	Conversion from g to MT	1 e^{-6}	MT per g	conversion

Further explanation of key variables:

- (B) – The local hire provision should specify the maximum average one-way travel distance for contracted staff.
- (C) – The number of employees required to report to the construction site and subject to the provision must be provided by the user.
- (D) – The average countywide vehicle trip lengths from the 2015 California Statewide Travel Demand Model (CSTDM) are provided in Table C-3.1 in Appendix C. The data are for home-based-work trips by traffic analysis zone averaged to the county level.
- (E) – The quantification method assumes all employees will make both an inbound and outbound trip per day.
- (F) – Users should obtain the carbon intensity of employee commute vehicles from CARB's (2021) EMFAC model. Employee commute vehicles are generally classified as light-duty automobiles (LDA) and trucks (light-duty truck class 1 [LDT1] and 2 [LDT2]). Users may obtain a weighted carbon intensity of these vehicle types using a 25/50/25 percent mix of LDA, LDT1, and LDT2, respectively. Alternatively, users may apply different weightings of vehicle fleet mixes if project-specific information is available.

GHG Calculation Caps or Maximums

(B<D). For implementation of this measure to result in a GHG reduction, the maximum average allowable travel distance must be less than the average countywide vehicle trip length assumed in the calculation.

Example GHG Reduction Quantification

The user reduces employee commute emissions by requiring all contracted employees to be located within a certain distance of a construction project. In this example, the construction project requires 100 employees per day (C) and is in Alameda County, where the average countywide home-based-work vehicle trip length from the 2015 CSTDM is 11.98 miles (D). The contractor agreement requires all staff reporting to the construction site to reside no more than 10 miles from the project (B). The weighted average carbon intensity for employee commute vehicles in Alameda County for the analysis year from EMFAC is 281 grams per mile (F).

$$A = \left(10\ \frac{\text{miles}}{\text{trip}} - 11.98\ \frac{\text{miles}}{\text{trip}}\right) \times 100\ \frac{\text{employees}}{\text{day}} \times 2\ \frac{\text{trips}}{\text{employee}}$$

$$\times\ 281\ \frac{\text{g } CO_2e}{\text{mi}} \times 1e^{-6}\ \frac{\text{MT}}{\text{g}} = 0.1\ \frac{\text{MT } CO_2e}{\text{day}}$$

Quantified Co-Benefits

VMT Reductions

Contracting construction work with a local company reduces construction employee commute VMT. The reduction in VMT can be calculated using the GHG reduction formula with the exception that (F and G) should be replaced with a value of 1 or otherwise be removed from the equation.

Energy and Fuel Savings

This measure will achieve vehicle fuel savings by reducing employee commute VMT. Total fuel consumption is a product of the vehicle fuel efficiency (gallons consumed per mile) and miles traveled. Fuel intensity factors can be obtained from CARB's (2021) EMFAC model. Users should multiply the vehicle fuel intensity factor by the VMT reduction (see above) to quantify fuel savings.

Improved Air Quality

Reducing fossil-fuel combustion from a local hire provision will also reduce local criteria pollutants. The reduction in criteria pollutant emissions can be calculated using the GHG reduction formula, where (F) represents the criteria pollutant intensity factors obtained from CARB's (2021) EMFAC model.

Sources

- California Air Resources Board (CARB). 2021. *EMFAC*. Available: https://arb.ca.gov/emfac/. Accessed: September 2021.

Refrigerants

Refrigerants are substances used in equipment for cooling and heating purposes. Most of the refrigerants used today are HFCs or blends thereof. HFCs are the third generation of synthetic fluorinated chemicals and were used to replace ozone depleting refrigerants. However, HFCs are potent GHGs that often have high GWP values. Different types of refrigeration equipment are used by different types of land uses. For example, an office may use various types of A/C equipment, while a supermarket may use both A/C equipment and refrigeration equipment.

All equipment that uses refrigerants has a charge size (i.e., quantity of refrigerant the equipment contains), and an operational refrigerant leak rate, and each refrigerant has a GWP that is specific to that refrigerant. The GWPs of common refrigerants are presented in Table R-1.1 in Appendix C, *Emissions Factors and Data Tables*. For purposes of calculating refrigerant emissions in this Handbook, the equipment charge sizes and leak rates have been determined for relevant land use and equipment types. This information is presented in Tables R-1.2 through R-1.5 in Appendix C.

Emissions from equipment can be reduced by decreasing the charge size and/or leak rate, or replacing the baseline refrigerant with a lower GWP refrigerant. The quantification method for all refrigerant measures, except Measure R-7, address emissions generated during equipment operation. Measure R-7 reduces emissions from the disposal of refrigeration and A/C equipment at the end of its lifetime. The quantification approach for Measure R-7 includes lifecycle considerations (i.e., downstream emissions) and, as a result, emission reductions from this measure should not be compared to the emission reductions calculated for other refrigeration measures in this Handbook, which do not include lifecycle emissions.

Refrigerants

Use the graphic to click on an individual measure to navigate directly to the measure's factsheet.

R-1. Use Alternative Refrigerants Instead of High-GWP Refrigerants

GHG Mitigation Potential

100%

Up to a 100% reduction in GHG emissions during operation

Co-Benefits (icon key on pg. 34)

Climate Resilience

Climate resilience benefits vary by alternative refrigerant; for example, use of NH_3 can reduce energy consumption, thereby reducing the strain on the overall grid, particularly the risk of power outages during peak loads. Reduced energy consumption would also reduce energy costs, particularly if extreme heat would otherwise increase these costs.

Health and Equity Considerations

Evaluate the entire lifecycle impact of alternative refrigerants and avoid those that will degrade into persistent chemicals harmful to the environment. Equipment should be installed in locations with adequate space and/or ventilation in accordance with U.S. EPA and CARB recommendations.

Measure Description

This measure replaces high-GWP refrigerants with lower-GWP refrigerants (e.g., natural refrigerants such as CO_2, ammonia [NH_3], and hydrocarbons, or next generation low-GWP synthetic refrigerants like hydrofluoroolefin-1234yf) in refrigeration and A/C equipment. When emitted into the atmosphere, high-GWP refrigerants (e.g., HFCs) absorb significantly more heat than CO_2 on a mass basis, resulting in larger global warming effects. Shifting to lower-GWP refrigerants reduces the potency of refrigerant leaks, decreasing GHG emissions on a CO_2e basis.

Scale of Application

Project/Site

Implementation Requirements

See measure description.

Cost Considerations

Implementation may require retrofitting existing equipment or purchasing new equipment, which may result in high initial capital costs. Alternative refrigerants, if synthetic and patented, may cost more than conventional refrigerants. Natural, non-patented refrigerants may cost less. Costs differences are expected to decrease over time with increased availability and commercialization of alternative refrigerants. Savings may also be achieved through increased energy efficiency of a refrigerant system using an alternative refrigerant.

Expanded Mitigation Options

Evaluate the entire lifecycle impact of alternative refrigerants and avoid those that will degrade into persistent chemicals harmful to the environment so as to improve local air quality, public health, and ecosystem health. Ensure that Clean Air Act and other regulations are followed during refrigerant disposal.

GHG Reduction Formula

$$A = \frac{(B \times C \times G) - (D \times E \times F)}{(D \times E \times F)}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from refrigerant emissions	0–100	%	calculated
User Inputs				
B	Total alternative refrigerant charge size	[ ]	kg	user input
C	Annual leak rate of equipment with alternative refrigerant	[ ]	%	user input
Constants, Assumptions, and Available Defaults				
D	HFC refrigerant charge size	Tables R-1.2 through R-1.5	kg	U.S. EPA 2016
E	Annual leak rate of equipment with HFC refrigerant	Tables R-1.2 through R-1.5	%	U.S. EPA 2016
F	GWP of HFC refrigerant	Table R-1.1	unitless	IPCC 2007
G	GWP of alternative refrigerant	Table R-1.1	unitless	IPCC 2007 and WMO 2018

Further explanation of key variables:

- (B, D) – The equipment charge size is the total quantity of refrigerant installed in the refrigeration or A/C equipment. The charge size may be the same for equipment using HFC and alternative refrigerants, or it may differ. Default charge sizes for equipment with HFC refrigerants are provided in Tables R.1-2 through R-1.5 in Appendix C. If the user can provide a project-specific value, they should replace the default quantity of refrigerant installed in the GHG reduction formula. Charge size for alternative refrigerants would vary by equipment type. In the case where the alternative charge size is not known, the corresponding HFC refrigerant charge size may be used as a substitute.
- (C, E) – Based on industry data, the average annual leak rates for the given equipment type, including operational and servicing leak rates for the equipment throughout the year. The leak rate may be the same for equipment using HFC and alternative refrigerants, or it may differ. Default leak rates for equipment with HFC refrigerants are provided in Tables R.1-2 through R-1.5 in Appendix C. These are average values and may vary with specific systems. Leak rates for alternative refrigerants would vary by equipment type. In the case where the alternative leak rate is not known, the corresponding HFC refrigerant leak rate may be used as a substitute.
- (F, G) – The GWP measures the contribution to global warming from the release of one unit of the given refrigerant relative to CO_2 on a 100-year time horizon. The GWPs of common refrigerants and alternatives are provided in Table R-1.1 in Appendix C.

GHG Calculation Caps or Maximums

This measure has a maximum GHG emissions reduction of 100 percent.

Example GHG Reduction Quantification

The user reduces high-GWP emissions by replacing a high-GWP refrigerant with a lower-GWP refrigerant alternative. In this example, a 60,000-sf supermarket has a conventional direct expansion system with 1,360 kg (D) of R-404A and a total leak rate of 33 percent (E). The supermarket also has A/C equipment with 13 kg (D) of R-410A and a total leak rate of 8 percent (E). The GWPs of R-404A and R-410A are 3,922 and 2,088 (F), respectively. The user replaces R-404A with R-448, a refrigerant with a GWP of 1,387 (G), and R-410A with R-407C, a refrigerant with a GWP of 1,774 (G). The charge sizes and leak rates for the alternative equipment would be the same as the high-GWP counterpart. Note that the A/C refrigerant transition from R-410A to R-407C is included for illustrative purposes and that this transition in supermarkets is not currently happening in practice. This would reduce GHG emissions from the refrigeration and A/C systems at the supermarket by 65 percent.

$$A = \frac{((1{,}360\ \text{kg} \times 33\% \times 1{,}387) + (13\ \text{kg} \times 8\% \times 1{,}774)) - ((1{,}360\ \text{kg} \times 33\% \times 3{,}922) + (13\text{kg} \times 8\% \times 2{,}088))}{((1{,}360\ \text{kg} \times 33\% \times 3{,}922) + (13\ \text{kg} \times 8\% \times 2{,}088))} = -65\%$$

Quantified Co-Benefits

Energy and Fuel Savings

Depending on system type and refrigerant selected, successful implementation of this measure could result in energy savings or energy penalties (U.S. EPA 2019). This co-benefit cannot be quantified for the purposes of this general methodology.

Sources

- Intergovernmental Panel on Climate Change (IPCC). 2007. *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp. Available: https://www.ipcc.ch/report/ar4/wg1/. Accessed: January 2021.
- U.S. Environmental Protection Agency (U.S. EPA). 2016. Accounting Tool to Support Federal Reporting of Hydrofluorocarbon Emissions: Supporting Documentation. October 2016. Available: https://www.epa.gov/sites/production/files/2015-09/documents/hfc_emissions_accounting_tool_supporting_documentation.pdf. Accessed: May 2021.
- World Meteorological Organization (WMO). 2018. *Scientific Assessment of Ozone Depletion: 2018, Global Ozone Research and Monitoring Project*. Report No. 58, 5886 pp., Geneva, Switzerland.

R-2. Install Secondary Loop and/or Cascade Supermarket Systems in Place of Direct Expansion Systems

GHG Mitigation Potential

100%

Up to a 100% reduction in GHG emissions during operation

Co-Benefits (icon key on pg. 34)

Climate Resilience

Increased energy efficiency in refrigeration systems can reduce the strain on the overall grid, particularly the risk of power outages during peak loads. Increased efficiency can also reduce energy costs, particularly if extreme heat would otherwise increase these costs.

Health and Equity Considerations

Non-applicable

Measure Description

This measure replaces conventional direct expansion systems in supermarkets with indirect systems such as secondary loop and cascade systems. Currently, direct expansion systems are the most used refrigeration system type in supermarkets in the U.S. (U.S. EPA 2016). Whereas direct expansion systems circulate one refrigerant from the machinery room out to the store and back to the machinery room, indirect systems employ a primary and secondary refrigerant or heat transfer fluid (U.S. EPA 2016, 2019). In secondary loop systems, the primary refrigerant remains in the machine room and cools the secondary fluid, which is then pumped throughout the store to cool products. Another type of indirect system is a cascade system, which contains two refrigeration systems that share a common heat exchanger. These systems often use HFCs, NH_3, or hydrocarbons as the primary refrigerant. Often water mixed with glycol is used as the secondary heat transfer fluid in secondary loop systems; CO_2 is often used as the second refrigerant in cascades. By either confining HFCs to the machinery room as the primary refrigerant or removing HFCs entirely (as in NH_3 and hydrocarbon systems), these systems require significantly lower refrigerant charge and have lower leak rates than conventional direct expansion systems (U.S. EPA 2013a, 2019). Decreasing the refrigerant charge and leak rates results in a reduction of potential direct GHG emissions.

Scale of Application

Project/Site

Implementation Requirements

See measure description.

Cost Considerations

While both secondary loop and cascade supermarket systems have a higher initial cost over traditional systems, minimized costs associated with rechanging systems due to reduced leakage and energy efficiency improvements may provide a net cost savings over the lifetime of the systems.

Expanded Mitigation Options

Pair with Measure R-1, *Use Alternative Refrigerants Instead of High-GWP Refrigerants*, for increased GHG reductions in supermarket refrigerant systems.

GHG Reduction Formula

$$A = \frac{[(B \times F \times H) + (C \times F \times I)] - (D \times E \times G)}{D \times E \times G}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from refrigerant emissions	0–100	%	calculated
User Inputs				
B	Equipment charge size of secondary loop and/or cascade system	[ ]	kg	user input
C	Equipment charge size of secondary refrigerant in secondary loop and/or cascade system	[ ]	kg	user input
Constants, Assumptions, and Available Defaults				
D	Equipment charge size of conventional direct expansion system	1,633	kg	U.S. EPA 2013a
E	Annual leak rate of conventional direct expansion system	25	%	U.S. EPA 2013b
F	Annual leak rate of secondary loop and/or cascade system	5–15	%	U.S. EPA 2013a
G	GWP of HFC refrigerant	Table R-1.1	unitless	IPCC 2007 and WMO 2018
H	GWP of HFC refrigerant	Table R-1.1	unitless	IPCC 2007 and WMO 2018
I	GWP of refrigerant	Table R-1.1	unitless	IPCC 2007 and WMO 2018

Further explanation of key variables:

- (B) – The equipment charge size is the total quantity of the primary refrigerant installed in refrigeration or A/C equipment.
- (C) – The equipment charge size is the total quantity of the secondary refrigerant installed in refrigeration or A/C equipment.
- (D) – Based on industry data, the equipment charge size of a conventional direct expansion system is 1,633 kg. If the user can provide a project-specific value, they should replace the default conventional direct expansion system charge size in the GHG reduction formula.
- (E and F) – Based on industry data, the average annual leak rates for the given equipment type, including operational and servicing leak rates for the equipment

throughout the year. Leak rates are provided as averages and may vary with specific systems.

- (G, H, and I) – The GWP of the refrigerant measures the contribution to global warming from the release of one unit of the given refrigerant relative to CO_2 on a 100-year time horizon. The GWP of common refrigerants and alternatives is provided in Table R-1.1 in Appendix C.

GHG Calculation Caps or Maximums

This measure has a maximum GHG emissions reduction of 100 percent.

Example GHG Reduction Quantification

The user reduces high-GWP refrigerant emissions by replacing a conventional direct expansion system in a supermarket with a secondary loop system. In this example, the conventional direct expansion system refrigerant is R-404A, which has a GWP of 3,922 (G). The direct expansion system equipment charge size of 1,633 kg (D) is assumed. The charge size for the primary refrigerant (R-407A) in the secondary loop system is 1,145 kg (B) and the GWP is 2,107 (H). The charge size for the heat transfer fluid refrigerant using water is 1,145 kg (C) with a GWP of 0 (I). Implementation of this project would reduce GHG emissions from the refrigeration system at this supermarket by 77 percent.

$$A = \frac{((1{,}145\text{ kg} \times 15\% \times 2{,}107) + (1{,}145\text{ kg} \times 15\% \times 0)) - (1{,}633\text{ kg} \times 25\% \times 3{,}922)}{(1{,}633\text{ kg} \times 25\% \times 3{,}922)} = -77\%$$

Quantified Co-Benefits

Energy and Fuel Savings

Successful implementation of this measure could achieve energy savings. While historically secondary loop and/or cascade systems have reduced energy efficiency, the past 15 years of development have resulted in energy efficiency improvements ranging from 0.5 percent to 35 percent compared to conventional direct expansion systems (U.S. EPA 2013a; Pan et al. 2020). Note that this range of values is a historical average and that, unlike the GHG reduction formula, the energy savings cannot be precisely quantified using a predictive formula for the purposes of this methodology.

Sources

- Intergovernmental Panel on Climate Change (IPCC). 2007. *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp. Available: https://www.ipcc.ch/report/ar4/wg1/. Accessed: January 2021.
- Pan, M., H. Zaho, D. Liang, Y. Zhu, Y. Lian, and G. Bao. 2020. *A Review of the Cascade Refrigeration System*. May. Available: https://www.mdpi.com/1996-1073/13/9/2254/pdf. Accessed: January 2021.

- U.S. Environmental Protection Agency (U.S. EPA). 2013a. *Global Mitigation of Non-CO_2 Greenhouse Gases: 2010–2030*. September. Available: https://www.epa.gov/sites/production/files/2016-06/documents/mac_report_2013.pdf. Accessed: January 2021.
- U.S. Environmental Protection Agency (U.S. EPA). 2013b. *The GreenChill Partnership. Refrigerant Leak Prevention through Regular Maintenance*. September. Available: https://www.epa.gov/sites/production/files/2013-12/documents/gc_preventativemaintenance_20130913.pdf. Accessed: January 2021.
- U.S. Environmental Protection Agency (U.S. EPA). 2016. *Advanced Refrigeration*. November 2016. Available: https://www.epa.gov/greenchill/advanced-refrigeration. Accessed: January 2021.
- U.S. Environmental Protection Agency (U.S. EPA). 2019. *Global Non-CO_2 Greenhouse Gas Emission Projections & Marginal Abatement Cost Analysis: Methodology Documentation*. U.S. EPA Office of Atmospheric Programs, EPA-430-R-19-012, Washington, DC, September 2019. Available: https://www.epa.gov/sites/production/files/2019-09/documents/nonco2_methodology_report.pdf. Accessed: January 2021.
- World Meteorological Organization (WMO). 2018. *Scientific Assessment of Ozone Depletion: 2018, Global Ozone Research and Monitoring Project*. Report No. 58, 5886 pp., Geneva, Switzerland.

R-3. Install Transcritical CO_2 Supermarket Systems in Place of High-GWP Systems

GHG Mitigation Potential

99.9%

Up to a 99.9 percent reduction in GHG emissions during operation

Co-Benefits (icon key on pg. 34)

Climate Resilience

Climate resilience benefits vary by climate; in cooler and more dry climates, a CO_2 transcritical system can be at parity or more energy efficient than conventional direct expansion systems. Increased energy efficiency in refrigeration systems can reduce the strain on the overall grid, particularly the risk of power outages during peak loads. Increased efficiency can also reduce energy costs, particularly if extreme heat would otherwise increase these costs.

Health and Equity Considerations

Non-applicable

Measure Description

This measure replaces conventional direct expansion systems in supermarkets with CO_2 transcritical systems. Whereas direct expansion systems typically use a high-GWP refrigerant, CO_2 transcritical systems use CO_2, which has a GWP of 1 and a lower leakage rate than typical conventional direct expansion systems. By reducing annual leak rates and replacing high-GWP refrigerants with CO_2, these systems result in a reduction of potential direct GHG emissions. CO_2 transcritical systems operate at high pressures but otherwise operate similarly to conventional direct expansion systems. Typically, the charge size of these systems is comparable to conventional direct expansion systems. CO_2 transcritical systems work most efficiently in cooler climates; but can also be used in warmer climates (Belusko et al. 2019; U.S. EPA 2019). Transcritical CO_2 systems can be used in all California climate zones given California's latest building codes require the use of specialized equipment to ensure that energy penalties are minimized.

Scale of Application

Project/Site

Implementation Requirements

See measure description.

Cost Considerations

Transcritical CO_2 supermarket systems carry a high initial cost over traditional systems. However, CO_2 systems have a lower operating cost, mainly due to the cost of CO_2 being much lower than the cost of conventional refrigerants.

Expanded Mitigation Options

Measure is a subset of Measure R-1, *Use Alternative Refrigerants Instead of High-GWP Refrigerants*, which should be selected for increased GHG reductions in supermarket refrigerant systems.

GHG Reduction Formula

$$A = \frac{(E \times G \times B) - (D \times F \times C)}{D \times F \times C}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from refrigerant emissions	0–99.9	%	Calculated
User Inputs				
B	Equipment charge size of CO_2 transcritical system	[ ]	kg	user input
Constants, Assumptions, and Available Defaults				
C	Equipment charge size of conventional direct expansion system	1,633	kg	U.S. EPA 2019
D	Annual leak rate of conventional direct expansion system	25	%	U.S. EPA 2013
E	Annual leak rate of CO_2 transcritical system	15	%	U.S. EPA 2019
F	GWP of HFC refrigerant	Table R-1.1	unitless	IPCC 2007
G	GWP of alternative refrigerant (CO_2)	1	unitless	IPCC 2007

Further explanation of key variables:

- (B) – The equipment charge size is the total quantity of refrigerant installed in refrigeration or A/C equipment.
- (C) – Based on industry data, the equipment charge size of a conventional direct expansion system is 1,633 kg. If the user can provide a project-specific value, they should replace the default conventional direct expansion system charge size in the GHG reduction formula.
- (D and E) – Based on industry data, the average annual leak rates for the given equipment type are provided. This includes operational and servicing leak rates for the equipment throughout the year. Leak rates are provided as averages and may vary with specific systems.
- (F and G) – The GWP of the refrigerant measures the contribution to global warming from the release of one unit of the given refrigerant relative to CO_2 on a 100-year time horizon. The GWP of common refrigerants and alternatives is provided in Table R-1.1 in Appendix C.

GHG Calculation Caps or Maximums

This measure has a maximum GHG emissions reduction of 99.9 percent.

Example GHG Reduction Quantification

The user reduces high-GWP emissions by replacing a conventional direct expansion system with a CO_2 transcritical system in a supermarket. In this example, the conventional direct expansion system refrigerant is R-404A, which has a GWP of 3,922 (G), and a charge size of 1,633 kg (D). The charge size for a CO_2 transcritical system is also 1,633 kg (B) and it has a 15 percent leak rate (F). Implementation of this project would reduce GHG emissions from the refrigeration system at this supermarket by 99.9 percent.

$$A = \frac{(15\% \times 1 \times 1{,}633\ \text{kg}) - (25\% \times 3{,}922 \times 1{,}633\ \text{kg})}{25\% \times 3{,}922 \times 1{,}633\ \text{kg}} = -99.9\%$$

Quantified Co-Benefits

Energy and Fuel Savings

Successful implementation of this measure could achieve energy and fuel savings. Depending on the climate in which a CO_2 transcritical system is installed, energy efficiency can show improvements up to 10 percent (U.S. EPA 2019). These improvements decrease, or become negative, in warmer and more humid climates (U.S. EPA 2019; Belusko et al. 2019). Note that, unlike the GHG reduction formula, the energy savings cannot be precisely quantified using a predictive formula for the purposes of this methodology.

Sources

- Belusko, M., R. Liddle, A. Alemu, E. Halawa, and F. Bruno. 2019. *Performance Evaluation of a CO_2 Refrigeration System Enhanced with a Dew Point Cooler*. Energies 12, 1079. March. Available: https://www.mdpi.com/1996-1073/12/6/1079. Accessed: May 2021.
- Intergovernmental Panel on Climate Change (IPCC). 2007. *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp. Available: https://www.ipcc.ch/report/ar4/wg1/. Accessed: January 2021.
- U.S. Environmental Protection Agency (U.S. EPA). 2013. *The GreenChill Partnership. Refrigerant Leak Prevention through Regular Maintenance*. September. Available: https://www.epa.gov/sites/production/files/2013-12/documents/gc_preventativemaintenance_20130913.pdf. Accessed: January 2021.
- U.S. Environmental Protection Agency (U.S. EPA). 2019. *Global Non-CO_2 Greenhouse Gas Emission Projections & Marginal Abatement Cost Analysis: Methodology Documentation*. U.S. EPA Office of Atmospheric Programs, EPA-430-R-19-012, Washington, DC, September 2019. Available: https://www.epa.gov/sites/production/files/2019-09/documents/nonco2_methodology_report.pdf. Accessed: January 2021.

R-4. Install Microchannel Heat Exchangers in A/C Equipment in Place of Conventional Heat Exchanger

GHG Mitigation Potential

Up to a 35.0% reduction in GHG emissions during operation

Co-Benefits (icon key on pg. 34)

None

Climate Resilience

Non-applicable

Health and Equity Considerations

Microchannel heat exchangers can reduce noise produced by the condenser fan.

Measure Description

This measure replaces conventional heat exchangers in A/C equipment (e.g., unitary A/C) with microchannel heat exchangers (MCHX). Whereas conventional heat exchangers use single or multiple large-diameter tubes to transfer heat in A/C equipment, MCHX use a series of small tubes. A/C equipment using MCHX require 35 percent to 40 percent less refrigerant than those using conventional heat exchangers (U.S. EPA 2019). The reduction in refrigerant charge in A/C equipment results in a reduction of potential GHG emissions.

Scale of Application

Project/Site

Implementation Requirements

See measure description.

Cost Considerations

MCHX have a lower overall equipment cost compared to conventional heat exchangers. Long-term maintenance costs are comparable.

Expanded Mitigation Options

Pair with Measure R-1 *Use Alternative Refrigerants Instead of High-GWP Refrigerants*, for increased GHG reductions in A/C equipment.

GHG Reduction Formula

A = -B

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from refrigerant emissions	35	%	calculated
User Inputs				
	None			
Constants, Assumptions, and Available Defaults				
B	Assumed charge size reduction due to MCHX	35	%	U.S. EPA 2019

Further explanation of key variables:

- (B) – Based on industry data, the percent reduction in charge size obtained from using MCHX in A/C equipment is provided as an average reduction across A/C equipment.

GHG Calculation Caps or Maximums

This measure has a maximum GHG emissions reduction of 35 percent.

Example GHG Reduction Quantification

The user reduces high-GWP emissions replacing a conventional heat exchanger in A/C equipment with MCHX. Implementation of this project would reduce GHG emissions from the A/C equipment by 35 percent.

A = -35%

Quantified Co-Benefits

None.

Sources

- U.S. Environmental Protection Agency (U.S. EPA). 2019. *Global Non-CO_2 Greenhouse Gas Emission Projections & Marginal Abatement Cost Analysis: Methodology Documentation*. U.S. EPA Office of Atmospheric Programs, EPA-430-R-19-012, Washington, DC, September 2019. Available: https://www.epa.gov/sites/production/files/2019-09/documents/nonco2_methodology_report.pdf. Accessed: January 2021.

R-5. Reduce Service Leak Emissions

GHG Mitigation Potential

Up to 95.0% reduction in GHG emissions during servicing

Co-Benefits (icon key on pg. 34)

None

Climate Resilience

Non-applicable

Health and Equity Considerations

Non-applicable

Measure Description

This measure reduces emissions of refrigerants during equipment servicing by employing improved refrigerant servicing technologies and practices. It is estimated that recovering refrigerants can reduce emissions in servicing by up to 95 percent (U.S. EPA 2019). Through implementation of refrigerant recovery, overall service GHG emissions can be reduced. Equipment should only be serviced by qualified technicians certified under Section 608 of the Clean Air Act and who also hold an active California contractor's license in accordance with California's Refrigerant Management Program (CARB 2020). Under CARB regulations, technicians must make a recovery attempt using refrigerant recovery or recycling equipment for that type of appliance and refrigerant type before opening the appliance to atmospheric conditions. Implementing more widespread and thorough refrigerant recovery practices while servicing refrigeration and A/C systems would go beyond regulatory requirements.

Scale of Application

Project/Site

Implementation Requirements

Require that all appliances are serviced by a qualified technician who must make a recovery attempt using refrigerant recovery or recycling equipment for each appliance and refrigerant type before opening the appliance to atmospheric conditions, in accordance with existing state and federal regulations.

Cost Considerations

Costs associated with reducing service leak emissions may include installation of leak detection systems and increased staff time to monitor and maintain the system. The benefit of reducing leak emissions depends on the price of the refrigerant and the quantity of leaked refrigerant. Because many refrigerants carry a high cost, detecting and repairing leaks is expected to provide a net cost savings and will also allow for quick and accurate servicing.

Expanded Mitigation Options

Non-applicable.

GHG Reduction Formula

$$A = \frac{B - C}{C}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from service emissions	0–95.0	%	calculated
User Inputs				
	None			
Constants, Assumptions, and Available Defaults				
B	Equipment service leak rate with measure	2	%	U.S. EPA 2020
C	Equipment service leak rate without measure	Tables R-1.2 through R-1.5	%	U.S. EPA 2016

Further explanation of key variables:

- (B) – The updated service leak rate of the equipment after improved technology and/or practices. Leak rates vary between equipment types. A service leak rate of 2 percent can be assumed in the event project-specific information is not available (U.S. EPA 2020). The user should replace this default in the GHG reduction formula if the user is able to provide a project-specific equipment leak rate.
- (C) – The service leak rate of the equipment.

GHG Calculation Caps or Maximums

This measure has a maximum GHG emissions reduction of 95.0 percent.

Example GHG Reduction Quantification

The user reduces service emissions by increasing refrigerant recovery during servicing. In this example, the user operates a commercial A/C and heat pump at a restaurant. The current service leak rate is 4 percent (C). The improved servicing leak rate of the equipment (B) is 2 percent, reducing GHG emissions by 50 percent.

$$A = \frac{2\% - 4\%}{4\%} = -50\%$$

Quantified Co-Benefits

None.

Sources

- California Air Resource Board (CARB). 2020. *Refrigerant Management Program: Service Technicians & Contractors.* Available: https://ww2.arb.ca.gov/our-work/programs/refrigerant-management-program/rmp-service-technicians-contractors. Accessed: January 2021.
- U.S. Environmental Protection Agency (U.S. EPA). 2016. *Accounting Tool to Support Federal Reporting of Hydrofluorocarbon Emissions: Supporting Documentation*. October 2016. Available: https://www.epa.gov/sites/production/files/2015-09/documents/hfc_emissions_accounting_tool_supporting_documentation.pdf. Accessed: May 2021.
- U.S. Environmental Protection Agency (U.S. EPA). 2019. *Global Non-CO_2 Greenhouse Gas Emissions Projections & Marginal Abatement Cost Analysis: Methodology Documentation*. September 2019. Available: https://www.epa.gov/sites/production/files/2019-09/documents/nonco2_methodology_report.pdf. Accessed: January 2021.
- U.S. Environmental Protection Agency (U.S. EPA). 2020. *Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2018*. *Stationary Refrigeration Leak Repair Requirements*. Available: https://www.epa.gov/ghgemissions/inventory-us-greenhouse-gas-emissions-and-sinks-1990-2018. Accessed: January 2021.

R-6. Reduce Operational Leak Emissions

GHG Mitigation Potential

99.9%

Up to 99.9% reduction in GHG emissions during operation

Co-Benefits (icon key on pg. 34)

None

Climate Resilience

Non-applicable

Health and Equity Considerations

Non-applicable

Measure Description

This measure reduces emissions from leakage of refrigerants during operation, decreasing emissions of refrigerants. A typical food retail store leaks an estimated 25 percent of refrigerants, or approximately 1,000 pounds annually (U.S. EPA 2013). Currently, under Section 608 of the Clean Air Act, corrective action must be taken when an appliance with a full charge of 50 or more pounds is discovered to be leaking ozone depleting substances that exceeds the applicable trigger rate. The trigger rate for industrial process refrigeration is 30 percent, commercial refrigeration 20 percent, and comfort cooling and all other appliances is 10 percent. Through implementing leak detection technology and preventative maintenance measures, leakages can be resolved before reaching trigger rates, thus significantly reducing GHG emissions (U.S. EPA 2020).

Scale of Application

Project/Site

Implementation Requirements

Under California's Refrigerant Management Program, leak inspections are required monthly for large refrigeration systems, quarterly for medium systems, and annually for small systems (CARB 2020). When reducing leak emissions, best practices include regularly conducted visual inspections to ensure no leakages occur. If a leak does occur, repairs must be made within 14 days of detection (CARB 2020).

Cost Considerations

Costs associated with reducing operational leak emissions may include installation of leak detection systems and increased staff time to monitor and maintain the detection system. The benefit of reducing leak emissions depends on the price of the refrigerant and the quantity of leaked refrigerant. Because many refrigerants carry a high cost, detecting and repairing leaks is expected to provide a net cost savings.

Expanded Mitigation Options

Non-applicable.

GHG Reduction Formula

$$A = \frac{B - C}{C}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from leak emissions	0–99.9	%	calculated
User Inputs				
B	Improved equipment leak rate with measure	[ ]	%	user input
Constants, Assumptions, and Available Defaults				
C	Annual equipment leak rate without measure	Tables R-1.2 through R-1.5	%	U.S. EPA 2016

Further explanation of key variables:

- (B) – The improved leak rate of the equipment after leak detection, leak repair, and leak prevention measures have been implemented. This varies on a case-by-case basis due to differences in equipment and leak control technologies used.
- (C) – The annual operational leak rate of the equipment.

GHG Calculation Caps or Maximums

This measure has a maximum GHG emissions reduction of 99.9 percent.

Example GHG Reduction Quantification

The user reduces operational leak rates by installing leak detection technology and increasing regular maintenance of the equipment. In this example, the user operates refrigeration and condensing units at a supermarket. The current operational leak rate is 25 percent (C) and the updated leak rate of the equipment (B) is decreased to 20 percent annually. Implementation of this project would reduce GHG emissions from the refrigeration and condensing units at this supermarket by 20 percent.

$$A = \frac{(20\% - 25\%)}{25\%} = -20\%$$

Quantified Co-Benefits

None.

Sources

- California Air Resource Board (CARB). 2020. *Refrigerant Management Program: Service Technicians & Contractors.* Available: https://ww2.arb.ca.gov/our-work/programs/refrigerant-management-program/rmp-service-technicians-contractors. Accessed: January 2021.
- U.S. Environmental Protection Agency (U.S. EPA). 2013. *The GreenChill Partnership. Refrigerant Leak Prevention through Regular Maintenance*. September 2013. Available: https://www.epa.gov/sites/production/files/2013-12/documents/gc_preventativemaintenance_20130913.pdf. Accessed: January 2021.
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- U.S. Environmental Protection Agency (U.S. EPA). 2020. *Global Non-CO_2 Greenhouse Gas Emissions Projections & Marginal Abatement Cost Analysis: Methodology Documentation*. September 2019. Available: https://www.epa.gov/sites/production/files/2019-09/documents/nonco2_methodology_report.pdf. Accessed: January 2021.

R-7. Reduce Disposal Emissions

GHG Mitigation Potential

99.9%

Up to a 99.9% reduction in GHG emissions during disposal

Co-Benefits (icon key on pg. 34)

None

Climate Resilience

Non-applicable

Health and Equity Considerations

Non-applicable

Measure Description

This measure reduces emissions from the disposal of refrigeration and A/C equipment at the end of its lifetime. Safe disposal requirements are included in U.S. EPA regulations (40 C.F.R. 82(F)) under Section 608 of the Clean Air Act, as well as under California's Refrigerant Management Program. These requirements are designed to minimize refrigerant emissions when equipment is disposed. Refrigerants must be properly recovered using U.S. EPA-certified refrigerant recovery equipment, meaning that a least 90 percent of the refrigerant must be recovered if the compressor is operating, and at least 80 percent must be recovered otherwise (U.S. EPA 2019).

Scale of Application

Project/Site

Implementation Requirements

This measure aims to capture the remaining amount of refrigerant that is not mandated to be recovered. Refrigerants must be reclaimed by an U.S. EPA-certified reclaimer for reuse or destroyed using approved destruction methods (U.S. EPA 2018).

Cost Considerations

The main cost is labor associated with hiring a technician to complete the recovery work.

Expanded Mitigation Options

Smaller equipment tends to have the highest disposal leak rates. Target this measure to small equipment to maximize GHG reductions.

GHG Reduction Formula

$$A = \frac{B - C}{C}$$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	Percent reduction in GHG emissions from disposal emissions	0–99.9	%	calculated
User Inputs				
B	Improved equipment disposal emissions rate with measure	[ ]	%	user input
Constants, Assumptions, and Available Defaults				
C	Equipment disposal emissions rate without measure	At least 20	%	U.S. EPA 2018

Further explanation of key variables:

- (B) – The improved disposal emissions rate of the equipment after implementation of improved refrigerant recovery technologies.
- (C) – The disposal emission rate of refrigeration and A/C equipment. Refrigerant must be properly recovered using U.S. EPA-certified refrigerant recovery equipment, meaning that at least 80 percent must be recovered (U.S. EPA 2018). This means the regulated disposal emissions rate would be at least 20 percent. The actual achieved-in practice rate may be much higher than this minimum requirement and could exceed 50 percent. The user should replace this default in the GHG reduction formula if they are able to provide a project-specific value.

GHG Calculation Caps or Maximums

($B<C$) In order for implementation of this measure to result in a GHG reduction, the improved equipment disposal emission rate must be less than the 20 percent required by federal and state regulations. For residential equipment, reducing disposal emissions from over 50 percent to 25–30 percent is considered adequate.

Example GHG Reduction Quantification

The user reduces disposal emissions by implementing more technologically advanced refrigerant recovery systems. The initial disposal rate of the equipment (C) is 20 percent and the improved disposal emission rate with the project (B) is 10 percent. Implementation of this project would reduce disposal emissions by 50 percent.

$$A = \frac{(10\% - 20\%)}{20\%} = -50\%$$

Quantified Co-Benefits

None.

Sources

- U.S. Environmental Protection Agency (U.S. EPA). 2018. *Responsible Appliance Disposal (RAD) Program: Guidance for Existing and Prospective Partners.* August 2018. Available: https://www.epa.gov/sites/production/files/2018-08/documents/rad-guidance-document.pdf. Accessed: January 2021.
- U.S. Environmental Protection Agency (U.S. EPA). 2019. *Global Non-CO_2 Greenhouse Gas Emissions Projections & Marginal Abatement Cost Analysis: Methodology Documentation*. September 2019. Available: https://www.epa.gov/sites/production/files/2019-09/documents/nonco2_methodology_report.pdf. Accessed: January 2021.

Miscellaneous

This sector includes several measures that will reduce GHG emissions through the implementation of novel or offsite projects defined by the user. The general quantification framework for three measures is outlined in this section, although all require users to identify the expected GHG reductions that will be achieved by the measures. A fourth measure, M-6, *Off-Road Equipment Efficiency*, is a more defined measure and has an identical methodology as Measures C-1-A, *Use Electric or Hybrid Powered Equipment*, in the Construction sector and N-8, *Agricultural Equipment Efficiency*, in the Natural and Working Lands sector. Measure M-6 is included in this sector because it applies to other (i.e., miscellaneous) equipment that is not used for construction or agricultural purposes. Use the below graphic to click on an individual measure to navigate directly to the measure's factsheet. *Supporting or Non-Quantified GHG Reduction Measures* includes two additional measures in the miscellaneous sector that target environmentally responsible purchasing and funding for incentives.

Miscellaneous

- M-1. Establish a Carbon Sequestration Project
- M-2. Establish Offsite Mitigation
- M-3. Implement an Innovative Strategy for GHG Mitigation
- M-6. Off-Road Equipment Efficiency

M-1. Establish a Carbon Sequestration Project

GHG Mitigation Potential

Varies

Variable reduction in GHG emissions

Co-Benefits (icon key on pg. 34)

Varies

Climate Resilience

Climate resilience benefits vary by sequestration project; for example, investing in a tree-planting project could provide heat reduction, flood prevention, and ecosystem benefits to areas surrounding the project.

Health and Equity Considerations

Local carbon sequestration projects should be prioritized, if possible, to create local co-benefits in pollution reduction and job creation. Consider including a local hiring provision (see *Inclusive Economy* measures in Chapter 5, *Measures for Advancing Health and Equity*).

Measure Description

This measure will establish a carbon sequestration project. Carbon emissions are sequestered by embedding the carbon in a structure that will hold the emissions and keep them out of the atmosphere. Sequestration can happen through biological, chemical, or physical processes.

Scale of Application

Project/Site and Plan/Community.

Implementation Requirements

Projects might include (a) geologic sequestration or carbon capture and storage techniques in which CO_2 from point sources, such as power plants and fuel processing plants, is captured and injected underground; (b) novel techniques involving advanced chemical or biological pathways; or (c) technologies yet to be discovered.

Cost Considerations

Carbon sequestration projects can cover a wide range, with the high-cost option being constructing carbon capture and storage facilities. The potential for these projects to achieve long-term costs savings depends on the type and project-specific circumstance.

Expanded Mitigation Options

Non-applicable.

GHG Reduction Formula

$A = -B$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	GHG reduction from sequestration project	[ ]	MT CO_2e	calculated
User Inputs				
B	Amount of CO_2e sequestered	[ ]	MT CO_2e	user input
Constants, Assumptions, and Available Defaults				
	None			

Further explanation of key variables:

- (B) – The amount of the sequestration must be defined by the user and should be quantified using a published carbon offset protocol or one of the California Climate Investments quantification methodologies.[28]

GHG Calculation Caps or Maximums

None.

Example GHG Reduction Quantification

The user reduces GHG emissions by funding and implementing a carbon sequestration project. In this example, a biomass plant is revitalized to use oxy-combustion technology to capture CO_2 from the biomass waste gasification process. The project achieves an annual emissions reduction of 1,500 MT CO_2e.

$$A = -1{,}500\ \frac{\text{MT } CO_2e}{\text{yr}}$$

Quantified Co-Benefits

Depending on the type, a sequestration project could achieve improved air quality, water conservation, or improved ecosystem health. The protocol used to quantify GHG reductions by the user may include methodologies or recommendations for quantifying these co-benefits.

Sources

- None.

[28] CARB approved compliance offset protocols for various project types are available on CARB's website here: https://ww2.arb.ca.gov/our-work/programs/compliance-offset-program/compliance-offset-protocols.

M-2. Establish Offsite Mitigation

GHG Mitigation Potential

Varies

Variable reduction in GHG emissions

Co-Benefits (icon key on pg. 34)

Varies

Climate Resilience

Climate resilience benefits vary by offsite mitigation project; for example, investing in a community energy efficiency retrofit program could reduce electricity consumption, minimizing risks of a power outage during peak loads. These programs could also reduce energy costs, particularly if extreme heat would otherwise increase these costs. If the program reduces residential or commercial natural gas consumption, it could reduce consumer sensitivity to fuel price shocks or scarcity.

Health and Equity Considerations

Local offsite projects should be prioritized, if possible, to create local co-benefits in pollution reduction and job creation. Consider including a local hiring provision (see *Inclusive Economy* measures in Chapter 5, *Measures for Advancing Health and Equity*).

Measure Description

This measure will reduce GHG emissions by funding and implementing emissions reduction actions that are not directly associated with the project or located on the project site. These actions could occur within the surrounding community, or elsewhere in the city, county, state, nation, or globe. This measure should only be pursued when all possible onsite measures have been implemented or deemed infeasible. Local reductions (i.e., reductions from GHG reduction projects nearest to the project) should be prioritized, to the extent feasible.

The geographic priority for offsite reductions should be as follows: in the community affected by the project, within nearby communities with existing disproportionate burdens, within the general nearby community, within the region, within California, and then outside California.

If GHG reduction credits (including carbon offsets) are purchased for a project, it is recommended that all GHG credits/offsets, including those outside of California, meet the six criteria defined in *17 C.F.R. Section 95802*, which are used in the California Cap and Trade System, which are that the credit/offset must be "real, additional, quantifiable, permanent, verifiable, and enforceable." All use of GHG reduction credits should be from sources that follow rigorous protocols and third-party verification.

Scale of Application

Project/Site and Plan/Community

Implementation Requirements

This measure should only be pursued as a last resort when all possible onsite measures have been implemented or deemed infeasible.

Cost Considerations

Offsite mitigation projects can cover a wide range, from low-cost options like financing community building energy efficiency improvements to high-cost options like funding utility-scale renewable energy infrastructure. The potential for these projects to achieve long-term costs savings depends on the type and project-specific circumstance.

Expanded Mitigation Options

Non-applicable.

GHG Reduction Formula

A = -B

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	GHG reduction from the offsite mitigation	[ ]	MT CO_2e	calculated
User Inputs				
B	Amount of CO_2e reduced by the mitigation	[ ]	MT CO_2e	user input
Constants, Assumptions, and Available Defaults				
	None			

Further explanation of key variables:

- (B) – The amount of the GHG reduction achieved by the offsite mitigation must be defined by the user. Users should establish a method for registering and verifying the GHG emissions reduction and ensure it meets the six offset criteria defined in *17 C.F.R. Section 95802*. These criteria ensure the mitigation would not subsidize or take credit for emissions reductions that would have occurred regardless of the mitigation.

GHG Calculation Caps or Maximums

None.

Example GHG Reduction Quantification

The user reduces GHG emissions by funding and implementing offsite mitigation. In this example, the user collaborates with a non-profit organization to fund removal of dead, diseased, and dying trees, which are converted to transportation fuels through pyrolysis. The project achieves an annual emissions reduction of 500 MT CO_2e.

$$A = -500\ \frac{\text{MT } CO_2e}{\text{yr}}$$

Quantified Co-Benefits

Depending on the type, offsite mitigation projects may have no co-benefits or achieve a considerable number. For example, offsite mitigation projects that involve removing or retrofitting combustion sources could achieve improved air quality, energy and fuel savings, and improved public health.

Sources

- None.

M-3. Implement an Innovative Strategy for GHG Mitigation

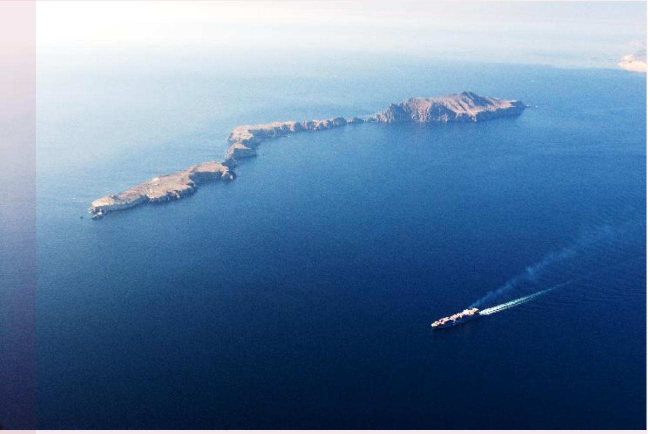
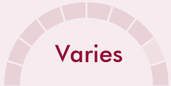


Photo Credit: Robert Schwemmer, July 2009

GHG Mitigation Potential



Variable reduction in GHG emissions

Co-Benefits (icon key on pg. 34)

(icon key on pg. 34)

Varies

Climate Resilience

Climate resilience benefits would vary by the strategy; however, any strategies that reduce costs; improve air, water quality, or public health; increase system redundancy or reliability; reduce water use; or reduce the urban heat island would have resilience benefits.

Health and Equity Considerations

Similar to climate resilience benefits, any health and equity benefits would depend on the specific strategy and actions taken.

Measure Description

This measure will develop and implement a novel strategy to reduce GHG emissions at the project site or off site. This measure may incorporate technologies which have yet to be developed at the time of the publication of this Handbook. Alternatively, this measure may also bring together multiple measures from this Handbook into a cohesive program or mechanism to facilitate the reduction of GHG emissions, such as development of a "VMT bank" that offers community-scale VMT measures that would not otherwise be available to individual land use projects.

It is recommended that all strategies or projects implemented under this measure meet the six criteria defined in 17 C.F.R. Section 95802, which are used in the California Cap and Trade System, which are that the GHG reductions must be "real, additional, quantifiable, permanent, verifiable, and enforceable." Quantification of emission reductions achieved by new strategies or projects should be from sources that follow rigorous protocols and third-party verification.

Scale of Application

Project/Site and Plan/Community

Implementation Requirements

See measure description.

Cost Considerations

A GHG mitigation strategy may be a low-cost way for a local government to encourage emission reduction activities across many levels of a community. Costs from developing and implementing the strategy are primarily related to staff time and document production. Costs and savings achieved by the strategy would vary depending on the action.

Expanded Mitigation Options

Non-applicable.

GHG Reduction Formula

$A = -B$

GHG Calculation Variables

ID	Variable	Value	Unit	Source
Output				
A	GHG reduction from the strategy	[ ]	MT CO_2e	calculated
User Inputs				
B	Amount of CO_2e reduced	[ ]	MT CO_2e	user input
Constants, Assumptions, and Available Defaults				
	None			

Further explanation of key variables:

- (B) – The amount of the GHG reduction achieved by the mitigation strategy must be defined by the user. To take quantifiable credit for this measure, the user must provide detailed and substantial evidence showing the quantification and verification of the GHG emissions reduction.

GHG Calculation Caps or Maximums

None.

Example GHG Reduction Quantification

The user reduces GHG emissions by funding and implementing an innovative GHG reductions strategy. In this example, the lead agency for a new development project collaborates with a local air quality management district and CARB to fund a project that achieves an annual emissions reduction of 2,000 MT CO_2e.

$$A = -2{,}000\ \frac{\text{MT } CO_2e}{\text{yr}}$$

Quantified Co-Benefits

Depending on the type, mitigation projects may result in none of the identified co-benefits or achieve several of them. For example, mitigation projects that involve removing or retrofitting combustion sources could achieve improved air quality, energy and fuel savings, and improved public health. This quantification methodology does not quantify the co-benefits from these projects.

Sources

- None.

M-6. Off-Road Equipment Efficiency

GHG Mitigation Potential

Large

Potentially large reduction in GHG emissions from operational equipment

Co-Benefits (icon key on pg. 34)

Climate Resilience

Improving off-road equipment efficiency through use of electric- or hybrid-powered equipment can reduce sensitivity to fuel price shocks or scarcity in conventional fuels. However, using all-electric equipment may decrease resilience if it is the only option available during a power outage.

Health and Equity Considerations

Replacing diesel and gas-powered equipment with cleaner-fuel or electric-powered equipment reduces the risk of pollutant-related health conditions and effects related to noise pollution for the user and surrounding communities.

Measure Description

This measure requires use of electric- or hybrid-powered off-road equipment over conventional diesel-fueled counterparts during operational activities. Replacing diesel-powered, off-road equipment with electric or hybrid-electric equipment reduces fossil fuel combustion and thus GHG emissions. However, all-electric equipment results in GHG emissions from the electricity used to charge the equipment. The indirect GHG emissions increase from electricity must be calculated in addition to the GHG emissions reduction from displaced fossil fuel combustion to estimate the total net GHG emissions reduction achieved by this measure if using all electric equipment. Variations of this measure are described in Measure C-1-A, *Use Electric or Hybrid Powered Equipment*, Measure N-8, *Agricultural Equipment Efficiency*, and Measure C-1-B, *Use Cleaner-Fuel Equipment*.

Scale of Application

Project/Site and Plan/Community

Implementation Requirements

Note that while this measure discusses off-road equipment used for general purposes, this measure can also be implemented for other off-road equipment applications (e.g., construction, agriculture).

Cost Considerations

Electric- or hybrid-powered equipment tends to be more expensive to purchase and install than conventional models powered by fossil fuels. These costs may be offset by savings in fuel use and maintenance.

Expanded Mitigation Options

Pair with Measure E-10, *Procure Electricity from Lower Carbon Intensity Power Supply*, to ensure that the energy supplied to power the electrified equipment has a lower carbon intensity than the local grid, thereby further reducing GHG emissions. Consider using portable batteries to support and extend implementation of this measure at more remote sites.

GHG Reduction Formula

$A1 = (C \times D \times F \times G1 \times H) - (C \times D \times \mathbf{G2_B} \times I)$

$A2 = (C \times D \times E \times \mathbf{G2_B} \times I)$

GHG Calculation Variables

ID	Parameter	Value	Unit	Source
Output				
A1	GHG reduction from using electric off-road equipment	[ ]	MT CO_2e	calculated
A2	GHG reduction from using hybrid off-road equipment	[ ]	MT CO_2e	calculated
User Inputs				
B	Fuel type of existing equipment	[ ]	text	user input
C	Hours of equipment operation	[ ]	hours	user input
G2	Carbon intensity of fossil fuel off-road equipment	[ ]	g CO_2e per hp-hour	CARB 2021; CAPCOA 2023
Constants, Assumptions, and Available Defaults				
D	Horsepower of electric or hybrid off-road equipment	[ ]	hp	user input; CARB 2023; CA CORE 2023
E	Percent fuel reduction of hybrid equipment compared to conventional equipment	10	%	Holian and Pyeon 2017
F	Conversion from horsepower to MW	0.0007457	MW per hp	conversion
G1	Carbon intensity of local utility provider	Tables E-4.3 and E-4.4	lbs CO_2e per MWh	CA Utilities 2021
H	Conversion from lbs to MT	0.000454	MT per lb	conversion
I	Conversion from grams to MT	$1\ e^{-6}$	MT per gram	conversion

Further explanation of key variables:

- (B) – The fuel type of the existing equipment is used to obtain the carbon intensity of the equipment (G2) from OFFROAD.
- (C) – This input represents the hours of operation that the equipment will be used over a user-specified time period.
- (D) – The horsepower of the electric off-road equipment that is electric or hybrid will need to be provided by the user.
- (E) – The percent fuel reduction is used in this formula as a proxy for the percent activity reduction that would be expected with hybrid off-road, heavy-duty equipment. Based on

a survey of 12 models of off-road, heavy-duty equipment from 10 different manufacturers, hybrid off-road equipment reduced fuel use by 10 to 45 percent, with an average of 28 percent (Holian and Pyeon 2017). To be conservative, the low end of the range is cited. If the user can provide an equipment-specific hp, the user should replace the default in the GHG calculation formula. If the user knows the make and model of the off-road equipment used, the user should replace the default in the GHG calculation formula.

- (F) – Conversion factor assumes that energy requirements and losses are the same for both a fuel-powered engine and an electrically charged engine.
- (G1) – GHG intensity factors for major California utilities are provided in Tables T-13.1 and T-13.2 in Appendix C. If the project study area is not serviced by a listed utility, or the user is able to provide a project-specific value (i.e., for the future year not referenced in Appendix C), the user should replace the default in the GHG calculation formula. If the utility is not known, the user may elect to use the statewide grid average carbon intensity.
- (G2) – GHG intensity factors for various off-road equipment can be obtained from CARB's (2021) OFFROAD model or from the CalEEMod User Guide. Note that the OFFROAD emissions rates are inclusive of equipment load. Therefore, the GHG reduction equation does not include a multiplier for load factor. In addition, GHG intensity factors for various off-road equipment can be obtained from the User Guide for CalEEMod: Appendix G.

GHG Calculation Caps or Maximums

None.

Example GHG Reduction Quantification

The user reduces off-road equipment emissions by replacing fossil-fuel combustion with electricity consumption, which generates fewer GHG emissions per unit of activity. In this example, a port is replacing a 2020 model year 575-hp diesel reach stacker forklift (D) that is used 8 hours per day (C) with an electric-powered equivalent (CARB 2023; CA CORE 2023). A 2020 model year 575-hp diesel reach stacker forklift has an approximate carbon intensity of 531 grams CO_2e per hp-hour (G2). The electric utility for the project area is Pacific Gas & Electric Company, and the analysis year is 2025. The carbon intensity of electricity is, therefore, 206 lbs CO_2e per megawatt-hour (G1).

$$A=\left(8\ \frac{\text{hours}}{\text{day}}\times 575\ \text{hp}\times 0.0007457\ \frac{\text{MW}}{\text{hp}}\times 206\ \frac{\text{lbs } CO_2e}{\text{MWh}}\times 0.000454\frac{\text{MT}}{\text{lb}}\right)-\left(8\ \frac{\text{hours}}{\text{day}}\times 575\ \text{hp}\times \mathbf{531}\ \frac{\text{g } CO_2e}{\text{hp-hour}}\times 1\text{x}10^{-6}\frac{\text{MT}}{\text{g}}\right)=-2.12\ \frac{\text{MT } CO_2e}{\text{day}}$$

Quantified Co-Benefits

Improved Air Quality

Reducing fossil-fuel combustion will also reduce local criteria pollutants. Emission savings can be calculated using the same formula used to quantify GHG reductions (A1 and A2). Criteria pollutant intensity factors for various off-road equipment can be obtained from CARB's (2021) OFFROAD model.

Electricity supplied by statewide fossil-fueled power plants will generate criteria pollutants. However, because these power plants are located throughout the state, electricity consumption from equipment charging will not generate localized criteria pollutant emissions at the equipment source. Consequently, for the quantification of criteria pollutant emission reductions, either the electricity portion of the equation can be removed or the electricity intensity (G1) can be set to zero.

Energy and Fuel Savings

Fossil fuel savings are a product of the equipment fuel efficiency (gallons consumed per hour) and the equipment operating time (hours). Fuel intensity factors for various off-road equipment can be obtained from CARB's (2021) OFFROAD model. Users should multiply the fuel intensity by the equipment operating hours to quantify fuel savings.

Increased electricity consumption for electric equipment is calculated as part of the GHG reduction formula (A). The abbreviated formula is also shown below.

$$MWh = C \times D \times F$$

Sources

- California Air Pollution Control Officer's Association (CAPCOA). 2023. User Guide for CalEEMod Version 2022.1: Appendix G, Default Data Tables Available: https://caleemod.com/user-guide. Accessed: January 2024.
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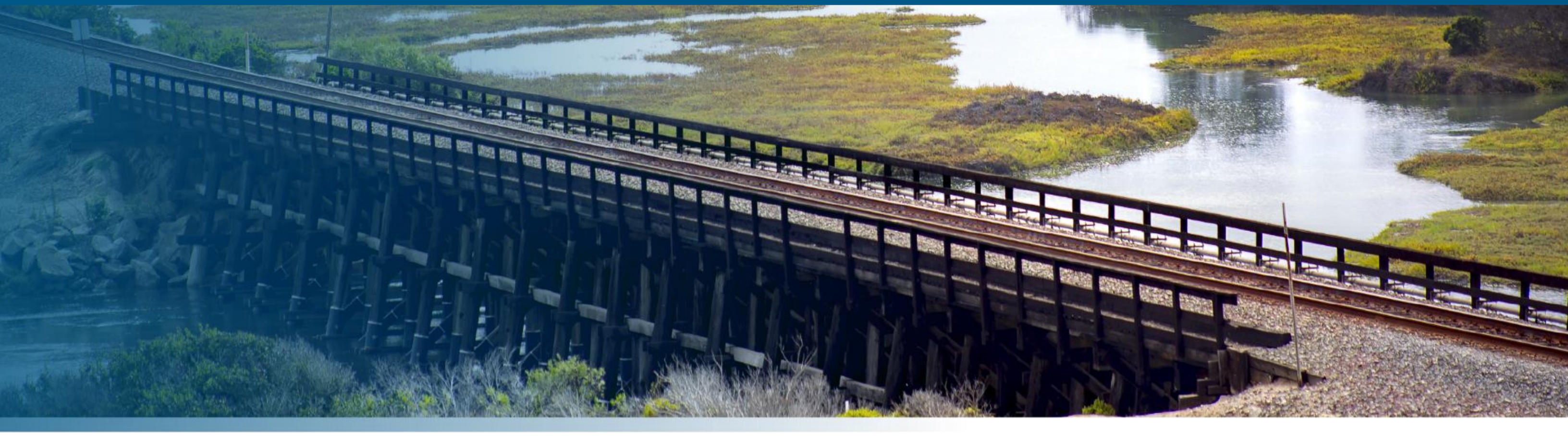
Assessing Climate Exposures and Measures to Reduce Vulnerabilities

CHAPTER 4



Introduction

This chapter provides a method to assess the potential benefits of different climate risk reduction measures at the project level. The climate exposures, sensitivities, and adaptive capacities of a project or asset all influence their vulnerabilities to current and expected impacts of climate change. This chapter presents a step-by-step process to identify and score these variables. These scores should be used to establish an initial vulnerability score, which will allow users to identify priority vulnerabilities, as well as measures to reduce these vulnerabilities. This chapter also provides descriptions of climate vulnerability reduction measures and guidance for assessing adaptive benefits of selected measures.

Climate change has already profoundly affected California's natural resources, communities, and infrastructure, and will continue to do so in the future. Existing and future developments must consider climate change in their planning processes to adequately prepare for anticipated hazards and risks. This chapter guides users through estimating their project's site- or regional-level climate vulnerability, as well as selecting risk reduction measures to address those vulnerabilities.

The *Adaptation Planning Guide* (APG) is the state's comprehensive guidance for assessing climate vulnerability at the local level. The APG is hosted on the California's Governor's Office of Planning and Research's (OPR) Resilient-CA website, where additional materials and local adaptation case studies can also be found. Resilient-CA is regularly updated as new climate vulnerability assessments are completed. To ensure alignment with the state's overall approach to vulnerability assessments, this chapter follows the structure and processes outlined in the APG, which was last revised in 2020 (OPR 2020).

The guidance presented in this chapter should be used as a starting point to help users understand and begin to analyze potential climate vulnerabilities. The methodology should not replace a full climate vulnerability assessment performed using the APG or other resources. Moreover, the scores alone should not be used to define or communicate the climate risks for a project. A climate vulnerability score of 5, for example, does not mean that a project will face certain climate catastrophe. Similarly, a score of 1 does not mean that a project will not face any climate hazards. The purpose of the Handbook scoring method is to aid users in prioritizing the most significant climate risks so that they can select appropriate risk reduction measures for their project. Users seeking a more thorough or tailored analysis should refer to the APG, the Resilient-CA website, or other resources (provided later in this chapter).

Assessing Climate Vulnerability and Risk Reduction

The step-by-step process detailed in this chapter is outlined below.

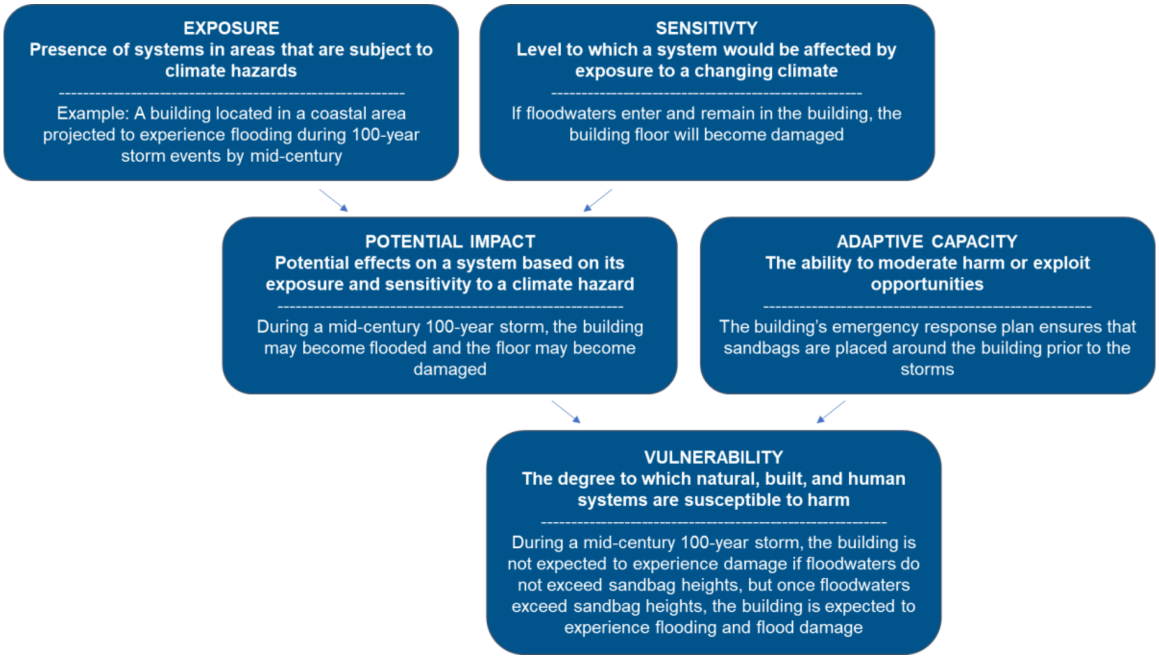
1. *Establish Initial Vulnerability Score* – this step guides the user through a high-level assessment of the contributing elements to a project's climate vulnerabilities, including exposure, sensitivity, and existing adaptive capacity to projected climate hazards. Steps for establishing the vulnerability score are as follows.
    a. Determine exposure score.
    b. Determine sensitivity score.
    c. Determine adaptive capacity score.
    d. Develop overall vulnerability score.
2. *Select Measures and Assess Vulnerability Reduction* – after establishing the initial vulnerability score, this step guides the user through selecting measures that can effectively reduce climate vulnerabilities. It also provides guidance for determining measure costs and benefits. Steps identifying and assessing vulnerability reduction measures are as follows.
    a. Select climate risk reduction measures.
    b. Identify adaptation benefits.
    c. Identify adaptation co-benefits.

Initial Vulnerability Score

Climate hazards, such as sea level rise, wildfire, flooding, and heat waves, will increasingly affect projects and project sites. The climate vulnerability of a project refers to the extent to which a project site or community is susceptible to harm from these climate hazards. In this step, users will establish a baseline for the current and projected vulnerabilities from climate hazards.

Developing an overall vulnerability score consists of combining three elements: exposure, sensitivity, and adaptive capacity. Figure 4-1 from the *California Adaptation Planning Guide* shows how these elements combine to determine climate vulnerability (Cal OES 2020).

Figure 4-1. Vulnerability Assessment Process in California Adaptation Planning Guide (Source: California's Governor's Office of Emergency Services 2020)



The following sub-steps provide guidance on developing scores to assess a project's exposure, sensitivity, and adaptive capacity. Users should first score these three components separately, using guidance provided below in the form of maps, tables, and guiding questions. Users will carry out the vulnerability scoring process in the following way.

1. Score the project's exposure to each climate hazard on a scale of 1 to 5.
2. Score the project's sensitivity to each climate hazard on a scale of 1 to 5.
3. Rate the project's adaptive capacity to each hazard using the ranking system of Low, Low–Med, Med, Med–High, and High. (Adaptive capacity is not scored from 1 to 5 to avoid confusion as the numeric scale for this component would be reversed from the scale for exposure and sensitivity.)

4. Average the project's exposure and sensitivity scores to develop a potential impact score for each climate hazard from 1 to 5.
5. Combine the potential impact scores and adaptive capacity ratings to develop a vulnerability score for each climate hazard from 1 to 5.
6. Select the highest-scoring vulnerabilities to address as priority climate vulnerabilities.

This section also provides a *use case example* for a hypothetical affordable housing project in Los Angeles County to illustrate these sub-steps and how to arrive at a final vulnerability score. Users can follow along the example to understand how the scoring system works, what kind of project characteristics may justify a score, and how users can use their final vulnerability score to choose adaptation measures.

Determine Exposure Score

This section guides the user through the following sub-steps to determine the exposure score.

1. Identify key climate hazards based on the project site location.
2. Select initial regional exposure scores.
3. Refine initial regional exposure scores.

The following sections provide a high-level exposure map and accompanying table for users to identify key climate hazards. Guiding questions and resources to define the exposure score from 1 to 5 (with 1 being the least exposed and 5 being the most exposed) are then presented.

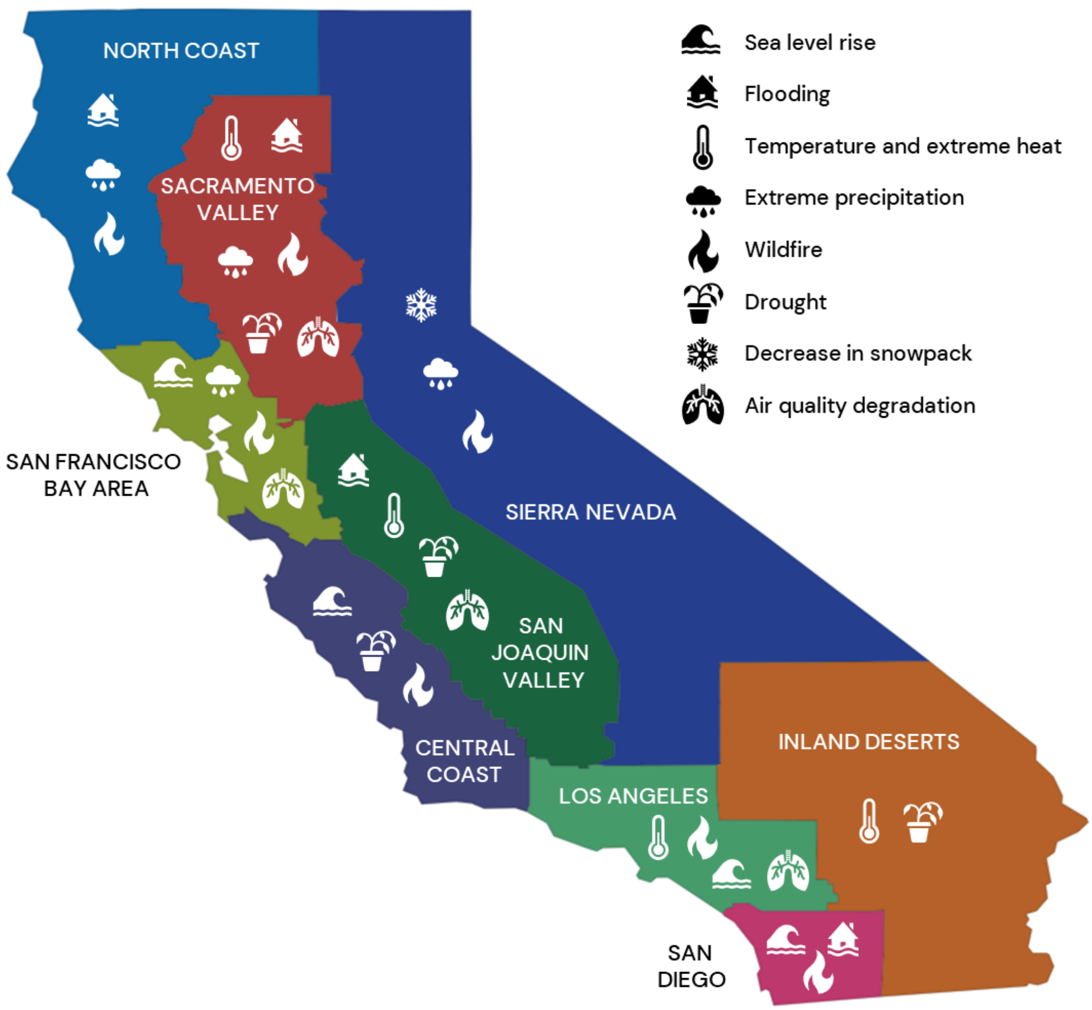
Identify Key Climate Hazards

Figure 4-2 shows the nine main climate regions of California as identified in the *California Fourth Climate Change Assessment* (Bedsworth et al. 2018).

Identify the climate region in which the user's project is located (Figure 4-2).

Use Case Example: The project is in the Los Angeles Region.

Figure 4-2. Illustrative Climate Hazards in Nine Climate Regions of California under the California Fourth Climate Change Assessment



Select Initial Regional Exposure Scores

For each of the nine regions, the *California Fourth Climate Change Assessment* identifies the most significant climate hazards, summarized in Table 4-1, along with initial regional exposure scores that allow users to screen for the hazards of greatest concern to their geography. These initial regional scores are based on an analysis of Cal-Adapt and the *California Fourth Climate Change Assessment's* summaries of the most relevant climate hazards in each region. Where given, a range reflects how much the vulnerability to climate change can vary within that region. For example, sea level rise does not occur everywhere in San Francisco (score of 1), but it can be a significant vulnerability (score of 5) for coastal areas.

Locate the climate region for the user's project in Table 4-1 and record the initial regional exposure score for each hazard.

Table 4-1. Initial Regional Climate Hazard Exposure Values [a]

Region	Sea Level Rise	Flooding	Temperature and Extreme Heat	Extreme Precipitation	Wildfire	Drought	Decrease in Snowpack	Air Quality Degradation
Central Coast	1–5	1–2	1–5	1–5	1–5	3–4	1–2	1–2
Inland Deserts	N/A	1–2	1–5	1–5	1–5	3–5	1–2	2–4
Los Angeles	1–5	1–3	1–5	1–5	1–5	4–5	2–3	3–5
North Coast	1–5	2–3	1–5	1–5	1–5	3–4	3–4	1–2
Sacramento Valley	N/A	3–4	1–5	1–5	1–5	3–4	2–3	3–4
San Diego	1–5	2–3	1–5	1–5	1–5	3–4	1	3–4
San Francisco Bay Area	1–5	2–4	1–5	1–5	1–5	2–4	2–4	3–4
San Joaquin Valley	N/A	2–3	1–5	1–5	1–5	3–5	2–4	2–3
Sierra Nevada	N/A	3–4	1–5	1–5	1–5	3–4	5	1–3

[a] Within the CalEEMod tool, some hazards (sea level rise, temperature and extreme heat, extreme precipitation, and wildfire) are evaluated in regional quantiles using Cal-Adapt data; to ensure consistency between this Handbook and CalEEMod, these four hazards have a score range of 1 to 5 here. The score range for the remaining four hazards (flooding, drought, decrease in snowpack, and air quality degradation) are based on a comparison of relevant hazards summarized in the *California's Fourth Climate Assessment* regional reports.

Use Case Example: The following climate hazards and initial regional exposure scores are applicable for the Los Angeles region.

- Sea level rise: 1–5
- Flooding: 1–3
- Temperature and extreme heat: 1–5
- Extreme precipitation: 1–5
- Wildfire: 1–5
- Drought: 4–5
- Decrease in snowpack: 2–3
- Air quality degradation: 3–5

Based on these initial regional scores, significant region-wide climate hazards for the Los Angeles region include sea level rise, temperature and extreme heat, extreme precipitation, wildfire, drought, and air quality degradation.

Refine Initial Regional Exposure Scores

Where Table 4-1 offers a range (e.g., 1–3) for a climate hazard exposure score, users can refine that range to a single score that is more specific to a project location. Table 4-2 provides key questions and considerations users could use to refine their exposure scores for their region. For example, a user with a site in the San Francisco Bay Area within the Coastal Zone Boundary that has experienced coastal flooding in the past should consider a "5" hazard rating for sea level rise.

Table 4-2 also indicates whether each question refers to a project area's past or potential future climate exposure. This distinction is important because susceptibility to climate hazards in the past is one factor indicating susceptibility to climate hazards in the future. However, the lack of past exposure does not mean future climate hazards will also be the same. As the climate changes, the frequency and severity of climate impacts increase, and climate risk areas extend beyond historic boundaries. Users should keep this in mind as they refine the initial exposure scores.

Table 4-2. Guidance Questions for Refining Initial Climate Hazard Exposure Scores

Past vs. Future	Question	User Answer	Exposure Score
Sea Level Rise			
Past	Has the project area experienced flooding in the past?	Yes	High
		No	Low–Med
Future	Is the project area projected to experience flooding under future sea level rise?	Yes	High
		No	Low–Med
Flooding			
Past	Is the project located in a 100-year Federal Emergency Management Agency (FEMA) floodplain?	Yes	High
		No	Low
Past	Is the project located in a 500-year FEMA floodplain?	Yes	Med
		No	Low
Past	Has the project area experienced flooding in the past?	Yes	High
		No	Low–Med
Future	Is the project area projected to experience an expansion in flood risk areas, increased flood depths, or increased extreme precipitation events?	Yes	High
		No	Low–Med
Temperature and Extreme Heat			
Past	Is the project located in an urban heat island? (Is the project located in a dense urban or suburban environment?)	Yes	High
		No	Med
Future	Is the project area projected to have higher projected temperature and extreme heat values compared to the region as a whole?	Yes	High
		No	Low–Med
Extreme Precipitation			
Past	Has the project area experienced extreme precipitation (e.g., over the 95th percentile) in the past?	Yes	High
		No	Low–Med
Future	Is the project area projected to have higher extreme precipitation values or changes in extreme precipitation compared to the region as a whole?	Yes	High
		No	Low–Med

Past vs. Future	Question	User Answer	Exposure Score
Wildfire			
Past	Is the project located in the wildland–urban interface (WUI) (as defined by CAL FIRE hazard and/or county WUI maps)?	Yes	High
		No	Low
Past	Is the project in or near an area that experiences high wind events?	Yes	High
		No	Low–Med
Past	Is the project area composed of vegetation that could serve as significant wildfire fuel?	Yes	High
		No	Low–Med
Past	Has the project area experienced wildfire in the past?	Yes	High
		No	Low-Med
Future	Is the project area projected to have higher wildfire risk compared to the region as a whole?	Yes	High
		No	Low–Med
Drought			
Past	Has or does the project area's local government impose water conservation requirements beyond the statewide requirements?	Yes	High
		No	Low-Med
Past	Has the project area experienced curtailments in water deliveries from local surface or groundwater sources in the past?	Yes	High
		No	Low-Med
Past	Has the project area ever been identified in a state drought emergency declaration?	Yes	High
		No	Low-Med
Future	Is the project area projected to experience an increase in the frequency or severity of drought in the future?	Yes	High
		No	Low-Med
Decrease in Snowpack			
Past	Does the project rely on annual snowfall directly (e.g., recreation facility relying on snow)?	Yes	High
		No	Low-Med
Past	Does the project depend on water sources that vary annually based on snowpack?	Yes	Med
		No	Low
Future	Is the project area projected to experience a decrease in future snowpack?	Yes	High
		No	Low-Med
Air Quality Degradation			
Past	Is the project area within a nonattainment area for federal or state ambient air quality standard?	Yes	High
		No	Low
Past	Is the project area within 0.25 mile of a major freeway?	Yes	High
		No	Low
Past	Is the project area within 0.25 mile of a major industrial zone or logistics center?	Yes	High
		No	Low
Past	Is this project area within the WUI?	Yes	High
		No	Low
Future	Is the project area projected to experience a decrease in future air quality due to climate change (e.g., due to increased smoke from wildfires)?	Yes	High
		No	Low-Med

When refining the exposure score, it may be useful to refer to climate projection tools to consider climate hazard exposure in the specific area where the project will be located. Users are also encouraged to consult any local climate vulnerability assessments, local hazard mitigation plans, or other climate planning documents for their region or project area. The following resources provide additional guidance on understanding climate exposures, as well as exposure maps, that can be used to further refine the exposure score. In some cases, selecting a refined exposure score may require users to make certain assumptions or judgements.

- CalEEMod: This model provides an exposure mapping tool that is based on data from Cal-Adapt and the Coastal Storm Modeling System (CoSMoS) (mentioned below).[29]
- Cal-Adapt: This is the official statewide climate hazard mapping tool. Use this tool to assess exposure to temperature, precipitation, and wildfire-related hazards by location.
- Our Coast, Our Future: A web visualization tool based on data from CoSMoS. Use this tool to assess exposure to sea level rise and coastal flooding hazards.
- Adaptation Planning Guide (APG): The California Governor's Office of Emergency Services (Cal OES) provides detailed guidance for conducting vulnerability studies that can help users expand on the baseline assessment here.
- Integrated Climate Adaptation and Resiliency Program (ICARP) Adaptation Clearinghouse: OPR's official database of adaptation case studies and technical reports. Users can search the ICARP database to look for detailed vulnerability assessments covering the project site.
- Caltrans 2019 Climate Change Vulnerability Assessments: The California Department of Transportation (Caltrans) has conducted climate change vulnerability assessments for each of its 12 regions. While the focus is on resilience of the state highway system, the climate hazard analysis and recommendations can be generalized to other land uses and projects. Each region also has an interactive map that provides localized climate impact projections.

Answer the questions in Table 4-2 to refine the climate hazard exposure ranges and obtain a single score for each climate hazard.

Use Case Example: The Los Angeles project is an affordable housing building located in a highly urban area. Table 4-3 shows the initial regional exposure ranges per hazard outlined above, as well as refinements to the initial regional scores with justifications.

[29] This version of CalEEMod is still in development and will be released in 2022.

Table 4-3. Refined Exposure Scores and Justifications for Use Case Example

Climate hazard	Initial Regional Exposure Range	Refined Exposure Score	Justification for Refined Exposure Score
Sea Level Rise	1–5	1	The project is not located within an area previously subject to coastal flooding and is not in an area with projected future sea level rise.
Flooding	1–3	1	The project is not located within any Federal Emergency Management Agency flood zones or within future flood risk areas determined from local flood risk studies sourced from the Resilient-CA website.
Temperature and Extreme Heat	1–5	5	The project is in an urban heat island and in an area projected to become hotter in the future.
Extreme Precipitation	1–5	2	The project area has experienced few extreme precipitation events in the past and is not in an area projected to experience extreme precipitation in the future.
Wildfire	1–5	2	The project is not located in the wildland-urban interface or in an area projected to experience an increase in wildfire risk in the future.
Drought	4–5	5	The project relies on water that comes from imported sources and is in an area highly vulnerable to increased frequency and severity of drought in the future.
Decrease in Snowpack	2–3	3	The project relies on water that comes from imported sources that will face increased future risk under climate change.
Air Quality Degradation	3–5	5	The project is located near a major freeway and in a non-attainment area for the federal 8-hour ozone standard.

Determine Sensitivity Score

This section guides the user through determining the sensitivity score. The sensitivity score reflects the extent to which a project would be adversely affected by exposure to a climate hazard. There are multiple aspects of sensitivity to consider.

- **Physical:** How sensitive the project may be to physical damage from climate hazards. For example, wildfire can impair the structural integrity of buildings through incineration and exposure to extreme temperatures. Historical data on events for the project site and similar projects can provide insights for how sensitive the project may be to physical effects from different hazards.
- **Operational:** How sensitive the project may be to disruptions of regular operations from climate hazards. For example, flooding along roads may disrupt public transportation operations. Historical data on events for the project site, similar projects,

and critical interconnections (e.g., local energy utilities, transportation networks) will be helpful in understanding potential operational disruptions.

- Safety: How sensitive populations associated with a project may be to different climate hazards. For example, apartments in urban areas may become hot and not cool down easily during extreme heat events due to urban heat island effects, endangering the health of residents. Some projects may serve populations that are more vulnerable to climate hazards, such as hospitals or nursing homes.

The questions below allow the user to understand how project specifics and site historical data can help provide insights to the sensitivities of a project to climate hazards. Some of the questions, such as those on populations served by the project or project elements vulnerable to physical impacts, are specific to the project type and the user's knowledge of the project. Other questions may require the Handbook user to access existing reports for the project area. For example, historical data on hazard impacts for the project area and similar projects may be found in local hazard mitigation plans or through engaging local community planners and decision makers.

Users can take an average of their scores across the four questions below to obtain an overall sensitivity score. However, users do not necessarily need to weigh the four questions below equally. A user may, for example, weigh the question on vulnerable populations much higher than the other questions if that is the project priority. Similarly, questions below are not meant to be all-encompassing in capturing the different aspects of climate sensitivity. Users may find there are other characteristics of their project not listed below that also have a factor in determining the project's climate sensitivity. The following questions serve as guidance in helping a user think through and understand their project's climate sensitivity and address the most sensitive parts. This is important to note particularly if the scores for each question vary widely, such as projects that are not very physically sensitive to a hazard but may have highly sensitive operations.

Answer the following four questions to assign the project a sensitivity score of 1 to 5 for each climate hazard.

Question #1. How have similar projects to the user's and the project site been impacted by past extreme climate events?

Score Spectrum

○ Similar projects and the project area have experienced little to no effects from this hazard.	○ Similar projects and the project area have faced damage from this hazard that may have been major and/or permanent but does not significantly affect the project.	○ Similar projects and the project area have faced catastrophic damage from this hazard that resulted in permanent effects and significantly altered the project's functionality and local community.

Question #2. Does the project include elements that are susceptible to physical damage from the climate hazards (either at their historic or projected levels)?

Score Spectrum

○ The project has no elements that are susceptible to physical damage from this hazard, including projected severity over the project lifetime.	○ The project has some elements that may be physically damaged by the hazard as projected over its lifetime, but they are not significant to the functionality of the project.	○ The project relies significantly on elements that are likely to be physically damaged by the hazard as projected to occur over its lifetime.

Question #3. If the project includes an operational component (e.g., a utility), how might that be affected by the climate hazards (either at their historic or projected levels)?

Score Spectrum

○ The project does not contain an operational component that is likely to be affected the hazard.	○ The project has an operational component, but it will only face minor disruptions from the hazard.	○ The project has a significant operational component that will be affected by this hazard.

Question #4. Does the project serve vulnerable populations who may be particularly sensitive to certain climate hazards (e.g., a nursing home) at their historic and projected levels?

Score Spectrum

○ The project is not likely to serve any vulnerable populations.	○ The project serves the public, some of whom may be vulnerable populations.	○ The project almost exclusively serves vulnerable populations.

Use Case Example: The Los Angeles affordable housing project does not have a significant operational component, nor does it house many fragile systems. However, it is a residence that serves a vulnerable population. We will give it the following sensitivity scores with justifications (Table 4-4).

Table 4-4. Sensitivity Scores and Justifications for Use Case Example

Climate Hazard	Question #1. (Impact of Past Events)	Question #2. (Elements Prone to Historic or Projected Damage)	Question #3. (Operations Vulnerable to Historic or Projected Hazards)	Question #4. (Populations Vulnerable to Historic or Projected Hazards)	Final Sensitivity Score
Sea Level Rise	1—Sea level rise impacts have not occurred in this location in the past	2—Building is slightly elevated, so inundation not likely to infiltrate units	3—Apartment operations may face minor disruptions from inundation, particularly if flooding occurs at a level not seen in the past	4—Serves low-income populations that may be sensitive to inundation from sea level rise, particularly if flooding occurs at a level not seen in the past	3
Flooding	4—Similar projects have faced damage or inaccessibility from flooding	2—Building is slightly elevated, so inundation not likely to infiltrate units	4—Apartment operations and access may face minor disruptions from inundation, particularly if flooding occurs at a level not seen in the past	4—Serves low-income populations that may be sensitive to flooding, particularly if flooding occurs at a level not seen in the past	4
Temperature and Extreme Heat	5—Other apartment buildings around this location have been affected by extreme heat in the past	2—Electrical equipment inside may be sensitive to extreme heat, but overall building is not	4—Cooling equipment may fail more frequently due to working outside of original design parameters	5—Serves low-income residents who may be especially sensitive to extreme heat due to cost of energy bills and lack of nearby access to cool locations and weatherization resources/services	5
Extreme Precipitation	1—Similar projects have not faced significant impacts from extreme precipitation	1—Project may experience light wear and tear, but no elements are highly sensitive to extreme precipitation	2—Apartment operations may face mild disruptions from extreme precipitation, particularly if rainfall occurs at an intensity level not seen in the past	3—Serves low-income residents who may face slight sensitivity to extreme precipitation, particularly if rainfall occurs at an intensity level not seen in the past	2
Wildfire	1—Wildfires have not occurred in this location in the past	4—Building may face damage from wildfire	4—Wildfire would affect apartment operations, particularly if wildfire occurs at a level not seen in the past; high building occupancy also makes this project sensitive	5—Serves low-income residents who may be highly sensitive to wildfire, particularly if wildfire occurs at a level not seen in the past	4

Climate Hazard	Question #1. (Impact of Past Events)	Question #2. (Elements Prone to Historic or Projected Damage)	Question #3. (Operations Vulnerable to Historic or Projected Hazards)	Question #4. (Populations Vulnerable to Historic or Projected Hazards)	Final Sensitivity Score
Drought	Unknown past impacts	2—Project does not have abundant landscaping that requires water	1—Drought unlikely to affect operations	2—Serves low-income residents who may be slightly sensitive to drought, particularly if drought occurs at a level not seen in the past	2
Decrease in Snowpack	Unknown past impacts	1—No elements prone to damage from decrease in snowpack	1—Decrease in snowpack unlikely to affect operations	1—Residents unlikely to be affected by decrease in snowpack	1
Air Quality Degradation	4—Other apartment buildings around this location have been affected by air quality degradation in the past	1—No elements prone to damage from air quality degradation	1—Air quality degradation unlikely to affect operations	5—Serves low-income residents who may be highly sensitive to air quality degradation due to cost of healthcare and lack of nearby access to clean air locations	4

Determine Adaptive Capacity Rating

The adaptive capacity of a project refers to its ability to manage and reduce vulnerabilities from projected climate hazards. For example, a housing development with heating, ventilation, and air conditioning (HVAC) throughout the building will provide residents with cooling and air filtration against projected increases in heat waves and smoke from wildfire events. Identifying the adaptive capacity of a proposed project will help users understand the degree to which vulnerabilities may be addressed before taking adaptation actions.

Rather than use a numerical score, users will rate their adaptive capacity on a spectrum from Low to High. Like sensitivity, users can take an average of their scores amongst the four questions below to obtain an overall adaptive capacity score, but users do not need to weigh them equally and the questions provided do not necessarily capture all aspects of adaptive capacity.

Answer the following four questions to assign the project an adaptive capacity rating of Low, Low–Med, Med, Med–High, or High for each climate hazard.

Question #1. How have similar projects or other developments in the project area managed climate impacts in the past?

Score Spectrum

Low: Similar projects and developments in the project area were not able to manage climate impacts or required significant cost/effort in doing so.

Med: Similar projects and developments in the project area required a fair amount of cost and effort to manage climate impacts.

High: Similar projects and developments in the project area adapted to climate impacts with little cost and effort.

Question #2. Does the project have design elements that may mitigate climate impacts planned (e.g., drainage system, cool roof, modifications that can be made over time)?

Score Spectrum

Low: The project does not have any elements that may mitigate climate impacts.

Med: The project has some elements that partially address the most relevant climate hazards.

High: The project already has elements that address the climate hazard of most relevance.

Question #3. Are there already policies and standards that the project incorporates (e.g., local community or state climate resilience planning and design requirements) that require planning for climate change impacts?

Score Spectrum

Low: The project does not follow any standards related to planning for climate change impacts.

Med: The project follows some standards related to planning for climate change impacts.

High: The project follows many standards that incorporate climate change considerations into design.

Question #4. Can the project qualify for or access funding for climate adaptation and resilience activities?

Score Spectrum

Low: The project has no access to funding related to climate adaptation activities.

Med: There is some funding available for climate adaptation, but the project would still require additional funding beyond that to finance adaptation.

High: There is plenty of funding available for climate change adaptation activities.

Use Case Example: The Los Angeles affordable housing project will follow the latest building safety standards but does not have access to abundant funding for climate adaptation activities. We will give it the following adaptive capacity ratings with justifications (Table 4-5).

Table 4-5. Adaptive Capacity Scores and Justifications for Use Case Example

Climate Hazard	Question #1. (Impact of Past Events)	Question #2. (Elements that Mitigate Climate Hazards)	Question #3. (Climate Change Standards)	Question #4. (Climate Change Funding)	Final Adaptive Capacity Score
Sea Level Rise	High—Sea level rise has not been an issue in this location	Low–Med—Building managers could put out sandbags or temporary flood barriers, but these would be less effective in permanent inundation scenarios	Not applicable—Building does not follow any sea level rise standards since it is not located on a coast	Low—Little funding for climate adaptation activities	Med
Flooding	Low–Med—Similar projects have struggled to manage flood impacts	Med–High—Building managers could put out sandbags or temporary flood barriers and have pumps in low-lying areas	High—Building follows flood standards	Low—Little funding for climate adaptation activities	Med–High
Temperature and Extreme Heat	Low—Extreme heat has been an issue in this area for apartments	Low–Med—project is not currently designed to have air conditioning	High—Building follows latest standards	Low—Little funding for climate adaptation activities	Low–Med
Extreme Precipitation	High—Similar projects have held up well against extreme precipitation	High—Project has well-sealed windows and doors as well as a stormwater capture system	High—Building follows latest standards	Low—Little funding for climate adaptation activities	High
Wildfire	Low–Med—Wildfires are not a big issue in this location but apartments that do burn from structure fires do not have much adaptive capacity	Low—Project does not have many elements that mitigate wildfire risks	High—Building follows latest wildfire protection standards	Low—Little funding for climate adaptation activities	Low–Med
Drought	High—Apartments in this area have fared well against past droughts	High—Project is served by a utility that draws from multiple water sources to aid resilience	Not applicable for this hazard	Low—Little funding for climate adaptation activities	High

Climate Hazard	Question #1. (Impact of Past Events)	Question #2. (Elements that Mitigate Climate Hazards)	Question #3. (Climate Change Standards)	Question #4. (Climate Change Funding)	Final Adaptive Capacity Score
Decrease in Snowpack	High—This hazard has not been an issue in the past	High—Few impacts expected from this hazard	Not applicable for this hazard	Low—Little funding for climate adaptation activities	High
Air Quality Degradation	Med—Apartments in this area have applied some cost and effort to manage this issue	Low–Med—This project does not have air filters that allow individual operability	High—Building follows latest standards	Low—Little funding for climate adaptation activities	Med

Develop Potential Impacts Score

The exposure and sensitivity scores for each climate hazard should be averaged to develop potential impacts scores. If the result is a decimal score (e.g., 2.5), round up or down using best judgment of the potential impacts from that climate hazard on the user's project.

Calculate the project's potential impact scores by averaging the scores for exposure and sensitivity.

Use Case Example: Table 4-6 shows the potential impact score for each climate hazard and the associated justification.

Table 4-6. Potential Impacts Scores and Justifications for Use Case Example

Climate Hazard	Exposure Score	Sensitivity Score	Potential Impact Score & Justification (if not a whole number)
Sea Level Rise	1	3	2
Flooding	1	4	2 (rounded down from 2.5); flooding is not a big concern in this area
Temperature and Extreme Heat	5	5	5
Extreme Precipitation	2	2	2
Wildfire	2	4	3
Drought	5	2	4 (rounded up from 3.5); drought impacts on water supply may become more significant, particularly when also considering extreme heat
Decrease in Snowpack	3	1	2
Air Quality Degradation	5	4	5 (rounded up from 4.5); air quality is a major issue in Los Angeles and residents are highly sensitive

Develop Overall Vulnerability Score

The potential impacts and adaptative capacity assessments should be combined to obtain an overall vulnerability score for each climate hazard. Figure 4-3 provides a matrix to convert the results of the two assessments into a single score. Users should locate their potential impacts score (1 to 5) in the first column and their adaptive capacity rating (low to high) in the bottom row. The intersection between these two data points is the resulting vulnerability score for the climate hazard.

Use the results from the potential impacts and adaptive capacity assessment to develop an overall vulnerability score for each climate hazard.

Figure 4-3. Vulnerability Score Matrix

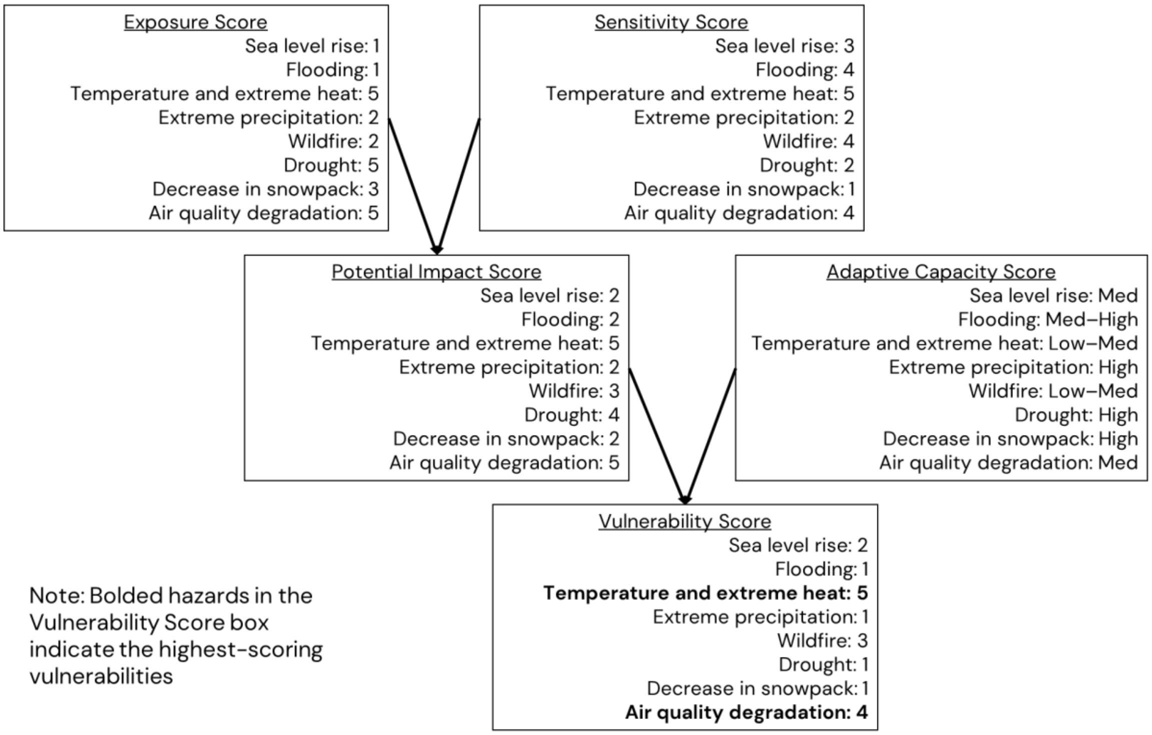
Potential Impacts	Low	Low-Med	Med	Mid-High	High
5	5	5	4	3	2
4	5	4	3	2	1
3	4	3	2	2	1
2	3	2	2	1	1
1	2	1	1	1	1

Adaptive Capacity

Note: Color coding indicates severity of the score, with green cells showing the lowest (least vulnerable) scores and dark red showing the highest (most vulnerable).

Use Case Example: Figure 4-4 shows how the exposure and sensitivity scores were combined to develop the potential impacts score, and then how the potential impacts score and adaptive capacity rating were combined to develop the overall vulnerability score for each climate hazard.

Figure 4-4. Hypothetical Exposure, Sensitivity, Potential Impact, Adaptive Capacity, and Vulnerability Scores for An Affordable Housing Unit in Los Angeles



Select Highest-Scoring Vulnerabilities

From the previous sub-steps, users should now have a climate vulnerability score between 1 and 5 for the following climate hazards.

1. Sea level rise.
2. Flooding.
3. Temperature and extreme heat.
4. Extreme precipitation.
5. Wildfire.
6. Drought.
7. Decrease in snowpack.
8. Air quality degradation.

Next, users should choose the priority climate hazards based on the final vulnerability scores. These priority hazards will be the focus for reducing vulnerabilities through adaptation measures in the following section.

Use Case Example: Figure 4-4 shows the vulnerability scores for the Los Angeles housing project example. Because the project scored a 5 for Temperature and Extreme Heat and a 4 for Air Quality Degradation, we will select these two as priority climate hazards.

It may be helpful to use a vulnerability score threshold (e.g., all hazards exceeding a score of three) for identifying priority climate hazards. This threshold may depend on the user's risk tolerance. For example, if a user has a high risk tolerance, the user may only wish to look at adaptation measures for climate hazards for which there was a vulnerability score of 4 or above. If the user has a lower risk tolerance, the user may wish to also consider addressing climate hazards for which the user's vulnerability score was 3 or above.

Once the user has chosen the priority climate risks that the user wants to address, the user can begin to choose and analyze adaptation measures.

Estimating Risk Reduction and Co-Benefits from Adaptation Measures

Following a similar process to establish a baseline vulnerability score, this section outlines steps that Handbook users can take to identify the reduction in vulnerability associated with specific adaptation measures. With this information, users can better prioritize and select adaptation actions to manage climate risks threatening their project. Users should consider priority climate risks and project budget in assessing measures and their benefits. Refer to *Climate Risk Reduction Measures* for a comprehensive list of potential measures.

Identify Adaptation Benefits

The following steps provide guidance on assessing the impact of a measure on overall vulnerability. Users can follow these steps using the worksheet provided in Appendix D, *Climate Vulnerability Worksheets*.

After selecting a climate hazard from the identified priority climate hazards, users will determine risk reduction from an adaptation measure in the following steps.

1. Identify the extent of the measure's reduction of potential impacts.
    a. Determine the exposure reduction.
    b. Determine the sensitivity reduction.
    c. Assess the overall effect of the measure on potential impacts on a scale of 0–4 reduction points (No effect, Low, Medium, High, and Very High).
2. Evaluate the extent to which the measure bolsters adaptive capacity on a scale of 0–4 reduction points (No effect, Low, Medium, High, and Very High).
3. Estimate impacts on the vulnerability score by considering the measure's effect on reducing exposure and sensitivity (i.e., potential impacts), and increasing adaptive capacity.

Use Case Example: The proposed affordable housing unit being developed in Los Angeles has a high vulnerability to temperature and extreme heat (5) and low-medium adaptive capacity. The developer elects to incorporate adaptation solutions by improving the building envelope efficiency to protect against extreme heat, such as by installing well-sealed doors and windows, adding window treatments such as solar shades, and increasing shading through enhanced landscaping.

The following section outlines guiding questions and applies the framework to adaptation measures for the use case discussed above. Measures may impact all the components of vulnerability to a hazard, or only target exposure, sensitivity, and/or adaptative capacity.

Determine Exposure Reduction

As discussed in the section *Determine Exposure Score*, the primary driver of exposure is location. A project's proximity to areas susceptible to a hazard will affect the extent to which the project will be subjected to a climate hazard. For example, a project located in a flood zone or in the WUI will be exposed to flooding and wildfire, respectively. While location primarily drives exposure, Handbook users can use adaptation actions to lessen the degree to which a project is exposed to a hazard. The degree to which an adaptation measure lessens the amount of exposure determines its exposure reduction. The following guiding questions can help users determine the extent to which a measure lowers exposure to a specific hazard.

- How does the measure remove exposure (e.g., relocating a project)?
- How much does the measure change the project design to reduce future exposure (e.g., raising a building to reduce flood exposure)?
- Does the measure change post-construction operations and management to reduce future exposure (e.g., wildfire fuel removal or management)?

Use Case Example: Enhancing building envelope efficiency does not change the location or otherwise reduce the exposure of the project. It instead reduces its sensitivity (see *Determine Sensitivity Reduction* section). Not all measures apply to each component of vulnerability.

In this use case example, exposure from the priority hazards of extreme heat and impaired air quality cannot be avoided without physically relocating the project, which is not feasible. The project developer can seek to reduce vulnerabilities by decreasing sensitivity or increasing adaptive capacity through adaptation measures.

Determine Sensitivity Reduction

To lower sensitivity, a measure must reduce the degree to which a project is affected by exposure to a hazard. The following guiding questions can support users in determining the extent to which a measure decreases harm to a project.

- How much does the measure mitigate the hazards' effect on fragile or critical components of the project (e.g., cooling systems for equipment sensitive to overheating)?
- Does the measure lower the hazard's effect on individuals, particularly members of vulnerable populations (e.g., greater access for underserved populations to parks)?

- Does the measure lower the impact to an operational component affected by the climate hazard (e.g., conduct regular cleaning and maintenance of storm drains along key roadways)?

Use Case Example: The measure reduces how severely building occupants will experience extreme heat. Given that the project is for affordable housing, the measure also has the potential to provide protection from heat events for those in vulnerable communities. Overall, the measure has a low sensitivity reduction.

Determine Potential Impact Reduction

To qualitatively determine the degree to which the measure reduces potential impacts from a climate hazard, Handbook users should consider the extent to the which the measure lowers each component of the potential impacts score (i.e., sensitivity and exposure). Then, users should combine the benefits of the measure's mitigation of sensitivity and exposure to determine the net effect using the following reduction rating scale.

0 = No Effect

1 = Low

2 = Medium

3 = High

4 = Very High

Points associated with the scale (0–4) will be used to assess vulnerability reductions. However, no measure, with the exception or relocating a project, can completely remove the threat from a particular climate hazard with a defined geographic footprint (e.g., floodplain). Measures mitigate, rather than remove, potential impacts from a hazard. The extent to which a measure will lower potential impacts from a climate hazard depends on the Handbook user's project.

Use Case Example: The building envelope enhancement measure has no effect on exposure to the hazard but has a relatively low effect on reducing building occupants' sensitivity to increased temperature and heat events. Combined, the measure provides a low potential impacts reduction rating (which results in a one-point reduction).

Identify Adaptive Capacity Gains

Adaptation measures can also increase a project's adaptive capacity. A measure provides adaptive capacity benefits if it improves the project's capacity to take advantage of opportunities or mitigate the hazard's consequences. These guiding questions support Handbook users in considering how a measure bolsters adaptive capacity.

- Does the measure add climate resilient components to the project (e.g., drainage system, cool roof)?
- Does the measure incorporate policies or standards that account for climate change (e.g., adopt or update heat emergency plan)?

- How does the measure improve the project's management of climate hazards (e.g., incorporating projected changes in precipitation and flooding into planned wastewater systems)?
- Does the measure reduce how project users are exposed to the hazard (e.g., using a notification system to provide evacuation information)?

After evaluating the measure's impacts using the guiding questions, the user should determine the net effect of the measure on adaptive capacity using the following rating increase scale.

0 = No Effect

1 = Low

2 = Medium-Low

3 = High

4 = Very High

Points associated with the scale (0–4) will be used to assess adaptive capacity gains. As with potential impacts, no measure can increase adaptive capacity to the extent to which overall vulnerability is eliminated. Rather, measures can only strengthen a project's overall adaptive capacity score.

Use Case Example: The building envelope enhancement measure improves adaptive capacity and climate resilience because it protects occupants more effectively from heat events and keeps cool air inside the building. Overall, the measure has a medium increase rating for adaptive capacity (which result in a 2-point increase).

Estimate Measure's Effect on Overall Vulnerability

After evaluating the measure's effect on potential impacts and adaptive capacity, the user can estimate the extent to which the measure reduces overall vulnerability. To determine a measure's overall reduction of overall vulnerability, the user should do the following.

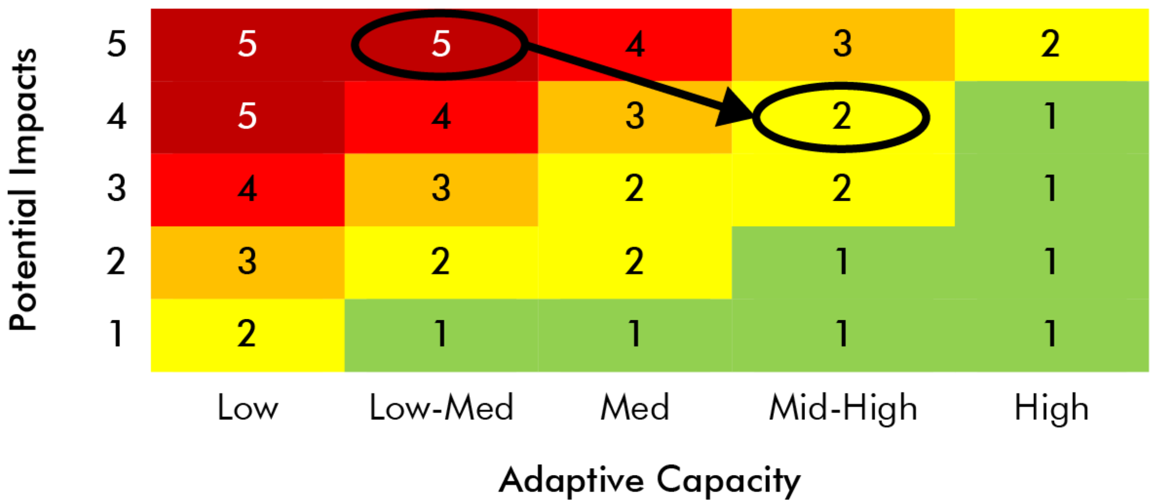
1. Subtract the points associated with the potential impact reduction rating (0–4) from the existing potential impact score to get a net potential impacts score.
2. Add the points associated with the adaptive capacity increase rating (0–4) to the existing adaptive capacity score to get a net adaptive capacity score.

By adopting a measure, the Handbook user can move the project down and right in the vulnerability matrix (see Figure 4-5) as the measure lowers potential impacts and increases adaptive capacity respectively. The evaluation of net changes in potential climate impact and adaptive capacity scores help guide the user in considering the extent to which a measure can decrease the overall vulnerability of a project.

The Handbook user should remember that the rating points act as a guide to estimate the overall effect of an adaptation measure on vulnerability and are not an absolute determination of the measure's effect on the project's vulnerability. The Handbook user should apply this process with careful consideration. For example, if a project has a potential impacts score of 4, and the measure has a high potential impacts reduction rating (3 reduction points), the net potential impacts score could be 1. However, the Handbook user might believe that the project could be considerably affected by a hazard despite adopting the measure and determine the net potential impacts score is 2. The example below highlights how a Handbook user can follow the process as a guide to determine the project's overall vulnerability score after applying a measure.

Use Case Example: The measure provides a low potential impacts reduction rating (1 reduction point) and a medium adaptive capacity increase rating (2 addition points). Given the project started at a vulnerability score of 5, the measure reduces the project's vulnerability score to a 2, as seen in Figure 4-5.

Figure 4-5. Vulnerability Score Matrix for Use Case Example



Identify Adaptation Co-Benefits

Adaptation measures may also result in co-benefits for a project, as shown in *Climate Risk Reduction Measures*. Possible co-benefits include improved air quality, energy and fuel savings, VMT reductions, water conservation, enhanced pedestrian or traffic safety, improved public health, improved ecosystem health, enhanced energy security, enhanced food security, and social equity. Some of these co-benefits are qualitative, while others are quantifiable. Chapter 3, *Measures to Reduce GHG Emissions,* includes methodologies to estimate measures' co-benefits specifically related to energy and fuel savings, VMT reductions, and water conservation. Additionally, the California Air Resources Board provides an expansive set of methodologies to evaluate co-benefits (CARB n.d.).

Climate Risk Reduction Measures

This section includes 99 potential climate risk reduction measures. All measures include the following descriptors.

- **Climate Hazard**: Identifies the climate hazard(s) for which the measure reduces risk. Most measures address multiple climate hazards. Hazards include sea level rise, flooding (coastal and inland), temperature/extreme heat, extreme precipitation, wildfire, drought, decrease in snowpack, and air quality degradation.
- **Climate Risk Reduction Benefit.** Describes which aspect of overall vulnerability the measure addresses. Each measure could have one or more of the following risk reduction benefits.
  - **Reduces exposure**: Reduces the presence of project elements in areas that are subject to climate hazards.
  - **Reduces sensitivity**: Reduces the degree to which a project element would be affected by exposure to a changing climate.
  - **Increases adaptive capacity**: Increases the ability of a project element to moderate harm or take advantage of risk reduction opportunities.
- **Potential Co-Benefits.** Describes the anticipated co-benefits achieved by the measure.
- **Action Type.** Identifies the required project action to successfully implement the risk reduction measure. Options include the following.
  - **Infrastructure Improvements and Projects**: Involves physically altering a current design or developing a new project element to address climate risks. These projects could range from minor (e.g., changing appliances) to major (e.g., sea wall).
  - **Education, Outreach, Coordination**: Involves initiating or expanding partnerships with relevant organizations, including intentional community engagement to communicate or share information that is culturally and linguistically appropriate, and expanding awareness with the public.
  - **Evaluation**: Involves conducting new or updated assessments to improve data/information, input, or feedback.
  - **Operational**: Involves changes to or development of new operational and maintenance protocols.
  - **Plans, Regulations, and Policy Development**: Involves developing or revising policies, plans, regulations, or guidelines, which will have project-level benefits if implemented.
  - **Programmatic**: Involves creating new or expanding existing programs, activities, or initiatives.

Table 4-7 identifies the risk reduction measures and their descriptors. Each measure is listed alphanumerically with the hazard serving as the letter code (e.g., SLR = sea level rise). For simplicity and ease of tabular review, the measure descriptors have been abbreviated as follows:

- Dark blue shaded rows identify the **climate hazard** for each group of measures, while light blue shaded rows identify the **action type** applicable to the measures that follow. Within the *Infrastructure Improvements and Projects* action type, an asterisk (*) is used to denote activities with extensive infrastructure investments that may require designing and constructing new project elements.
- The **scale of application** is abbreviated as one of the following:

  - P/S = Project/Site
  - P/C = Plan/Community.
  - All = Project/Site and Plan/Community.

  Project/Site refers to measures that reduce risk at the scale of a parcel, employer, or development project. *Plan/Community* refers to measures that reduce risk at the scale of a neighborhood (e.g., specific plan), corridor, or entire municipality (e.g., city or county-level).

- The **climate risk reduction benefit** columns identify how the measure reduces climate vulnerability, where:
  - ● = may be achieved by the measure.
  - ○ = likely not achieved by the measure.
- Remaining columns identify applicable **co-benefits**, where:
  - ● = achieved by the measure.
  - ⦿ = may be achieved by the measure depending on local implementation specifics.
  - ○ = not achieved by the measure.

Table 4-7, below, includes a more detailed description of each measure.

Table 4-7. Summary of Climate Risk Reduction Measures and Descriptors

			Risk Reduction Benefit			Co-Benefits									
#	Measure Title	Scale of Application	Reduces Exposure	Reduces Sensitivity	Increases Adaptive Capacity	Improved Air Quality	Energy and Fuel Savings	Vehicle Miles Traveled Reductions	Water Conservation	Enhanced Pedestrian or Traffic Safety	Improved Public Health	Improved Ecosystem Health	Enhanced Energy Security	Enhanced Food Security	Social Equity
Multiple Hazards															
Infrastructure Improvements and Projects															
MH-1.	Strengthen Energy Infrastructure*	P/C	0	2-4	0	●	○	○	○	○	○	○	●	○	⊙
MH-2.	Use Climate-Resilient Design for Infrastructure	P/C	0	1-3	1-3	○	○	○	⊙	●	⊙	○	○	○	○
MH-3.	Coordinate Redundant Transportation Access*	P/C	0	0	2-4	○	○	○	○	●	⊙	○	○	○	○
MH-4.	Strengthen Building Structures	P/S	0	1-3	0	○	○	○	○	○	○	○	○	○	○
MH-5.	Use Green Infrastructure for Stormwater Management*	All	2-3	0	1-3	○	○	○	●	○	○	●	○	○	○
MH-6.	Upgrade Water Systems*	P/C	0	0	2-3	○	○	○	●	○	○	●	○	○	○
MH-7.	Construct Water Storage Facilities*	P/C	0	0	2-3	○	○	○	○	○	○	○	○	○	○
MH-8.	Decrease Road Vulnerability to Landslides	All	0	1-3	0	○	○	○	○	○	○	○	○	○	○
Education, Outreach, Coordination															
MH-9.	Support Business Resiliency	P/C	0	0	1-3	○	○	○	○	○	○	○	○	○	●
MH-10.	Implement Community-wide Climate Change Outreach Program	P/C	0	0	1-3	○	○	○	○	○	○	○	○	○	●
MH-11.	Encourage/Actively Engage Community in Local Planning	P/C	0	0	1-2	○	○	○	○	○	●	○	○	○	●
MH-12.	Enhance Community Network Support	P/C	0	0	1-2	○	○	○	○	○	○	○	○	○	●
MH-13.	Support Local Food Systems	All	0	0	1-2	○	○	○	○	○	●	○	○	●	●
MH-14.	Maintain Trails and Parks	P/C	0	1-2	1-2	○	○	○	○	○	●	○	○	○	●
MH-15.	Identify Alternative Activities in Climate Sensitive Recreation Areas	All	0	0	1-3	○	○	○	○	○	○	○	○	○	○

#	Measure Title	Scale of Application	Risk Reduction Benefit			Co-Benefits									
			Reduces Exposure	Reduces Sensitivity	Increases Adaptive Capacity	Improved Air Quality	Energy and Fuel Savings	Vehicle Miles Traveled Reductions	Water Conservation	Enhanced Pedestrian or Traffic Safety	Improved Public Health	Improved Ecosystem Health	Enhanced Energy Security	Enhanced Food Security	Social Equity
Evaluation															
MH-16.	Identify At-Risk Transportation Corridors	P/C	0	0	1-3	○	○	○	○	●	○	○	○	○	○
MH-17.	Identify Alternative Routes for Transit Service	P/C	0	0	1-3	○	○	⊙	○	●	○	○	○	○	⊙
Operational															
MH-18.	Maintain Soil Health	All	0	1-2	1-2	○	○	○	○	○	○	●	○	●	○
MH-19.	Stabilize Burned Slopes in Key Assets	All	0	1-2	0	○	○	○	○	○	○	○	○	○	○
MH-20.	Improve Medical Facility Preparedness	P/C	0	0	1-4	○	○	○	○	○	○	○	○	○	○
MH-21.	Ensure Homeless Services' Availability in Hazardous Conditions	P/C	0	1-3	2-4	○	○	○	○	○	●	○	○	○	●
MH-22.	Improve Poor Drainage	All	0	1-3	0	○	○	○	○	○	●	○	○	○	○
Plans, Regulations, and Policy Development															
MH-23.	Landscape with Climate Considerations	All	0	1-2	0	○	○	○	●	○	○	●	○	○	○
MH-24.	Develop Climate Emergency/Business Resilience Plan	All	0	0	1-3	○	○	○	○	○	○	○	○	○	○
MH-25.	Revise Emergency Plans	P/C	0	0	1-3	○	○	○	○	○	○	○	○	○	○
MH-26.	Integrate Climate Change Considerations into Public Safety and Emergency Planning	All	1-3	1-3	1-4	○	○	○	○	○	○	○	○	○	●
MH-27.	Provide Greater Affordable Housing Options	P/C	0	1-2	1-3	○	○	○	○	○	●	○	○	○	●
MH-28.	Transition to Climate-Smart Energy	All	0	2-3	2-3	○	○	○	○	○	○	○	●	○	○
MH-29.	Identify Climate Hazard Overlay Zones	All	2-4	1-3	1-3	○	○	○	○	○	○	○	○	○	○
MH-30.	Establish Community Resilience Hubs	P/C	0	0	2-3	○	○	○	○	○	○	○	○	○	●
MH-31.	Improve Transportation Maintenance	P/C	0	1-3	0	○	○	○	○	●	○	○	○	○	○
MH-32.	Establish Urban Tree Management Plan	All	1-2	1-2	0	●	●	○	○	○	●	●	○	○	●

#	Measure Title	Scale of Application	Risk Reduction Benefit: Reduces Exposure	Risk Reduction Benefit: Reduces Sensitivity	Risk Reduction Benefit: Increases Adaptive Capacity	Co-Benefits: Improved Air Quality	Co-Benefits: Energy and Fuel Savings	Co-Benefits: Vehicle Miles Traveled Reductions	Co-Benefits: Water Conservation	Co-Benefits: Enhanced Pedestrian or Traffic Safety	Co-Benefits: Improved Public Health	Co-Benefits: Improved Ecosystem Health	Co-Benefits: Enhanced Energy Security	Co-Benefits: Enhanced Food Security	Co-Benefits: Social Equity
MH-33.	Implement Park and Natural Resources Protection	P/C	1-2	1-2	0	○	○	○	●	○	○	●	○	○	○
MH-34.	Implement Integrated Watershed Management	P/C	1-4	0	0	○	○	○	●	○	○	●	○	○	○
MH-35.	Increase Parks in Underserved Communities	P/C	1-2	2-3	0	○	○	○	○	○	●	○	○	○	●
MH-36.	Decentralize and Localize Energy Production and Storage	All	0	1-3	2-4	●	○	○	○	○	○	○	●	○	●
Programmatic															
MH-37.	Develop Climate Hazard Notification System	P/C	0	0	1-3	○	○	○	○	○	●	○	○	○	●
MH-38.	Integrate Climate into Health Programs	P/C	0	0	1-4	○	○	○	○	○	●	○	○	○	●
MH-39.	Implement Pervious and Climate-Smart Surfaces	All	0	1-3	0	⊙	●	○	●	○	⊙	●	○	○	○
MH-40.	Address Energy/Water Efficiency Funding Barriers	P/C	0	1-2	1-3	○	●	○	●	○	○	○	○	○	●
MH-41.	Expand Urban Greening/Agriculture	P/C	1-2	1-2	1-2	⊙	○	○	⊙	○	●	○	○	●	●
MH-42.	Provide Vaccinations for Changed Transmission Vectors	P/C	0	1-2	1-3	○	○	○	○	○	●	○	○	○	●
Sea Level Rise and Coastal Flooding/Erosion															
Infrastructure Improvements and Projects															
SLR-1.	Implement Engineering Solutions*	All	2-4	0	0	○	○	○	○	○	○	○	○	○	○
SLR-2.	Raise Building Floor Elevations	P/S	2-4	1-4	0	○	○	○	○	○	○	○	○	○	○
SLR-3.	Implement Natural Coastline Infrastructure*	All	1-4	0	2-3	○	○	○	○	○	○	●	○	○	○
SLR-4.	Strengthen Building Against Flood	P/S	0	2-3	0	○	○	○	○	○	○	○	○	○	○
SLR-5.	Use Moveable Infrastructure	P/S	0	2-3	0	○	○	○	○	○	○	○	○	○	○

#	Measure Title	Scale of Application	Risk Reduction Benefit: Reduces Exposure	Risk Reduction Benefit: Reduces Sensitivity	Risk Reduction Benefit: Increases Adaptive Capacity	Co-Benefits: Improved Air Quality	Co-Benefits: Energy and Fuel Savings	Co-Benefits: Vehicle Miles Traveled Reductions	Co-Benefits: Water Conservation	Co-Benefits: Enhanced Pedestrian or Traffic Safety	Co-Benefits: Improved Public Health	Co-Benefits: Improved Ecosystem Health	Co-Benefits: Enhanced Energy Security	Co-Benefits: Enhanced Food Security	Co-Benefits: Social Equity
Evaluation															
SLR-6.	Develop Adaptive Management Plan	All	0	0	2-4	○	○	○	○	○	○	○	○	○	●
Plans, Regulations, and Policy Development															
SLR-7.	Require Consideration of Sea Level Rise for New Development	All	2-4	2-4	0	○	○	○	○	○	○	○	○	○	○
SLR-8.	Develop Setbacks	All	1-3	0	0	○	○	○	○	○	○	○	○	○	○
SLR-9.	Develop Regional Sediment Management	All	0	1-2	2-3	○	○	○	○	○	○	●	○	○	○
SLR-10.	Sell off High-Risk Area Development Rights	All	1-3	0	2-3	○	○	○	○	○	○	○	○	○	○
SLR-11.	Site Outside Coastal Hazard Zone	All	2-4	0	0	○	○	○	○	○	○	○	○	○	○
SLR-12.	Limit Basements in Flood Zones	P/S	0	2-3	0	○	○	○	○	○	○	○	○	○	○
SLR-13.	Provide Removal Options in Flood Zones	All	1-2	1-3	0	○	○	○	○	○	○	○	○	○	○
SLR-14.	Coordinate with Regional Planning Efforts	All	1-3	1-3	1-3	○	○	○	○	○	○	○	○	○	○
SLR-15.	Alert Public of Storm Surge Risk	P/C	0	1-2	0	○	○	○	○	○	○	○	○	○	○
Extreme Precipitation and Inland Flooding															
Infrastructure Improvements and Projects															
EP-1.	Incorporate Runoff Projections in Hydrologic Designs	All	1-3	0	0	○	○	○	○	○	●	●	○	○	○
EP-2.	Install Stormwater Outfall Pumps/Lift Station for Water Drainage	All	0	1-3	0	○	○	○	○	○	●	●	○	○	○
EP-3.	Install Stormwater Cistern/Retention Basin	All	0	1-3	0	○	○	○	●	○	○	○	○	○	○
EP-4.	Waterproof Operational Equipment	All	0	2-4	0	○	○	○	○	○	○	○	○	○	○
EP-5.	Upgrade Wastewater Systems	All	0	0	2-3	○	○	○	●	○	○	●	○	○	○

#	Measure Title	Scale of Application	Risk Reduction Benefit: Reduces Exposure	Risk Reduction Benefit: Reduces Sensitivity	Risk Reduction Benefit: Increases Adaptive Capacity	Co-Benefits: Improved Air Quality	Co-Benefits: Energy and Fuel Savings	Co-Benefits: Vehicle Miles Traveled Reductions	Co-Benefits: Water Conservation	Co-Benefits: Enhanced Pedestrian or Traffic Safety	Co-Benefits: Improved Public Health	Co-Benefits: Improved Ecosystem Health	Co-Benefits: Enhanced Energy Security	Co-Benefits: Enhanced Food Security	Co-Benefits: Social Equity
Plans, Regulations, and Policy Development															
EP-6.	Site Outside Floodplain	All	2-4	0	0	○	○	○	○	○	○	○	○	○	○
Operational															
EP-7.	Maintain Stormwater Infrastructure on Key Routes	All	0	1-2	0	○	○	○	○	●	○	○	○	○	○
Wildfire															
Infrastructure Improvements and Projects															
WF-1.	Implement Fire-Safe Landscaping	All	0	1-2	0	●	○	○	○	○	●	●	○	○	○
WF-2.	Install Fire Suppression Systems and Improve Structural Strength	P/S	0	1-3	0	●	○	○	○	○	●	○	○	○	○
WF-3.	Strengthen Vulnerable Assets in High Wildfire Risk Areas*	All	0	2-4	0	○	○	○	○	○	○	○	○	○	○
Education, Outreach, Coordination															
WF-4.	Educate on Wildfire Resistant Landscaping	P/C	0	0	1-2	○	○	○	○	○	●	○	○	○	○
WF-5.	Site Outside Wildland-Urban Interface (WUI)	All	2-4	0	0	○	○	○	○	○	●	○	○	○	○
Evaluation															
WF-6.	Designate and Strengthen Wildfire Emergency Routes	P/C	0	0	1-3	○	○	○	○	○	●	○	○	○	●
WF-7.	Develop Fire Risk Assessment for New Development	All	1-2	1-2	0	○	○	○	○	○	●	○	○	○	○
Operational															
WF-8.	Implement Fuel Management	All	2-3	0	0	●	○	○	○	○	●	○	○	○	○
WF-9.	Install Air Filters	All	0	1-3	1-2	●	○	○	○	○	●	○	○	○	○
WF-10.	Adopt WUI Building Standards	All	0	1-3	1-2	○	○	○	○	○	●	○	○	○	○

#	Measure Title	Scale of Application	Risk Reduction Benefit: Reduces Exposure	Risk Reduction Benefit: Reduces Sensitivity	Risk Reduction Benefit: Increases Adaptive Capacity	Co-Benefits: Improved Air Quality	Co-Benefits: Energy and Fuel Savings	Co-Benefits: Vehicle Miles Traveled Reductions	Co-Benefits: Water Conservation	Co-Benefits: Enhanced Pedestrian or Traffic Safety	Co-Benefits: Improved Public Health	Co-Benefits: Improved Ecosystem Health	Co-Benefits: Enhanced Energy Security	Co-Benefits: Enhanced Food Security	Co-Benefits: Social Equity
Temperature/Extreme Heat															
Infrastructure Improvements and Projects															
EH-1.	Install Green Infrastructure*	All	1-3	1-3	0	●	⊙	○	○	○	●	●	○	○	●
EH-2.	Provide Heat Mitigation for Public Walkways and Transit Stops	All	2-4	0	0	●	○	○	○	○	●	○	○	○	●
EH-3.	Install Heat-Reducing Roof	All	2-3	0	0	●	●	○	○	○	●	○	○	○	●
EH-4.	Enhance Building Envelope Efficiency	P/S	0	0	1-3	●	●	○	○	○	●	○	○	○	⊙
EH-5.	Upgrade to Efficient Equipment/Infrastructure	All	0	0	1-3	○	●	○	○	○	○	○	○	○	○
EH-6.	Install Refillable Water Stations	All	0	0	1-2	○	○	○	○	○	●	○	○	○	●
EH-7.	Install Equipment Cooling System	All	0	2-3	0	○	●	○	○	○	○	○	○	○	○
EH-8.	Use Alternative Pavement Surfaces	All	0	1-2	0	○	●	○	○	○	○	○	○	○	○
EH-9.	Expand Urban Tree Canopy	All	1-2	1-2	0	●	●	○	○	○	●	○	○	○	⊙
EH-10.	Install Covered Parking	P/S	0	0	1-2	●	○	○	○	○	●	○	○	○	○
Education, Outreach, Coordination															
EH-11.	Work with Schools to Reduce Heat Exposure	P/C	1-3	1-3	0	○	○	○	○	○	●	○	○	○	●
Plans, Regulations, and Policy Development															
EH-12.	Provide Backup Power for Cooling Centers	All	0	1-2	1-3	○	○	○	○	○	●	○	○	○	●
EH-13.	Develop Heat Emergency Plan	P/C	0	0	2-4	○	○	○	○	○	●	○	○	○	●
Programmatic															
EH-14.	Develop Low-Income Energy Programs	P/C	0	1-2	2-3	○	●	○	○	○	●	○	○	○	●
EH-15.	Provide Low-Income Air Conditioning	All	0	2-4	2-4	○	○	○	○	○	●	○	○	○	●
EH-16.	Establish a Shuttle System to Cooling Centers	P/C	0	1-2	2-3	○	○	○	○	○	●	○	○	○	●

#	Measure Title	Scale of Application	Risk Reduction Benefit: Reduces Exposure	Reduces Sensitivity	Increases Adaptive Capacity	Co-Benefits: Improved Air Quality	Energy and Fuel Savings	Vehicle Miles Traveled Reductions	Water Conservation	Enhanced Pedestrian or Traffic Safety	Improved Public Health	Improved Ecosystem Health	Enhanced Energy Security	Enhanced Food Security	Social Equity
Drought															
Infrastructure Improvements and Projects															
D-1.	Install Water Efficient Appliances	P/S	0	0	1-3	○	○	○	●	○	○	○	○	○	●
D-2.	Install Water Reuse Infrastructure	P/S	0	0	1-3	○	○	○	●	○	○	○	○	○	○
Education, Outreach, Coordination															
D-3.	Install Drought Resistant Landscaping	P/S	0	1-2	1-2	○	○	○	●	○	○	○	○	○	○
D-4.	Educate on Water Conservation	P/C	0	0	1-2	○	○	○	●	○	○	○	○	○	○
D-5.	Outreach to Educate About Recycled Water Safety	P/C	0	0	1-2	○	○	○	●	○	○	○	○	○	○
D-6.	Build Alternatives Forms of Water Recreation	All	0	0	1-2	○	○	○	○	○	○	○	○	○	○
Plans, Regulations, and Policy Development															
D-7.	Diversify Water Supply Sources	P/C	0	0	2-4	○	○	○	○	○	●	○	○	○	●
D-8.	Develop Groundwater Sustainability Plan	P/C	0	0	2-4	○	○	○	○	○	○	●	○	○	○
D-9.	Implement Local Water Recycling	All	0	0	1-4	○	○	○	●	○	○	○	○	○	○

Climate hazard abbreviations: MH = multiple hazards; SLR = sea level rise; F = flooding; EH = temperature/extreme heat; EP = extreme precipitation; WF = wildfire; D = drought; DS = decrease in snowpack; AQ = air quality degradation.

For action type, major infrastructure improvements and projects are noted with an asterisk (*).

Scale of application column abbreviations: P/S = Project/Site; P/C = Plan/Community; All = Project/Site and Plan/Community.

Risk reduction benefit and co-benefits columns symbols: ● = may be achieved by the measure; ⊙ = may be achieved by the measure depending on local implementation specifics; ○ = likely not achieved by the measure.

Table 4-8 provides an overview of each measures' descriptions and benefits. These measures are organized by the climate hazard(s) that they address. Measures that can help reduce risk to multiple hazards (categorized as "Multiple Hazard Measures") are presented first. Most climate risk reduction measures fall under this category, followed by measures that address individual climate hazards or, in some cases, two similar hazards (e.g., extreme precipitation and flooding). The measure descriptions broadly summarize the measure at a high level. Where applicable, an implementation example is provided.

Table 4-8. Description of Climate Risk Reduction Measures

Climate Risk Reduction Measures
Multiple Hazards
MH-1. Strengthen Energy Infrastructure. Strengthen energy infrastructure systems against damage from climate-related effects and expand redundancy in the energy network. For example, retrofit infrastructure components; ensure redundant energy systems (e.g., backup generators, multiple transmission lines feeding a given area). Relevant Hazards: Sea level rise, flooding, temperature/extreme heat, extreme precipitation, and wildfire.
MH-2. Use Climate-Resilient Design for Infrastructure. Use the best available science and resilient design features in infrastructure to improve resiliency to extreme climate events. For example, special sealants and other materials on roadways can help prevent roadways from softening during extreme heat. Another example to maintain a state of good repair, minimize breaks, and ensure structural integrity in the face of climate change hazards is to use high density polyethylene (HDPE) pipes, which are less expensive and easier to install than metal cast iron pipes. Other resilient design features include choosing appropriate materials for wildfire-prone areas and treating critical outdoor infrastructure pieces to be heat-resistant. Infrastructure reinforcement, stormwater improvements and drainage upgrades, and pumping and water storage facilities can also be installed to increase resiliency to flooding and wave action by coastal storms. Design features should be incorporated to match asset vulnerabilities. The California Department of Transportation (Caltrans) completed a vulnerability assessment of its assets by district, which can serve as a useful resource (Caltrans 2020). Relevant Hazards: Sea level rise, flooding, temperature/extreme heat, extreme precipitation, and wildfire.
MH-3. Coordinate Redundant Transportation Access. Coordinate with regional transportation agencies to ensure redundancy of critical transportation routes to allow for continued access and movement in the event of an emergency. Have multiple points of ingress and egress to improve evacuation and emergency response access. Relevant Hazards: Sea level rise, flooding, temperature/extreme heat, extreme precipitation, and wildfire.
MH-4. Strengthen Building Structures. Ensure building structure is strengthened against severe weather impacts through building design. Relevant Hazards: Flooding, extreme precipitation, and wildfire.
MH-5. Use Green Infrastructure for Stormwater Management. Use green infrastructure to reduce stormwater volume and enhance stormwater capture and infiltration. For example, low-impact development, such as the installation of bioretention elements in parking lots and on the street margin, can be implemented through landscape codes, green street standards, and off-site standards. Other examples include rainwater harvesting, permeable pavements, and bioswales. Relevant Hazards: Flooding, extreme precipitation, and drought.

Climate Risk Reduction Measures

MH-6. Upgrade Water Systems.

Upgrade water systems to accommodate projected changes in water quality and availability. For example, wells and intake systems may be too shallow to effectively pull enough water supplies from groundwater aquifers and surface water bodies, higher levels of water contaminants may exceed the capacity of water treatment systems, and water storage tanks may not be able to hold enough water to meet demand if there is a supply interruption. In all these cases, the water system could be upgraded to address the risk.

Relevant Hazards: Flooding and drought.

MH-7. Construct Water Storage Facilities.

Construct additional water storage facilities and improve existing facilities to augment surface and groundwater supplies that can capture excess flows and add protections against flooding and high stormwater flow events. For example, install a dedicated groundwater recharge facility for utilizing excess flows in wet years.

Relevant Hazards: Flooding, extreme precipitation, drought, and decrease in snowpack.

MH-8. Decrease Road Vulnerability to Landslides.

Use retaining walls, slope stabilization techniques, and other strategies to make roads less vulnerable to landslides, mudflows, and erosion. Emphasize resiliency for roads and trails that are on or below steep slopes and have a history of being damaged or blocked by landslide events and affected by erosion.

Relevant Hazards: Extreme precipitation, and wildfire.

MH-9. Support Business Resiliency.

Collaborate with local and regional partners to support business resiliency through preparedness education, trainings, and resources. Target support to small businesses, minority-owned business, and businesses in underserved communities.

Relevant Hazards: Sea level rise, flooding, temperature/extreme heat, extreme precipitation, wildfire, drought, decrease in snowpack, air quality degradation.

MH-10. Implement Community-wide Climate Change Outreach Program.

Collaborate with local, regional, state, and federal partners to develop a community-wide outreach program to educate a diverse community on how to prepare for and recover from climate change effects. An example program would be a climate preparedness outreach program focused on vulnerable populations that provides information on staying healthy and safe during hazardous events.

Relevant Hazards: Sea level rise, flooding, temperature/extreme heat, extreme precipitation, wildfire, drought, decrease in snowpack, and air quality degradation.

MH-11. Encourage/Actively Engage Community in Local Planning.

Explore opportunities to incorporate resident empowerment, leadership, and decision-making such as training programs, guided reviews of plans, neighborhood scans, and mapping activities as part of resident-led planning. For example, fund or solicit participation from schools, faith-based communities, neighborhood-based groups, health equity or environmental justice groups, and businesses in climate resilience planning. Allow and encourage residents to be the decisionmakers in planning.

Relevant Hazards: Sea level rise, flooding, temperature/extreme heat, extreme precipitation, wildfire, drought, decrease in snowpack, and air quality degradation.

Climate Risk Reduction Measures

MH-12. Enhance Community Network Support.

Support and strengthen community social networks and other assets to build climate resilience. For example, support community-driven efforts by assisting with outreach, and learning from and disseminating best practices developed by community groups or local jurisdictions (Deas, Hoverter, & DeWeese 2017).

Relevant Hazards: Sea level rise, flooding, temperature/extreme heat, extreme precipitation, wildfire, drought, decrease in snowpack, and air quality degradation.

MH-13. Support Local Food Systems.

Support local farmers and local food network. Increase access to healthy food markets, farmer's markets, and other local food sources. Encourage community gardens.

Relevant Hazards: Sea level rise, flooding, temperature/extreme heat, extreme precipitation, wildfire, drought, decrease in snowpack, and air quality degradation.

MH-14. Maintain Trails and Parks.

Collaborate with local and regional partners to provide robust trail and park maintenance to prevent and respond to damage from the effects of climate change. For example, park management agencies can strengthen and stabilize park buildings and trails to prevent future damage. Additionally, park resilience can be furthered with overlapping green infrastructure and stormwater measures such as detention/retention ponds and basins and decreasing impermeable surfaces to naturally capture and treat stormwater flows.

Relevant Hazards: Temperature/extreme heat, flooding, extreme precipitation, and wildfire.

MH-15. Identify Alternative Activities in Climate Sensitive Recreation Areas.

Coordinate with owners of winter recreation areas and water recreation areas to support additional recreational activities that are less dependent on snowpack and water levels. For example, alternative forms of recreation could include biking and hiking trails on skiing mountains during the summer season, or ropes courses and other alternative recreational activities at water recreation sites.

Relevant Hazards: Temperature/extreme heat, drought, and decrease in snowpack.

MH-16. Identify At-Risk Transportation Corridors.

Coordinate with community members, transportation agencies, and private entities to identify local and regional transportation, transit, and active transportation corridors that are at-risk from the effects of climate change. Prioritize further climate risk reduction actions for these routes.

Relevant Hazards: Sea level rise, flooding, temperature/extreme heat, and extreme precipitation.

MH-17. Identify Alternative Routes for Transit Service.

Coordinate with regional transit providers to identify and communicate to the public alternative routes and stops and other redundancies in the transportation network if normal infrastructure is damaged or closed because of extreme events.

Relevant Hazards: Sea level rise, flooding, temperature/extreme heat, and extreme precipitation.

MH-18. Maintain Soil Health.

Maintain and improve soil health. For example, increase soil organic matter to improve soils' water-holding capacity, soil structure, and water infiltration, and to reduce erosion (use cover crops and mixes, native grasses, crop or livestock residues, compost, mulch, biochar, or other organic amendments).

Relevant Hazards: Temperature/extreme heat, drought, and decrease in snowpack.

Climate Risk Reduction Measures

MH-19. Stabilize Burned Slopes in Key Areas.

Stabilize burned slopes located above developed areas, important infrastructure, or key transportation corridors as soon as possible after a wildfire event.

Relevant Hazards: Extreme precipitation and wildfire.

MH-20. Improve Medical Facility Preparedness.

Work with local medical providers and hospitals to ensure that medical facilities are prepared to meet any increased demand because of hazardous events. For example, this could be stocking up on specific medical supplies for local emergencies or working with emergency management agencies to have medical professionals and supplies at emergency shelter locations. Training could also be provided to medical staff to help improve recognition of new and emerging diseases in expanded geographies.

Relevant Hazards: Sea level rise, flooding, temperature/extreme heat, extreme precipitation, wildfire, drought, decrease in snowpack, and air quality degradation.

MH-21. Ensure Homeless Services' Availability in Hazardous Conditions.

Coordinate with local homeless services to ensure that emergency shelters are available during extreme heat events, poor air quality events, severe weather events, and other highly hazardous conditions. Ensure that people experiencing homelessness are made aware of these resources. Work with social care organizations to distribute necessities.

Relevant Hazards: Sea level rise, flooding, temperature/extreme heat, extreme precipitation, wildfire, drought, decrease in snowpack, and air quality degradation.

MH-22. Improve Poor Drainage.

Identify and remedy poor drainage areas to reduce disease risk from stagnant water.

Relevant Hazards: Flooding and temperature/extreme heat.

MH-23. Landscape with Climate Considerations.

Encourage landscaping projects to use plants that will continue to be viable in the area under long-term climate conditions. For example, update landscape ordinances and other applicable standards to include plants that are resistant to drought and extreme heat.

Relevant Hazards: Temperature/extreme heat, drought, and decrease in snowpack.

MH-24. Develop Climate Emergency/Business Resilience Plan.

For large commercial developments, develop a climate emergency/business resilience plan.

Relevant Hazards: Flooding, extreme precipitation, and wildfire.

MH-25. Revise Emergency Plans.

Revise emergency management plans, programs, and activities to account for changing hazard profiles and their consequences.

Relevant Hazards: Sea level rise, flooding, temperature/extreme heat, extreme precipitation, wildfire, drought, decrease in snowpack, and air quality degradation.

MH-26. Integrate Climate Change Considerations into Public Safety and Emergency Planning.

Integrate climate change risk reduction considerations into general plan Safety Elements, Local Hazard Mitigation Plans, public safety document, and all phases of emergency planning. A potential resource for implementing this measure is the Coastal Plan Alignment Compass (OPR n.d.).

Relevant Hazards: Sea level rise, flooding, temperature/extreme heat, extreme precipitation, wildfire, drought, decrease in snowpack, and air quality degradation.

Climate Risk Reduction Measures

MH-27. Provide Greater Affordable Housing Options.

Facilitate affordable housing options outside of hazardous zones for all residents.

Relevant Hazards: Sea level rise, flooding, temperature/extreme heat, extreme precipitation, wildfire, drought, decrease in snowpack, and air quality degradation.

MH-28. Transition to Climate-Smart Energy.

Transition to climate-smart sources of energy. For example, move away from vulnerable sources like hydroelectric, refineries and seaports, centralized power generation facilities that rely on long-range transmission infrastructure; move toward renewable and decentralized energy sources with storage capacity for variations in daily/seasonal demands.

Relevant Hazards: Sea level rise, flooding, temperature/extreme heat, extreme precipitation, and wildfire.

MH-29. Identify Climate Hazard Overlay Zones.

Identify and establish climate hazard overlay zones for consideration during zoning and development of general and project site plans. Users can start by looking at hazard zone maps in existing general plans, as these maps have already been developed due to regulatory requirements. Available resources to identify climate hazard zones include the *Adaptation Planning Guide*, OPR's General Plan Guidelines, Cal-Adapt, the *Ocean Protection Council's 2018 Sea-Level Rise Guidance*, and the Integrated Climate Adaptation and Resilience Program Adaptation Clearinghouse.

Relevant Hazards: Sea level rise, flooding, temperature/extreme heat, extreme precipitation, and wildfire.

MH-30. Establish Community Resilience Hubs.

Establish resilience hub locations in neighborhoods throughout the community. For example, develop existing community centers into cooling/clean air centers.

Relevant Hazards: Sea level rise, flooding, temperature/extreme heat, wildfire, and air quality degradation.

MH-31. Improve Transportation Maintenance.

Update transportation maintenance protocols to incorporate climate vulnerabilities.

Relevant Hazards: Sea level rise, flooding, temperature/extreme heat, extreme precipitation, and wildfire.

MH-32. Establish Urban Tree Management Plan.

Establish policies and management plans to develop urban forests and incentivize the use of best practices for the long-term maintenance and preservation of urban trees.

Relevant Hazards: Temperature/extreme heat, flooding, extreme precipitation, wildfire, and air quality degradation.

MH-33. Implement Park and Natural Resources Protection.

Develop coastal management plan to protect park infrastructure and natural resources. For example, the plan could include protecting existing open space adjacent to the coast, restoring dune habitat to increase the resilience of beaches, using soft or natural solutions for protecting structures facing flooding or inundation, require mitigation for impacts to public access, and the retrofitting or relocation of recreation and visitor-serving facilities. Develop equivalent plans for parks at risk of wildfire or inland flooding.

Relevant Hazards: Sea level rise, wildfire, and flooding.

MH-34. Implement Integrated Watershed Management.

Reduce flood and drought risk through integrated watershed management. For example, a healthy watershed maintains wetland areas as flood mitigation and maintains undeveloped natural areas, promoting soil health to blunt flood impacts and to assure greater resilience to drought.

Relevant Hazards: Flooding and drought.

Climate Risk Reduction Measures

MH-35. Increase Parks in Underserved Communities.

Increase access for underserved populations to parks, which can provide relief against extreme heat and flooding. Identify park-poor communities and ensure that new urban parks and trail systems are within walking distance to high-density infill, homes, and offices.

Relevant Hazards: Flooding and temperature/extreme heat.

MH-36. Decentralize and Localize Energy Production and Storage.

Increase local, decentralized renewable energy production and energy storage capacity to improve energy independence. For example, remove reliance on long-range transmission electricity infrastructure that may start wildfires by installing micro-grids, local renewable energy generation, and battery storage. Create municipal energy utilities and/ or form electric co-ops between rural jurisdictions for more local control over infrastructure and energy supply.

Relevant Hazards: Sea level rise, flooding, temperature/extreme heat, extreme precipitation, wildfire, drought, decrease in snowpack, and air quality degradation.

MH-37. Develop Climate Hazard Notification System.

Develop a notification system for natural hazards that provides early warnings and evacuation notifications. Ensure that the system can be deployed across multiple scales, is responsive to community needs, and reaches vulnerable populations.

Relevant Hazards: Sea level rise, flooding, temperature/extreme heat, extreme precipitation, wildfire, drought, decrease in snowpack, and air quality degradation.

MH-38. Integrate Climate into Health Programs.

Integrate climate change and health equity into traditional public health programs and core functions.

Relevant Hazards: Sea level rise, flooding, temperature/extreme heat, extreme precipitation, wildfire, drought, decrease in snowpack, and air quality degradation.

MH-39. Implement Pervious and Climate-Smart Surfaces.

Encourage and incentivize the use of pervious and climate-smart landscaped surfaces to reduce the urban heat island effect, catch stormwater, and lower overall water use.

Relevant Hazards: Flooding, temperature/extreme heat, and drought.

MH-40. Address Energy/Water Efficiency Funding Barriers.

Address programmatic, funding, and financing barriers for energy/water efficiency retrofits for low-income households and small businesses. Coordinate with local and tribal governments to provide low-income and disadvantaged community energy efficiency and demand response services.

Relevant Hazards: Temperature/extreme heat, drought, and decrease in snowpack.

MH-41. Expand Urban Greening/Agriculture.

Collaborate with community-based organizations to develop or expand urban greening and urban agriculture programs. For example, urban greening can include adding trees, parks, green infrastructure, and other green elements to a neighborhood. Urban agriculture includes community gardens or small farms within urban areas of a community.

Relevant Hazards: Flooding, temperature/extreme heat, and air quality degradation.

MH-42. Provide Vaccinations for Changed Transmission Vectors.

Ensure that free or reduced-cost vaccinations for vector-borne diseases are widely available.

Relevant Hazards: Flooding and temperature/extreme heat.

Climate Risk Reduction Measures
Sea Level Rise and Coastal Flooding/Erosion
SLR-1. Implement Engineering Solutions. Build a seawall or offshore reefs to protect the project. Build levees to reduce flooding. Consider jetties and groins.
SLR-2: Raise Building Floor Elevations. Ensure buildings have raised finished floor elevations.
SLR-3. Implement Natural Coastline Infrastructure. Use natural shoreline protection methods, such as beach nourishment, living shorelines, and dune restoration, where feasible.
SLR-4. Strengthen Buildings Against Flood. Strengthen buildings against flooding using dry or wet floodproofing techniques.
SLR-5. Use Moveable Infrastructure. Incorporate modular components in the building design to allow the project to move away from coastal flooding and erosion zones.
SLR-6. Develop Adaptive Management Plan. Develop an adaptive management plan to address the long-term impacts of sea level rise. In the plan, include an assessment of local vulnerability, including infrastructure such as roads and water reclamation facilities, buildings in the inundation areas, and ecosystems. For example, adaptive management techniques can include flexible adaptation pathways. Adaptation pathways are a planning approach that address uncertainty by considering multiple possible futures and analyzing the robustness and flexibility of various options across those futures.
SLR-7. Require Consideration of Sea Level Rise for New Development. Require accounting of sea level rise in all applications for new development in shoreline areas. Ensure that all applications for new development account for projected sea level rise and provide adequate protection (e.g., setback, armoring). For example, require applications develop a vulnerability and risk reduction plan that uses the *Ocean Protection Council Sea-Level Rise Guidance*. Provide guidance for applicants in considering most suitable sea level rise scenarios in planning.
SLR-8. Develop Setbacks. Develop adequate setbacks for new development. For example, ensure structures are set back far enough inland from the beach or bluff edge such that they will not be endangered by erosion (including sea level rise induced erosion) over the life of the structure, without the use of a shoreline protective device.
SLR-9. Develop Regional Sediment Management. Develop a regional sediment management program including strategies designed to allow the use of natural processes to solve engineering problems.
SLR-10. Sell off High-Risk Area Development Rights. Allow landowners in high-risk areas to sell their development rights. In conjunction, designate areas for increased density in a community for this.
SLR-11. Site Outside Coastal Hazard Zone. Select sites outside of coastal hazard zone or coordinate with long-term community managed retreat plans. Develop plans allowing for coastal inundation in defined areas.

Climate Risk Reduction Measures
SLR-12. Limit Basements in Flood Zones. Limit basements and first floor habitable space in flood zones and keep critical assets (such as major electrical infrastructure) on higher floors.
SLR-13. Provide Removal Options in Flood Zones. Analyze options for removal of the structure or critical assets connected to the structure when planning and designing new development in flood zones.
SLR-14. Coordinate with Regional Planning Efforts. Coordinate with regional agencies on developing policies and/or plans where project-level solutions alone may not be able to mitigate sea level rise risk.
SLR 15. Alert Public of Storm Surge Risks. Include signage to warn people about flooding during storms and king tides. Provide materials to visitors and communities on risks of storms and king tides.
Extreme Precipitation and Inland Flooding
EP-1. Incorporate Runoff Projections in Hydrologic Designs. Incorporate projected increases in runoff into site-specific hydrologic design. Account for uncertainty in future runoff due to potential changes in precipitation, where past data is not a reliable predictor of future events.
EP-2. Install Stormwater Outfall Pumps/Lift Station for Water Drainage. Install stormwater outfall pumps/lift stations to drain water from the system if outfalls were to become submerged.
EP-3. Install Stormwater Cistern/Retention Basin. Build or enhance stormwater cisterns or retention basins.
EP-4. Waterproof Operational Equipment. Protect mechanical, electrical, and other key operational equipment from flooding at critical facilities/locations by dry proofing or wet proofing facilities.
EP-5. Upgrade Wastewater Systems. Upgrade wastewater systems to accommodate projected changes in precipitation and flooding. For example, enhance wastewater system capacity to prepare for increased flows and strengthen facilities against extreme events.
EP-6. Site Outside Floodplain. Select site outside the floodplain. If not completely possible, keep most climate-sensitive elements of the project outside the floodplain.
EP-7. Maintain Stormwater Infrastructure on Key Routes. Conduct regular cleaning and maintenance of storm drains and other stormwater infrastructure assets along key roadways, especially in advance of the rainy season. Improve storm drain capacity in areas where ponding is regularly observed.

Climate Risk Reduction Measures
Wildfire
WF-1. Implement Fire-Safe Landscaping. Implement fire-safe landscaping. A toolkit for fire-safe landscaping is available online (IBHS n.d.).
WF-2. Install Fire Suppression Systems and Improve Structural Strength. Install fire suppression systems in high fire risk locations. Incorporate hardening and strengthening aspects into structure design and material selection, such as tile roofs and mesh in attic vents to prevent ember sparks.
WF-3. Strengthen Vulnerable Assets in High Wildfire Risk Areas. Strengthen vulnerable assets in high wildfire risk areas. For example, replace wooden electricity distribution poles with steel poles.
WF-4. Educate on Wildfire Resistant Landscaping. Provide information to homeowners about statutory vegetation management requirements (CAL FIRE 2019a) and promote defensible space to slow fire spread in forested and wildland-urban interface (WUI) areas. For example, send educational materials encouraging homeowners to create fire-resistant zones with stone walls, patios, decks and roadways. Similarly, promote the use of rock, mulch, flower beds and gardens as ground cover for bare spaces and as effective firebreaks. Additional resources are available from CAL FIRE (CAL FIRE 2019b).
WF-5. Site Outside WUI. Direct site selection outside of the WUI, the zone where development meets wildland areas, including fire hazard severity zones as mapped by CAL FIRE. (Some Counties also have WUI maps.) If not able to site outside the WUI and/or fire hazard severity zones, implement other fire-safe management, such as creating defensible space or carrying out fuel management.
WF-6. Designate and Strengthen Wildfire Emergency Routes. Identify and mark emergency routes or recommend additional roads in the wildland-urban interface in case of evacuations. Provide advanced public education on evacuation routes and deliver emergency evacuation orders and warnings. Make all notices and guidelines accessible in multiple languages. Ensure redundancy in evacuation routes.
WF-7. Develop Fire Risk Assessment for New Development. Develop a fire risk assessment for all new development within fire hazard severity zones or the WUI.
WF-8. Implement Fuel Management. Carry out fuel (i.e., live vegetation or dead biomass) removal/management techniques, such as fuel breaks, in the WUI and in the wildfire influence zone. Conduct controlled/prescribed burns to mitigate wildfire risk.
WF-9. Install Air Filters. Encourage the installation of air filters to protect against indoor air quality impacts during wildfire smoke exposure events.
WF-10. Adopt WUI Building Standards. Recommend in Local Responsibility Areas that households adopt WUI Building Standards and consider using WUI-approved construction materials if they are in High and Moderate Fire Hazard Severity Zones.
Temperature/Extreme Heat
EH-1. Install Green Infrastructure. Install green infrastructure to increase shading and reduce heat impact. For example, green streets and pocket parks.

Climate Risk Reduction Measures

EH-2. Provide Heat Mitigation for Public Walkways and Transit Stops.

Collaborate with public works departments and regional transit providers to increase shading and heat-mitigating materials on pedestrian walkways and transit stops. For example, build bus shelters or plant trees at bus stops to provide shade for waiting passengers.

EH-3. Install Heat-Reducing Roof.

Install green roofs, cool roofs, or other high-albedo or heat reducing roofs.

EH-4. Enhance Building Envelope Efficiency.

Improve building envelope efficiency to protect against extreme heat. For example, install well-sealed doors and windows or window treatments such as solar shades. May also include passive cooling design/architecture.

EH-5. Upgrade to Efficient Equipment/Infrastructure.

Upgrade equipment and infrastructure to be more energy-efficient to minimize stress on the electrical grid.

EH-6. Install Refillable Water Stations.

Install refillable water stations at parks, trailheads, community centers, and sport courts/fields with available water supplies to encourage proper hydration and protection against heat-related illnesses.

EH-7. Install Equipment Cooling System.

Provide cooling systems for equipment sensitive to overheating.

EH-8. Use Alternative Pavement Surfaces.

Use alternative pavement surfaces (to reduce rutting, cracking, heat impacts, etc.) when resurfacing roads, critical intersections, multi-use paths, and city parking lots.

EH-9. Expand Urban Tree Canopy.

Develop or expand urban tree canopy to help cool urban environments.

EH-10. Install Covered Parking.

Install a form of covered parking, such as trees or solar panels, that mitigates heat islands and reduces off-gassing from cars.

EH-11. Work with Schools to Reduce Heat Exposure.

Provide education, partnership, and other support to local schools to reduce outdoor exposure during extreme heat events.

EH-12. Provide Backup Power for Cooling Centers.

Ensure that facilities used as cooling centers are equipped with backup power supplies, including onsite renewable energy generation and energy storage systems as feasible.

EH-13. Develop Heat Emergency Plan.

Adopt or update heat emergency plan. Ensure that the needs of vulnerable and remote populations are accounted for in the plan.

EH-14. Develop Low-Income Energy Programs.

Work to coordinate energy-related programs that target low-income communities with broader climate risk reduction efforts.

Climate Risk Reduction Measures
EH-15. Provide Low-Income Air Conditioning. Provide reduced-cost, energy-efficient air conditioning systems to low-income households.
EH-16. Establish a Shuttle System to Cooling Centers. Establish a shuttle system to operate during extreme heat events with specific pickup points and provide access to local cooling centers for persons who are unable to drive or lack access to a vehicle.
Drought
D-1. Install Water Efficient Appliances. Install water-efficient appliances, such as water-efficient faucets and pipe fixtures.
D-2. Install Water Reuse Infrastructure. Install infrastructure that encourages water reuse, such as greywater appliances and stormwater capture.
D-3. Install Drought Resistant Landscaping. Install pervious and landscaped surfaces to reduce heat island effects and improve groundwater recharge. Installation may include the use of native, arid ecosystem plants as well as water-smart technologies, such as drip irrigation.
D-4. Educate on Water Conservation. Educate the public on and encourage water conservation behavior. For example, running education campaigns or having information available at a community center.
D-5. Outreach to Educate About Recycled Water Safety. Initiate public outreach to encourage acceptance of recycled potable water sources.
D-6. Build Alternatives Forms of Water Recreation. Work with owners of water recreation sites to begin installing alternative forms of recreation that are less dependent on water levels.
D-7. Diversify Water Supply Sources. Diversify water supply sources to have backup sources during drought when some water supplies (e.g., surface water) may be scarce to ensure all communities have access to water. For example, increase sourcing from groundwater or local recycled water.
D-8. Develop Groundwater Sustainability Plan. Work with local water utilities, agencies, and stakeholders to comply with or develop a groundwater sustainability plan.
D-9. Implement Local Water Recycling. Implement local water recycling, either decentralized at residential/commercial facilities, or centralized at larger community facilities.

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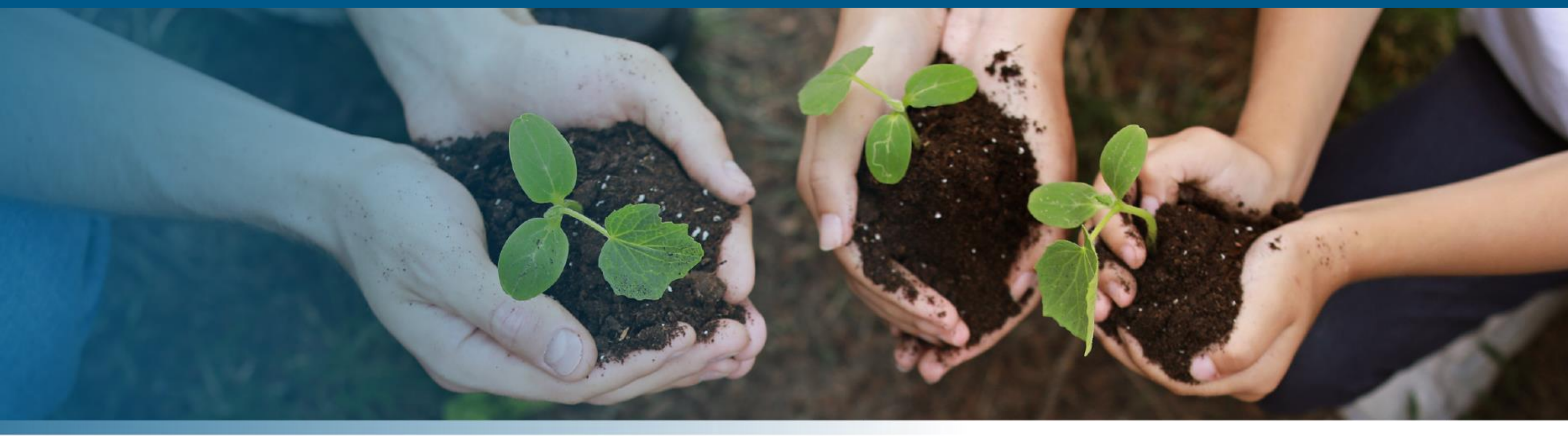
Measures for Advancing Health and Equity

CHAPTER 5



Introduction

California may be the world's fifth-largest economy, but there is a vast disparity in health, economic, and wellbeing outcomes across our state. We may have gleaming towns in the golden hills, but we also have communities in the shadows of refineries and oilfields, in agricultural valleys and arid deserts, facing high housing costs and low wages, drinking contaminated groundwater, and breathing air that is of some of the worst quality in the United States.

All this is not by chance. Such discrepancies are driven by land use planning decisions, which have in turn led to inequities in the social determinants of health—the characteristics of built environments, social networks, and economic opportunities that lead neighboring census tracts and communities to have vastly different life expectancies and health outcomes. Yet location only tells part of the story: Race and racism have had a profound influence on where people in the United States live, how they live, and how their communities are shaped and built.

The history of land use planning in California is inextricably rooted in exclusion and structural racism—starting with the centuries-long forced displacement of Native Californians and dispossession of Native lands. The first zoning ordinances were passed in the late nineteenth century in Modesto and San Francisco to restrict where Chinese residents could live and where laundries owned by Chinese residents could operate (Chou 2014; Fan 2015). The 1913 and 1920 Alien Land Laws of California banned Asian immigrants, especially those from Japan, as well as their U.S.-born children, from owning agricultural land in California. During the New Deal, federal agencies designated immigrant communities and communities of color, particularly Black communities, as hazardous for investment—redlined on a map—while predominantly white neighborhoods were greenlined. Armed with these maps, federal housing agencies refused to insure mortgages in redlined communities, while lenders denied mortgages to Black residents, leading to systemic, compounding divestment from communities of color. At the same time, racial zoning, racial covenants, and terror campaigns restricted housing choice and prohibited people of color from buying homes in desirable suburban communities. Redevelopment and freeway construction further targeted communities of color, whose mere presence was used as evidence of blight and lower property values. These neighborhoods were either placed next to, or targeted with, sources of pollution such that even today, people of color breathe dirtier air than their white counterparts (Lloyd 2021).

The consequences of redlining and other deliberately racist housing practices can still be felt today. Formerly redlined neighborhoods continue to be ravaged by predatory lending and housing insecurity, and 87 percent of San Francisco's formerly redlined neighborhoods remain low-income (Hernandez 2009). Home values and household incomes are nearly twice as high in predominantly white neighborhoods than in communities of color (Menendian, Gailes, and Gambhir 2021). Redlining has denied homeownership to generations of people of color—excluding them from one of the primary means of wealth accumulation in the U.S.—and denied lines of credit to businesses, barring communities of color from equitably sharing in the decades of twentieth-century prosperity. The cascading consequences are far-reaching, affecting every facet of life from the distribution of environmental pollution burdens and public goods and services to school and education funding and opportunity access.

This persistent and pervasive racism and discrimination is not only economically inequitable, but actively erodes the health and longevity of communities of color. The stress alone of experiencing lifelong racism and discrimination leads to worsened physical and mental health outcomes (Bichell 2017). Furthermore, communities of color and low-income, marginalized, and immigrant communities have been excluded from the many social determinants critical to supporting healthy, thriving, prosperous lives. To reverse the harms of decades of divestment, communities must have the power and capacity to access these resources.

Our planning systems have created and entrenched these unfair outcomes—and so it is not only necessary but also appropriate for our planning systems to provide restitution. This situation, built over hundreds of years and embedded in the laws, finance, economy, transportation, public health, education, governing processes, and buildings of California, can only be addressed in the same manner it was created: one decision at a time. Equity and health cannot be considered separately from land use planning and zoning, and land use decisions are never undertaken in a neutral vacuum but must co-exist in conversation with the aggressions of the past. Each budget, each project, each approval, each building, each job, each school, each tree, each road, each ordinance, each loan, each salary, must be designed and realized in a manner that is more inclusive, fair, and equitable.

Purpose

This chapter seeks to provide a non-exhaustive list of measures, examples, and resources to aid proponents, lead agencies, and communities to make the planning, approval, construction, and operation of projects more inclusive and the outcomes of these projects more equitable.

These measures seek to promote health equity, defined in state code as "efforts to ensure that all people have full and equal access to opportunities that enable them to lead healthy lives" (Health and Safety Code 131019.5).

These measures are also intended to support progress toward racial equity, or "when race can no longer be used to predict life outcomes and outcomes for all groups are improved" (GARE 2015). More specifically, achieving health and racial equity requires ensuring that all communities have full access to safe and affordable homes, education, good jobs, walkable neighborhoods, clean air and water, green spaces, healthy food, and mobility choices—as well as freedom from discrimination, and the capacity and empowerment to participate in and influence civic processes.

Finally, these measures are intended to support inclusion of and solidarity with marginalized, underrepresented, and vulnerable communities, including people of all race and ethnic groups; low-income people; people who are incarcerated and those who have been incarcerated; people who are unhoused; people who are undocumented; people with disabilities; people with mental health conditions; children; youth and young adults; seniors; immigrants and refugees; people who are limited-English proficient; women; gender-expansive people; and lesbian, gay, bisexual, transgender, queer/questioning, intersex, asexual, and other gender identities (LGBTQIA+) communities.

Statewide Goals and Policies

Through the various levers of government, the State of California seeks to elevate the centrality of health, equity, and environmental justice as a goal and priority. With the continued evolution of California Environmental Quality Act (CEQA) caselaw, health and equity are becoming recognized parts of the environmental review process. The courts have long held that "[P]ublic participation is an 'essential part of the CEQA process'" (Laurel Heights II (1993) 6 Cal.4th 1112 at 1123), and as such, it should be meaningful. Beyond outreach, the potential impacts of land use decisions that must be considered have increased to include "urban decay impacts" (Bakersfield Citizens for Local Control v. City of Bakersfield (2004) 124 Cal.App.4th 1184) and impacts on human health (Sierra Club v. County of Fresno (Friant Ranch, L.P.) (2018) 6 Cal.5th 502).

Beyond CEQA contexts, the legislature is recognizing the failures of current systems to address inequity. In 2012, Senate Bill (SB) 535 (de Léon) acknowledged the disproportionate burden of environmental pollution on California's disadvantaged communities, and accordingly required them to be prioritized for emissions reduction projects funded by cap-and-trade proceeds. This led to the State of California's development of CalEnviroScreen, a tool that identifies disadvantaged communities, currently defined as census tracts ranking in the top 25 percentile for environmental burdens and socioeconomic conditions; census tracts without scores but having the highest 5 percent of cumulative pollution burden scores in CalEnviroScreen 4.0; disadvantaged census tracts from the 2017 designation of disadvantaged communities; and land under control of federally recognized Tribes. In 2016, the legislature expanded funding prioritization to include low-income communities with the passage of Assembly Bill (AB) 1550 (Gomez).

Also, in 2016, SB 1000 (Leyva) required local jurisdictions to identify communities that are disproportionately burdened by environmental justice issues within their boundaries and address environmental justice in their general plans. This includes developing goals and policies to reduce pollution exposure, reduce unique or compounded health risks, promote safe and sanitary homes, and prioritize the needs of disadvantaged communities, among other focus areas. In addition, the Community Air Protection Program and other initiatives authorized by AB 617 (Garcia) aim to develop community-driven planning to reduce air pollution locally. Starting in 2018, air districts began working with community-led steering committees to implement air monitoring and emissions reduction projects in communities experiencing some of California's most severe air pollution impacts.

Looking forward, it is anticipated that the state will continue to prioritize environmental justice and health and racial equity in its environmental and climate programs. Project proponents and jurisdictions are encouraged to take the lead and embrace placing the healthy and equitable treatment of their residents front and center.

Using this Chapter

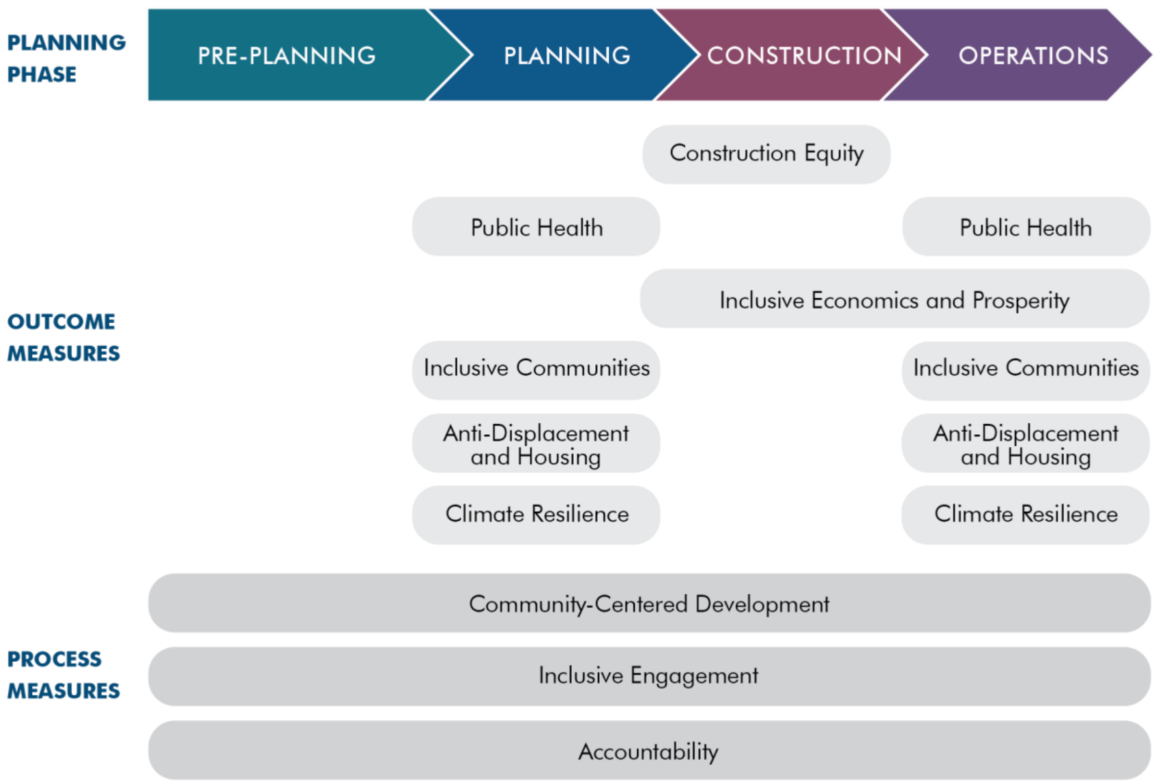
This chapter is divided into two parts: *process measures* focus on facilitating greater community participation and decision-making in the process of land use planning, and *outcome measures* focus on enhancing the project features and operational practices that advance equity-supportive outcomes.

Process measures are further grouped into three categories. We recommend starting with the community-centered development category for strategies to help the project align with community priorities and needs, ideally through a collaborative process working side by side with community-based organizations (CBOs). The inclusive engagement category is crucial to all phases of project development to ensure that outreach is inclusive, accessible, culturally competent and respects community experience and capacity. Finally, the accountability section is intended to provide community members with methods to hold project proponents accountable for their commitments.

The outcome measures comprise six categories, each pertaining to a desired outcome area. Construction equity measures focus on reducing the air quality, traffic, noise, and other impacts of construction for the surrounding community. Public health and air quality measures aim to improve the health outcomes of project residents as well as nearby neighborhoods. The inclusive economics and prosperity measures aim to ensure that the economic benefits of new development are shared equitably, particularly for underserved and marginalized communities. The inclusive communities category seeks to ensure that projects are designed to be inclusive, accessible, and supportive for all people. The anti-displacement and housing measures aim to increase affordable housing and protect residents from displacement. Finally, the climate resilience category complements the larger set of climate adaptation measures in Chapter 4, *Assessing Climate Exposures and Measures to Reduce Vulnerabilities*, with three additional strategies to enhance resilience in vulnerable communities.

Critically, equity as a process remains essential to the outcome measures: all community members should be able to participate meaningfully in the development and decision-making around desired project outcomes and features. Thus, users should refer to the process section for guidance around community priorities, inclusive engagement, and accountability. Providing open, inclusive engagement throughout project development, for example, can support community members to give feedback at any phase. Figure 5-1 demonstrates how process measures should be considered throughout planning and illustrates how outcome measures can be integrated into specific planning phases.

Figure 5-1. Equity Measures by Planning Phase



Measures involving outreach or engagement can be done voluntarily by the proponent or imposed as a requirement by the local jurisdiction as part of the outreach process. Measures involving design features, construction practices, or operational practices should be incorporated as a condition of approval, mitigation measure, or part of a developer agreement. In general, the project proponent will be responsible for undertaking most measures, with a select few implemented by lead agencies, local jurisdictions, or community groups and coalitions.

The nine measure categories are illustrated in Figure 5-2. Users may click on an individual measure to navigate directly to the description of that measure. Each measure description includes applicability guidelines, implementation considerations, a discussion of how the measure impacts various equity outcomes, case study examples, and resources. Each of the process measures also pose a key question to guide users in their thinking and to help determine if they are implementing the measure both in letter and spirit.

Figure 5-2. Navigation Tree for Equity Measures

Process Measures

COMMUNITY-CENTERED DEVELOPMENT

- CCD-1. Consult Pre-existing Community Knowledge/Priorities
- CCD-2. Conduct a Stakeholder Analysis and Develop a Community-Centered Outreach Plan
- CCD-3. Conduct a Community Needs Assessment
- CCD-4. Conduct Community Asset Mapping
- CCD-5. Establish a Community Benefits Agreement

INCLUSIVE ENGAGEMENT

- IE-1. Prioritize Outreach to Communities of Color and Underserved Groups
- IE-2. Establish or Join a Community Project Steering Committee
- IE-3. Elevate Voices of Underrepresented Groups in Project Direction and Outreach
- IE-4. Inclusive Community Meetings
- IE-5. Provide Education on Essential Topics Related to Project
- IE-6. Conduct an Equity Assessment with Community Project Steering Committee

ACCOUNTABILITY

- A-1. Use Participatory Budgeting
- A-2. Establish Incentive and Penalty Provisions for Community Priorities
- A-3. Evaluate Project Performance with Community Project Steering Committee/Community Based-Organizations
- A-4. Establish Clear Points of Contact
- A-5. Public Disclosure of Project Commitments

Outcome Measures

CONSTRUCTION EQUITY

- CE-1. Create a Construction Plan with Community Input
- CE-2. Ensure Active Modes Access During Construction
- CE-3. Post a Clear, Visible Enforcement and Complaint Sign
- CE-4. Portable Indoor Air Filtration for Nearby Residents During Construction
- CE-5. Air Quality Monitoring and Response Plan
- CE-6. Provide Funds to Businesses Impacted by Construction Activities

PUBLIC HEALTH AND AIR QUALITY

- PH-1. Establish Vegetative Barriers to Reduce Pollution Exposure
- PH-2. Increase Urban Tree Canopy and Green Spaces
- PH-3. Highly Rated Air Filtration
- PH-4. Create Healthful, Sustainable Indoor Spaces
- PH-5. Provide Equitable Food Access and Food Justice

INCLUSIVE ECONOMICS & PROSPERITY

- IEP-1. Local Labor and Apprenticeships (Construction)
- IEP-2. Local Labor and Apprenticeships (Operations)
- IEP-3. Contract with Diverse Suppliers
- IEP-4. Use of Locally/Regionally Manufactured Products and Materials
- IEP-5. Higher Wage and Working Condition Standards

INCLUSIVE COMMUNITIES

- IC-1. Invests in Local Arts and Culture to Affirm Community Identity
- IC-2. Adopt Design Standards
- IC-3. Promotes Accessibility
- IC-4. Enhanced Open and Green Spaces
- IC-5. Designated Space for Community-Based Organizations, Disadvantaged Businesses, and Community Assets
- IC-6. Create Non-Standard Commercial or Retail Spaces
- IC-7. Equal Access to Building Amenities
- IC-8. Enhanced Access to Community Resources

ANTI-DISPLACEMENT AND HOUSING

- AH-1. Support Community Land Trusts
- AH-2. Promote Affordable Housing in Transit-Rich Areas
- AH-3. Protection for Existing Tenants of Redevelopment Projects
- AH-4. Incorporates Permanent Supportive Housing
- AH-5. Make Housing Units Permanently Affordable
- AH-6. Support the Formation of Collective Ownership Models. Limited-Equity Housing Cooperatives or Mutual Housing Associations
- AH-7. No Net Loss of Affordable Housing Units/One-For-One Affordable Housing Policies

CLIMATE RESILIENCE

- CR-1. Adapt and Re-use Vacant Lots for Green Infrastructure
- CR-2. Support the Development and Operations of Community Resilience Centers
- CR-3. Passive Survivability

The measures presented in this chapter provide broad guidelines and best practices and should be tailored to the needs and characteristics of individual communities. Project proponents should respect community experts, build upon existing work done in the community, and provide compensation to CBOs in return for their knowledge, networks, and labor.

Development of this chapter relied greatly upon the City University of New York's *Equitable Development Guidelines,* and the guidance and feedback from TAC members.

While the challenge of dismantling structural racism cannot be tackled by one project alone, it is hoped that these measures help to provide support and momentum toward building more equitable communities.

Process Measures

While California provides various ways for the public to engage and participate in the land use development process, these channels and the systems by which local government operates are often exclusionary of under-resourced, historically marginalized, and underrepresented communities. As a result, their perspectives are frequently overlooked from decision-making, risking furthering structural inequities and the concentrations of locally unwanted uses, gentrification, displacement, and the erosion of community.

This section provides strategies and best practices to help re-imagine the role of community members in land use development. The aim is to transition to a community-centered process in which the community determines their needs and priorities and is empowered to work closely with lead agencies and project proponents to achieve these goals. These measures encourage the meaningful involvement and participation of CBOs and other community stakeholders from the outset of the development process, continuing through project completion to ensure accountability. The outcome will be a project that prioritizes community desires and needs, uplifts the perspectives of underserved and marginalized residents, and helps to support healthier, more equitable communities.

While many of these measures emphasize involving the community in the design, mitigation, and approval process, users of this guide are encouraged to *build community capacity* and *acknowledge structural inequities*. Wealthier communities have greater capacity and access to act on their interests, while historically marginalized communities lack similar resources, a reality overlooked by one-size-fits-all outreach processes. Indeed, vulnerable communities must often labor *more* on their own behalf to advocate for the rights and amenities that are provided to wealthier communities as a matter of course. Regardless, all communities should have the opportunity for meaningful engagement and participation that respects their time and circumstances. An equitable engagement process asks the project proponent or lead agency to provide additional resources, assistance, and opportunities in some communities, so *all* residents can participate meaningfully.

Engagement is not counted in hours spent in meetings, but how the project changes and reacts in dialogue with the needs and priorities of the community. For engagement to be meaningful, the community must be able to effect change and shape outcomes and processes, not merely provide feedback to be filed away.

Although this process may be more labor-intensive at the outset, in the long term it can lead to a project that is supported by the community both in the development phase and in its operational lifetime. Equity is not a barrier in project development, nor a box to be checked, but rather an opportunity and a continuous practice to build a more inclusive, prosperous community. The process measures that follow focus on centering around community needs, inclusive engagement, and accountability.

Community-Centered Development (CCD)

This section focuses on measures designed to promote community-driven planning and highlight community priorities, with the aim of ensuring that issue and priority identification starts from the community. True equity arises from a community-centered, collaborative approach to identify and understand community concerns and priorities and create solutions together. Measures here represent crucial first steps foundational to achieving these goals and should be incorporated prior to the initial planning phase of project development.

These measures recommend consulting existing priority identification efforts before developing new efforts. It is important for project proponents to be mindful of community engagement fatigue, as some underserved and underrepresented communities have been part of numerous neighborhood studies and community engagement projects – without ever seeing resulting change. To avoid placing excess burden on communities, proponents should first consult existing studies and plans and align the project proposal with their recommendations and identified goals. However, only consulting prior studies and plans is not sufficient to understanding community concerns; in every process the community must have the opportunity to express their concerns directly to those responsible for planning.

Photo Credit: City of West Hollywood / Jon Viscott, February 2020

Thus, other measures in this section offer practices when pre-existing knowledge may be sparse or not accepted by existing community members. These measures call for project proponents to thoroughly research community priorities and consult with local CBOs' knowledge and expertise. Finally, the last measure calls for project proponents to formalize identified community priorities into a community benefits agreement.

CCD-1. Consult Pre-Existing Community Knowledge/Priorities

As a first step, before embarking on more extensive community outreach, the project should consult existing neighborhood and community plans or studies, such as community needs assessments, community asset mapping, and neighborhood plans. By recognizing and understanding the work that has already been done, project proponents have a greater opportunity to address community concerns and needs that have already been identified. Proponents also demonstrate respect for the existing wisdom and lived experiences of the community. Additionally, consulting existing knowledge helps avoid engagement fatigue for already-burdened communities. If existing knowledge is outdated, not accessible, or not aligned with community priorities, conduct a community needs assessment to identify specific community needs.

Key Question: Is the project in alignment with existing plans accepted by the community?

Applicability

Applicable to all projects. Projects in greenfields or smaller jurisdictions may need to rely on general, regional, or state planning efforts.

Scale and Timing

- Scale: Neighborhood/City and Project/Site
- Timing: Planning

Dimensions of Equity

Because a given community's priorities can range widely, this measure has the potential to impact all dimensions of equity, depending on project context.

Implementation Considerations

Project proponents should prioritize community-led and community-generated plans and documents. Examples of these can range from a local school class project on proposals for a nearby vacant lot, a business improvement district visioning their main corridor, a community health needs assessment, or a full economic development and housing plan drafted by a CBO.

Government plans originate at different levels of government: California has 58 counties, 482 cities, and 3,300 special districts, including air, water, transit, and park districts. Additionally, councils of governments, joint powers authorities, metropolitan planning organizations and regional transportation planning agencies will often have controlling plans with various levels of community outreach and acceptance. These plans may be in conflict, offering differing perspectives on the locations of future bus corridors, bike lanes, housing densities, or development intensities. Areas of disagreement should be explored with the community to better understand priorities. In addition, plan priorities should be ground-truthed with community members.

When consulting these plans, be mindful of who led their development, whose perspectives are included, and whose are missing. Some communities, including those historically marginalized, may be underrepresented in existing documents and resources. Evaluate the methodologies of these documents to determine their degree of representativeness. For example, a specific plan may have held two to three public meetings, while a community-led effort may have attended multiple events and meetings held by hard-to-reach communities. If the perspectives of vulnerable populations are absent or excluded, conduct additional outreach to ensure their insights are incorporated into the project.

As the project progresses into later phases, the proponent should hold open communications with community members to evaluate the project's continued alignment with identified community priorities.

Example

Focused around a 5-square-mile area encompassing Chinatown, southwest Fresno, and parts of downtown Fresno, the Transform Fresno project is comprised of 22 projects that tackle affordable housing, energy efficiency upgrades, solar panel installation, tree planting, bike lanes and trails, urban gardening and farming, parks, and clean transportation. In its community engagement plan, Transform Fresno examined its local community's history with community engagement and other project plans. Specifically, Transform Fresno highlighted the *City of Fresno General Plan*, *Southwest Fresno Specific Plan*, *Downtown Neighborhoods Community Plan*, and *Fulton Corridor Specific Plan*. Additionally, local CBOs involved with these plans were recognized in the community engagement plan. This information was used to leverage existing relationships within the community and help guide the community engagement plan (Raimi + Associates 2019).

Related Measures

- CCD-3. Conduct a Community Needs Assessment
- CCD-4. Conduct a Community Asset Mapping

CCD-2. Conduct a Stakeholder Analysis and Develop a Community-Centered Outreach Plan

Based on the evaluation of existing plans, the project proponent may identify engagement gaps and accordingly must conduct a stakeholder analysis to fully understand the project's potential impact on residents and ensure that no stakeholders have been left out. A stakeholder analysis strives to identify stakeholders, recognize the degree of influence of different groups, and prioritize those who have been historically overlooked and excluded when it comes to land use planning and local development. A stakeholder analysis can uncover why community members are interested in a project and potential obstacles to a project's success according to community knowledge. A project proponent may also wish to conduct the stakeholder analysis prior to conducting a community needs assessment or asset mapping to ensure that it engages fully with residents traditionally left out of planning decisions.

It is advised that project proponents contract with CBOs on a stakeholder analysis to recognize the value of local knowledge and expertise, and work with a partner that community members trust and recognize. In addition, working with multiple CBOs may offer the most complete analysis, as different organizations serve different demographics.

Once stakeholders have been identified, the project proponent should undertake tailored outreach efforts to underrepresented groups to uplift their voices and invite them to participate in the development process. Project proponents should invite and compensate CBOs and community leaders to develop a community outreach plan together. This approach increases the inclusivity of outreach efforts by leveraging existing CBO networks. An inclusive outreach effort can increase the representation and participation of underrepresented community members in decision-making spaces, which is critical to achieving a more community-focused development process. Furthermore, tapping into community knowledge can elevate important outreach considerations otherwise overlooked. The project proponent should be mindful of outreach fatigue and consider best strategies to facilitate community participation and reduce barriers; see the *Inclusive Engagement* section for outreach strategies.

A community-focused outreach plan includes the following key components.

- Scheduled public involvement timeframes:
  - Outreach events, meetings, and other methods of community engagement.
- Identified stakeholders (from stakeholder analysis plan), underrepresented communities, and other audiences to include.
- Defined goals, outcomes, and performance metrics.
- Identified opportunities for public involvement that are accessible and convenient.
- Timeframe for reporting project progress and data on agreed-upon equity and project performance metrics.

Key Questions: Who is affected by the project? Which groups are not represented in the project development process? What outreach activities can help to support and encourage underrepresented communities to participate?

Applicability

Applicable to all projects.

Scale and Timing

- Scale: Project/Site or Neighborhood/City
- Timing: Planning

Dimensions of Equity

By increasing stakeholder representation and prioritizing vulnerable stakeholders and their concerns, a project can help improve the translation between community concerns and project development. An outreach strategy developed in collaboration with CBOs and community leaders can enhance community member representation, capture feedback, and elevate residents' voices. These critical elements help promote *racial equity* in outreach efforts and enhance community *self-determination* during project development.

Implementation Considerations

- Many stakeholders have few advocates and may be easily left out of community decision-making processes. Thus, it is highly important to work with trusted CBOs that serve underrepresented and marginalized communities.
- Compensate CBOs for their time and expertise, just as one would with consultants.
- There are a variety of approaches to conducting a stakeholder analysis, and CBOs may have their own preferred methodology.
- The outreach strategy must incorporate a variety of different formats to reach a diverse range of residents. Specify roles and responsibilities for each member involved with the outreach strategy. Schedule engagement activities throughout the project's development and implementation to ensure adequate public involvement when resolving issues that might arise during any point in project development.
- Community outreach does not end with the planning phase and is essential across all stages of the project. Consider revisiting the outreach plan at regular intervals to ensure that community input is consulted throughout the project development process.

Example

The Transform Fresno initiative outlined goals to include the full spectrum of stakeholders to be informed, engaged, and take project development-related leadership and guidance roles. Transform Fresno emphasized community-led transformation and listened to residents to identify key barriers to participation for hard-to-reach communities. Community members were given the opportunity to provide suggestions on how to overcome such barriers and to facilitate broad community participation.

In collaboration with community members, Transform Fresno identified several underrepresented target groups: the Latinx, Black, and Asian populations; young children; older people; people with low educational attainment; people living in poverty; people with limited English proficiency; and workers commuting to the project area. Next, Transform Fresno identified barriers to participation associated with each group, such as limited mobility, concerns over deportation, and historical lack of trust in government.

Engagement activities and strategies to mitigate these barriers were highlighted including hosting/attending an arts and culture event, translation services, door-to-door canvassing, and providing introductory education on issues. Finally, to ensure full opportunity for engagement, Transform Fresno identified additional community partners with established ties to underrepresented groups such as Fresno Barrios Unidos, Tenants Together, senior centers, and local businesses.

In creating its outreach strategy, Transform Fresno actively leveraged CBO relationships while creating space for the inclusion of new community partners. The initiative recognized numerous local civic organizations and advocacy groups such as Fresno Building Healthy Communities, West Fresno Family Resource Center, and Centro la Familia. The City of Fresno used this strong civic infrastructure to guide its proposal for the Transformative Climate Communities Implementation Grant and to create a Community Engagement Collaborative. Anyone who lived, worked, or owned property in the project area was encouraged to participate. Community partners were tapped to engage community members in ways to help connect projects to people.

For its outreach strategy, Transform Fresno clearly identified roles of each party involved and paired them with outreach methods and tangible deliverables. For instance, the outreach strategy calls for the Direct Outreach Community Partner to print materials for distribution, maintain a volunteer interest database, maintain an online community engagement calendar, and administer surveys (Raimi + Associates 2019).

Related Measures

- CCD-3. Conduct a Community Needs Assessment
- CCD-4. Conduct a Community Asset Mapping

CCD-3. Conduct a Community Needs Assessment

Photo Credit: City of West Hollywood / Jon Viscott, December 2017

If existing knowledge on community priorities is outdated, lacks detail, or does not represent the perspectives of marginalized groups, the project proponent should contract with CBOs or other partners to conduct a community needs assessment. A needs assessment asks community members what they see as the most important needs for their group or community. Community needs can vary endlessly, from providing childcare to improving local infrastructure; therefore, needs assessments uncover the key priorities for a local community. Furthermore, needs assessments help engage stakeholders before project development begins.

Ideally, the needs assessment should be led by a CBO, other community group, property business improvement district, or local jurisdiction. The format of a community needs assessment can take a variety of shapes including surveys, conversations, workshops, charettes, crowdsourced mapping, and focus groups. While the needs assessment is likely to be far broader than the scope of individual projects, the needs surfaced and opportunities identified can help to inform and address project design, as well as the conditions of approval from the lead agency.

Additionally, it is crucial to analyze the benefits and burdens changes and investments have on vulnerable populations. Here, a project proponent analyzes a community needs assessment to explore how a project addresses a community's communicated priorities, who and what is impacted by project development, and how to mitigate negative effects and align a project more closely with community priorities.

Key Question: How can the project be designed to help address community needs and priorities?

Applicability

Community and neighborhood planning efforts, as well as very large development projects in areas where this work has not been done.

Scale and Timing

- Scale: Neighborhood/City and Project/Site
- Timing: Planning

Dimensions of Equity

Successful community needs assessments allow communities to communicate their individual priorities and then see development projects address them. This process helps promote a community's capacity for *self-determination* and can enhance *racial equity*.

Implementation Considerations

- Timing: Allow enough time to collect responses early during the project planning process.
- A local agency, CBO, or other local group should lead the needs assessment, but the project proponent should provide funding or compensation to support the effort.
- A good needs assessment must represent the perspectives and voices of all community members, including those of historically marginalized communities, communities of color, hard-to-reach groups, immigrants, undocumented residents, seniors, and youth. Consider who may be overlooked by online surveys or other outreach methodologies, as well as languages, internet literacy, typical work schedules, outreach fatigue, and other potential barriers to participation. Best practices include meeting community

members where they are, attending meetings of existing neighborhood organizations, and conducting pop-ups at existing community events, gatherings, and festivals.

- Compensate community members for their time, expertise, and local knowledge. Compensation can also help to support broad and more diverse participation.
- Demonstrate clearly to the local community how the feedback provided is being used to inform the project design.
- Make the community needs assessment publicly available.

Example

The San Diego County Community Action Partnership's 2016 community needs assessment demonstrates key components of a comprehensive community needs assessment: detailed community demographic data, robust community engagement, and actionable next steps rooted in community input. In gathering demographic information, the Community Action Partnership (a public agency within San Diego County's Health and Human Services Agency) examined age, gender, race/ethnicity, primary language spoken, residents in labor force and their occupations, and poverty thresholds. Other additional demographic information projects should consider include families with young children, members of the LGBTQIA+ community, and undocumented residents.

Community Action Partnership contracted with Community Health Improvement Partners, a local non-profit, to seek community input on priorities for services. Six local CBOs also participated as subcontractors to help enhance outreach to low-income communities. This demonstrates the good practice of partnering directly with CBOs and paying them for their time, services, community knowledge, relationships, and expertise. Community forums (with live polling features) were held in communities with high concentrations of poverty to amplify their concerns. Surveys (paper and digital) were used to identify and rank community priorities countywide. Outreach materials and content were translated and interpreted as needed into Spanish, Arabic, and Vietnamese.

The results of the needs assessment informed the *2018–2019 County of San Diego Community Action Plan*, which helps to direct the use of Community Service Block Grants as well as other funding, including applying for additional funds to enhance services for low-income communities. (San Diego County Health and Human Services Agency 2017).

Related Measures

- CCD-1. Consult Pre-existing Community Knowledge/Priorities
- CCD-4. Conduct Community Asset Mapping

CCD-4. Conduct Community Asset Mapping

Community asset mapping identifies the people, places, institutions, and services in a community that aim to improve residents' quality of life. Examples of community assets include local gardens, schools, CBOs, hospitals, and parks. They can also include cultural assets such as arts groups, public art, and places of traditional, heritage, or historical value. The format of a community asset map can vary from an actual map that locates physical assets to a database that organizes a neighborhood's social, economic, and institutional assets. Creating a community asset map not only builds local capacity and knowledge base but also reveals gaps and areas where a project proponent might be able to enhance levels of service or meet missing needs through their project.

Key Question: What are the existing assets, resources, and strengths in this community, and what gaps and opportunities remain to be filled?

Applicability

Community and neighborhood planning efforts, as well as projects costing $250 million or more in areas where this work has not been done.

Scale and Timing

- Scale: Neighborhood/City and Project/Site
- Timing: Planning

Dimensions of Equity

Identifying and collating community assets helps build a community's *social resilience* by revealing neighborhood resources. Furthermore, publicly available community asset mappings can help promote *community ownership*. They can also help to identify valued assets and resources to be protected from climate change and other hazards.

Implementation Considerations

- Gather feedback from a large sample of residents to capture as many assets as community members can identify. A large sample is also important as people will have different perspectives on what they view as contributing positively to their community.
- Consider the frequency at which assets are identified by community members.
- Make the community asset map publicly available so this knowledge can be dispersed across the community and used by future projects.

Example

California early childhood services and advocacy organization First 5 LA initiated the Best Start effort to develop community-based solutions to ensure neighborhoods are safe, healthy, and happy places for children. As part of its community assessment report, the organization conducted asset mapping to engage community members in identifying existing resources and to help clarify focus areas for new efforts.

During the community asset mapping sessions, residents and service providers engaged in facilitated conversations about the resources, supports, strengths, and concerns in their community. Participants used color-coded stickers to identify resources on large, printed maps, and were also encouraged to include additional information from their perspectives. All maps were then compiled into a single community asset map that identified fresh food outlets, hospitals, clinics, public schools, places of learning, children's play areas and public transportation. The community also identified unsafe places, sources of pride, and opportunities for change. Key findings from the East LA Best Start Community Asset Map revealed that the area has numerous public hospitals, clinics, and parks, but the community also identified areas for improvement for these assets.

Resources

- Alabama Youth Justice Alliance and the Southern Poverty Law Center: *Unlocking Your Community's Hidden Strengths*.
- *Participatory Asset Mapping—A Community Research Lab Toolkit*.

Related Measures

- CCD-1. Consult Pre-existing Community Knowledge/Priorities

CCD-5. Establish a Community Benefits Agreement

Community benefits agreements (CBAs) are project-specific, legally enforceable contracts between project proponents and the community that explicitly describe the benefits a project agrees to fund or implement in the community. CBAs help ensure residents, particularly those in low-income areas, receive the economic and other benefits from development projects. These contracts help amplify community priorities and outline direct, specific actions for a project proponent to contribute improvements to the local community. CBAs can be particularly important in areas where a new project may increase the risk of gentrification. Sometimes, but not always, community members may support the project in exchange for a CBA, while other projects clearly note that participation in the CBA does not imply community support.

Key Question: What steps can the project take to mitigate potential negative effects on the nearby community, and how can it ensure its benefits flow equitably to underrepresented or marginalized community members?

Negotiating CBAs

Importantly, CBAs are negotiated before a development project goes to the jurisdiction for approval. Typically, a CBA is then integrated into the development agreement signed by the project proponent and the jurisdiction—allowing the CBA to be enforced by local officials and community groups.

CBAs are typically negotiated between a project proponent (i.e., a developer) and a coalition representing a range of community members. It is essential that community groups are authentically representative of the local community to establish the legitimacy of the CBA. CBA negotiations should be transparent and open to as many community groups as possible. All proceedings and agreements should be made publicly available. Following these strategies can help ensure that the project proponent is not intentionally selecting groups with which to negotiate.

When drafting benefits and commitments for a CBA, be sure to address the following questions (Gross, LeRoy, and Janis-Aparicio 2005):

- What is the time frame for the commitment to be fulfilled?
- How will performance be measured?
- Who will monitor performance?
- How and when will information on performance be made available?
- What will happen if the commitment is not fulfilled?

Enforcement

Establishing strong enforcement mechanisms in a Community Benefits Agreement is an essential step for accountability. Effective enforcement measures must lead to real consequences, should a project proponent fail to meet expectations. While each CBA may differ in its enforcement approach depending on project context and location, examples of effective enforcement measures include the following (Santacroce and Weber 2007):

- *Rescission*: Canceling a contract or incentive agreement if terms are not met; Terminates the incentive agreement in the event of non-performance.
  - Important consideration: Note that if rescission is the only remedy in the CBA, the project can breach the agreement mid-term and leave the public with little value.
- *Clawback*: Recovery of all or part of costs if specified goals are not met.
- *Recalibration*: Adjustment of terms to reflect changing conditions; allows agreement to be flexible and not completely terminated if certain aspects change.
- *Liquidated Damages/Monetary Damages*: Additional charges for non-performance; may be proportional to the project proponent's failure.
- *Revocation* of land transfers or land sales.
- *Injunctive Relief:* Court order requiring an entity to do or to refrain from doing a specified act; allows parties to turn to courts to enforce CBA deliverables.
- *Debarment and suspension:* Prohibits the non-compliant company from receiving incentives in the future and/or conducting business with the public agency in the event of a breach; typically in state statute.

Applicability

This measure is recommended for projects costing at least $250 million, particularly those proposed in census tracts where median household income is below the California

Department of Housing and Community Development's 80 percent of area median household income definitions; considered as disadvantaged according to CalEnviroScreen; ranked in the lowest 25th percentile of the Healthy Places Index; designated as a federal opportunity zone; or another metric of income and advantage as determined by the local jurisdiction.

Scale and Timing

- Scale: Neighborhood/City and Project/Site
- Timing: Planning

Dimensions of Equity

The benefits derived from CBAs can vary across different projects and communities. CBAs have been used to promote workforce development, affordable housing, and green space for underserved communities. Due to their roots in the needs of individual communities, CBAs serve as potent tools to promote *community ownership* and *self-determination*.

Implementation Considerations

Successful CBAs in the long-term require a large, diverse, and organized coalition of groups with strong ties to communities to ensure communities' interests are well-represented. The coalition must stay involved and hold project proponents accountable beyond implementation.

It is essential that CBAs have transparent timeframes for deliverables and include a set of enforcement mechanisms to ensure accountability. A strong CBA has a transparent, inclusive, and accessible process throughout its creation.

Clearly define expectations, roles, and responsibilities for each party included in a CBA. Only assign provisions to organizations that are experienced in the subject matter and have the capacity to meet responsibilities.

Private agreements between community coalitions and a private project developer are free from legal constraints that typically apply to government conditions on development projects. To become enforceable by local officials, CBAs can be incorporated into a development agreement signed between the proponent and local government.

The CBA should establish project progress monitoring systems and clear processes of how to address negative impacts produced by project development.

Other best practices include the following (Gross, LeRoy, and Janis-Aparicio 2005).

- CBA clearly states when a provision kicks in.
- CBA identifies parties and the specific obligations of each.
- CBA outlines a clear timeframe for commitment fulfillment.
- Strong monitoring, oversight, and reporting processes are key elements to of robust enforcement mechanisms.
  - Establish affirmative reporting requirements.

  - Ensure monitoring body has the authority and capacity to investigate complaints of noncompliance through strategies such as records inspection.
  - Required reports should be published at least once per year with a specified due date and be made publicly available.
- Make enforcement mechanisms applicable to third parties and successors of each party to ensure long-term accountability.
  - Contract chains: To ensure obligations transfer to subsequent parties, set up systems that provide enforcement throughout project development and operational phases.
    - Each business is informed of and agrees to the applicable substantive requirements.
    - Each business agrees that it will include these requirements in other contracts it enters.
    - Each business agrees that the community groups, the local government, or affected individuals can enforce the requirements.
- Incorporate the CBA into a development agreement to authorize local government monitoring or enforcement.
- In the event of a CBA breach, specify which other clauses will remain in effect after the contract violation.
- Set up a remedy system to provide opportunities for mediation in the event of a breach.

Examples

2001 Los Angeles Staples CBA

The Figueroa Corridor Coalition for Economic Justice—a broad coalition of over 30 community-based groups, including Strategic Actions for a Just Economy (SAJE), Los Angeles Alliance for a New Economy, and Coalition L.A, as well as hundreds of individuals—successfully negotiated a strong CBA with the $4.2 billion mixed-use Los Angeles Sports and Entertainment District development. The benefits include the following (Partnership for Working Families 2015a):

- Funding to assess community park & recreation needs, and $1 million for park and recreational facilities to meet those needs.
- 70 percent of jobs created in the project will pay the City of Los Angeles's living wage, and consultation with the coalition on selection of tenants.
- Job training and a local hiring program for low-income individuals and those displaced by the project.
- Affordable housing increased to 20 percent of new housing, and a commitment of seed money for other affordable housing projects.
- Standards for responsible contracting and leasing decisions.

A coalition member (SAJE) is responsible for monitoring and tracking compliance. Outcomes have been successful: the developer has met most benefits and exceeded some, such as continuing the local hiring policy beyond the first 5 years. Because the CBA was approved by the City and entered into the development agreement, it is enforceable by both the City of Los Angeles and community groups.

Building on its successes and movement-building, the Figueroa Corridor Coalition has since evolved into United Neighbors in Defense Against Displacement (UNIDAD) and negotiated many other CBAs to ensure that development is equitable and inclusive, and that local communities will directly benefit (Pastor et al. 2015).

Kingsbridge Armory/National Ice Center CBA, New York

In April 2013, the Knightsbridge Armory Redevelopment Alliance (KARA), a coalition of 25 different local community groups, entered a CBA regarding the redevelopment of the Kingsbridge Armory into a National Ice Center in the Northwest Bronx. The developer, KNIC Partners, agreed to the following outlined in the CBA:

- Contributions to the community:
  - $8 million toward building approximately 52,000 square feet of community space used in any way to which KARA agrees.
  - $1 million per year for in-kind access to ice center facilities, including discounted rates for school children who receive free school lunch.
  - 1 percent of annual gross ice-rink rental revenue up to $25 million, plus 2 percent of any revenue above $25 million for community issues.
- Local hiring, training, and prevailing wages:
  - At least 51 percent of jobs designated for Bronx residents.
  - At least 25 percent of construction employees must be residents who were formerly incarcerated or are currently unemployed or underemployed.
  - Living wages indexed to inflation.
- Local procurement: Majority of all needed goods and services for the development and operation of the ice center would be sourced from local businesses and minority- and women-owned businesses in the Bronx.
- Environmental practices:
  - Developers pledged to attain a Leadership in Energy & Environmental Design (LEED) certification of silver or higher for the project.
  - Developers pledged to incentivize public transportation use, mitigate pollution, and ensure healthy indoor air quality.
  - Developers pledged to provide green space for 20 percent of the whole project site.
  - Developers pledged to provide $10,000 per year to train residents in skills required for work with alternative-energy-generation systems.
- New school construction: If the developer decides to develop an adjoining property, the developer agreed to apply for approval to develop a surrounding area for a school.
- Community involvement: Established a Community Advisory Council as a legal oversight body.

Crucial to the support of this CBA is the high degree of community representation provided by the 25 different local community organizations that helped draft the agreement (De Barbieri 2017; Partnership for Working Families 2015b).

Oakland Army Base: West Gateway Operations Jobs Policy

In 2012, as part of the Oakland Army Base Project, a comprehensive set of jobs policies were developed and agreed upon by project developers, City of Oakland staff, City Councilmembers, and a broad community coalition, Revive Oakland!. These jobs policies were included as terms of the Lease Disposition and Development Agreement made between Oakland and the project developers (Partnership for Working Families 2015c).

To help enforce its resident and disadvantaged worker hiring measures, the Oakland Army Base West Gateway Operations Job Policy outlines clear consequences for the failure of an employer to meet associated requirements. If a large employer fails to comply with the hiring requirements, the employer will pay the City liquidated damages in the amount of $5,000 per job short of the set hiring targets. The Operations Job Policy also details how these damages are to be spent by the City: to support training, referral, monitoring, or technical assistance to advance resident and disadvantaged worker hiring policies (City of Oakland 2012).

Resources

The Partnership for Working Families' [Community Benefits Agreements—A Framework for Success] provides an online step-by-step guide to building a community benefits agreement.

Related Measures

- CCD-3. Conduct a Community Needs Assessment

Inclusive Engagement (IE)

As the previous section touched on the topic of making use of existing community knowledge and priorities, this section seeks to build upon such findings and ensure local communities are heard, represented, and given opportunities to make decisions. Throughout the planning, construction, and operations phases, project proponents should seek to incorporate opportunities for community-led decision making as thoroughly as possible. These steps not only help legitimize the project with community members but can also yield valuable information crucial to a project's long-term success.

Photo Credit: Port of San Francisco, September 2017

Figure 5-3 presents the spectrum of public engagement, which provides a framework for evaluating the degree of community participation, leadership, and empowerment in a public engagement process. Figure 5-3 was adapted from Equity Matters (2015). The spectrum of public engagement was developed originally by the International Association of Public Participation (IAP2) and has since been refined and adapted by advocacy groups, such as the Facilitating Power & Movement Strategy Center.

Figure 5-3. IAP2 Spectrum of Public Engagement

	INFORM	CONSULT	DIALOGUE	COLLABORATE	DIRECT
DESCRIPTION	Project proponent or local jurisdiction initiates outreach and uses a variety of channels to inform community on project development.	Project proponent or local jurisdiction gathers information from the community to inform projects; obtains community feedback on analysis, alternatives, and /or decisions.	Project proponent or jurisdiction engages community to shape priorities and plans; directly works with community throughout process to understand and consider community issues and concerns.	Community and project proponent or jurisdiction share in decision-making authority to co-create solutions together. Partner with community in each aspect of planning, including initial development of alternatives and preferred solution.	Community takes leading role in decision-making and determining strategy with participation and technical assistance from project proponent or lead agency. The community or public has final decision-making.
EXAMPLE	Proponent-led presentations, factsheets, and flyers.	Proponent-led interviews, public meetings, surveys, and focus groups.	Proponent- or agency-led interactive workshops and forums.	Ongoing interactions between community and project proponent in a proponent-led format. Establishing a community advisory/steering committee. Consensus-building efforts, participatory decision-making.	Ongoing interactions between community and project proponent in a community-led format, with support from project or lead agency. Participatory budgeting. Decision-making powers delegated to community advisory/steering committee.

Many interactions between government agencies or project proponents and the community or the public remain at the *informed* or *consulted* level. These interactions can be more one-sided and passive, with community testimony unable to affect real change in project design or policy, and there is often a lack of follow-up with the community to share how their input has been used. Consequently, communities may feel wearied by a constant stream of requests for input with few tangible improvements.

This section offers strategies to help move community engagement from *informed* to *collaborate* or *direct,* and to ensure that community members from diverse backgrounds have ample opportunity to communicate their priorities and concerns and participate in planning and decision-making activities. Government agencies and proponents should actively listen, learn, acknowledge past shortcomings, and make space for community perspectives in plans and documents. Increasing direct participation from community members can help to build equity, community ownership, and local capacity, providing communities with greater determination over how their environments are designed, built, and developed.

IE-1. Prioritize Outreach to Communities of Color and Underserved Groups

Photo Credit: Capital Region Climate Readiness Collaborative, April 2018

This measure looks at specific strategies to incorporate when attempting to reach underserved groups. Make direct, targeted efforts to reach communities of color and underresourced groups to increase their opportunities for participation/engagement. Consult with community leaders and a variety of CBOs with relationships in the community to determine effective outreach approaches.

Engagement strategies should be diverse and include multiple modes of communication, such as online posts, social media content, posters and flyers, and advertisements in multiple languages across different radio stations, television stations, and newsletters and magazines that are popular amongst target groups. Engagement strategies can also include attending meetings and events hosted by CBOs, other local organizations, and neighborhood associations. Pop-up events across different neighborhoods can also be effective in reaching underrepresented groups.

When engaging with the public, proponents should be mindful of differing levels of subject matter expertise. Proponents should be prepared to provide community members education and background materials on subject matter to facilitate greater understanding and confidence. Proponents should also be prepared to direct community members to resources for additional support. These strategies are far from all-inclusive, and project proponents and community members are encouraged to incorporate strategies based on what works best for their specific communities.

Key Question: How can the project proponent make sure that low-income, underserved, and marginalized communities and communities of color are not excluded from the project development processes?

Applicability

Applicable to all projects.

Scale and Timing

- Scale: Neighborhood/City and Project/Site
- Timing: Planning, construction, operations

Dimensions of Equity

Explicit efforts to reach communities of color and frontline groups not typically represented in decision-making structures is an important step in the process of inclusive outreach. Inclusive outreach can lead to a greater *racial justice and equity, community ownership,* and *self-determination* by reducing inequities in representation and decision-making authority.

Implementation Considerations

- Partner with community leaders and/or a CBO. Leverage their networks and relationships to reach groups.
- Outreach is not a one-off, check-the-box exercise, but should be conducted across all phases of project development to increase community input, feedback, and participation.
- Go *to* the community, instead of expecting them to attend another meeting whose importance may not be clear: Ask to get on the agenda of existing community and other local meetings and go to community events.
- Create a welcoming atmosphere and honor the community's history and lived experiences.
- Genuinely listen to community concerns. Be aware that community members may raise a range of issues with the project proponent or local agency; participating staff should be prepared to listen to and acknowledge all concerns and bring information back to the appropriate departments or agencies.
- Develop a long outreach timeframe to reach as many communities as possible.
- Make use of multiple channels and modes of communication to disperse information and updates to a broad audience.
- Employ multilingual content to be more inclusive, for example working with local Spanish (or other language) community newspapers, radio stations, or newsletters.
- Technological platforms are powerful tools to reach broad audiences. However, they should not be the sole outreach method as different groups have different levels of

access to technology. Make use of traditional media sources such as television and radio, as well as flyers and posters at popular community locations (e.g., community center, library, local grocery). Physical outreach events at public spaces (when safe) are also highly encouraged.

- Provide incentives for feedback and engagement that would be of value to residents. Provide compensation for CBO and community partner assistance.
- Be conscious and respectful of cultures and norms.

Examples

Somali Health Board, King County

King County, Washington, has developed a model of community health boards to help improve health in immigrant communities, who may face language, cultural, and other barriers in accessing health care and health information. Based on input from Somali leaders on improving outreach to their communities, in 2011 the King County Department of Public Health helped to create a community advisory board consisting of Somali health professionals and community leaders. Unlike outside government agencies, the Somali Health Board can effectively outreach to Somali immigrant communities in King County, providing health information and education with a cultural lens and from a position of trust (Ali 2018). It also advocates on behalf of the community, develops partnerships with local health services and systems, and grows community leaders. The model has led to the development of other community-led health boards, including those serving the African-American, Eritrean, Ethiopian, Vietnamese, Cambodian, Arab/Iraqi, and Pacific Islander communities (Public Health – Seattle & King County 2019). The health boards operate independently as non-profits but have liaisons with the county public health department.

San Francisco Municipal Transportation Agency Bayview Community-Based Transportation Plan

The Bayview Community-Based Transportation Plan (Bayview CBTP) is a project developed for the Bayview-Hunters Point community in the southeast corner of San Francisco. Decades of disinvestment and institutional racism has left community members of San Francisco's once prosperous and largest Black neighborhood at risk of displacement. The Bayview CBTP is a community-driven planning effort focused on improving the physical mobility and needs for existing residents and businesses. The plan synthesized local knowledge of the community with San Francisco Municipal Transportation Agency technical expertise to create a plan with a list of projects that emphasize walking, public transit, and improving access for underserved groups such as seniors, young people, residents of color, residents with disabilities, and residents of public housing.

The Bayview CBTP partnered with five CBOs to help identify and engage hard-to-reach groups and elevate the needs of vulnerable residents. CBOs were full collaborators on the public outreach plan, co-designed three stages of public engagement events, co-hosted engagement events in the community, reviewed all outreach materials for cultural competency, clarity, and accuracy, reviewed all Bayview CBTP recommendations for the project, and facilitated a participatory budgeting process.

During the initial community engagement planning steps, residents directed efforts with assistance from the Bayview CBPT team to create an equity index map to help ensure the project would provide the greatest benefit to Bayview-Hunters Point's most vulnerable residents. This equity index map depicted community assets as well as the distribution of vulnerable groups within the community to help prioritize projects. Community members were then asked to develop a scoring system to determine how much the equity index should influence project selection. Importantly, the equity index scoring was also balanced against direct resident input, ensuring that voices left out during the initial equity index creation would still be represented.

The Bayview CBTP team sponsored several pop-up events and met residents at a variety of spaces, including the Bayview-Hunters Point Black Cuisine Festival, the Shekinah Christian Fellowship service, the Lunar New Year and Black History Month Celebration, and the Youth Transportation Summit. Workshops were also launched in collaboration with CBOs to engage Spanish and Chinese languages speakers. All worksheets and display boards were translated into Spanish and Chinese and made publicly available online. (San Francisco Municipal Transportation Agency 2020)

Resources

The California Air Resources Board's California Climate Investments program has developed a summary of best practices for community engagement: *Best Practices for Community Engagement and Building Successful Projects: A Summary from the 2018 Community Leadership Summit*.

Related Measures

- IE-3. Elevate Voices of Underrepresented Groups in Project Direction and Outreach

IE-2. Establish or Join a Community Project Steering Committee

Community project steering committees help shift decision-making power back to the communities where the project is being developed. This power shift facilitates greater community engagement and enhances equity in decision-making. The extent to which a community steering planning committee is invested with decision-making authority can be captured by the spectrum of community engagement, with greater ownership and authority in the process associated with the higher ends of the spectrum (dialogue, collaborate, and direct); see the *Inclusive Engagement* section introduction for more information.

To establish a community steering committee, project proponents should rely upon its stakeholder analysis and outreach strategy (see CCD-2. Conduct a Stakeholder Analysis and Develop a Community-Centered Outreach Plan) and ensure that steering committee members are representative and inclusive of the project area.

Oversight authorities and responsibilities should be granted to a community committee during all phases of a project's development. The community project steering committee *must be able to request information and review a project's performance to satisfy this measure*. Additional actions that a community project steering committee may take include the following:

- Directing and approving community outreach and engagement plans.
- Reviewing and approving construction plans, including any construction activity outside of normal working hours.
- Reviewing and approving proposed road detours and closures, including impacts on transit and active transportation.
- Reviewing and approving agreed-upon project benefits, local hiring provisions, and other project commitments.
- Reviewing project performance.

At the project outset, the project proponent and community steering committee should clearly define the full scope and bounds of the committee's decision-making authority. This establishes transparency and clear expectations and can help avoid the project committee devoting time to decisions and items it cannot influence.

It is also important to keep in mind that steering committees may not be the right structure for every community. Some communities may feel more comfortable with a less formalized organizational structure to discuss, engage with, and direct project progress. Other options could include informal working groups, weekly coffee meetings, or other informal meeting settings. Project proponents could also consider engaging with the community through community coalitions, anchor institutions, neighborhood associations, and collaboratives. The key is to understand what format would be the most comfortable and inclusive for the residents of each community.

Key Question: How can community members provide input and direction to the project development process?

Applicability

Applicable to all projects.

Scale and Timing

- Scale: Neighborhood/City and Project/Site
- Timing: Planning, construction, operations

Dimensions of Equity

Establishing or joining with a community project steering committee allows for greater community engagement and relationship building and can yield valuable insights from community members. Shifting decision-making power to the community is an important step to enhancing a community's degree of *self-determination* during project development.

Implementation Considerations

- Understand that statistics, indicators, and data do not tell the whole story, and that a community's lived experiences should also be part of the picture. Incorporating community members into decision-making structures is an essential step to gain these insights. Ground truth statistics and data with meaningful community engagement.
- Ensure robust and equitable outreach strategies to reach all stakeholders, especially those in marginalized and underresourced groups, and incorporate them into the community project steering committee.
- Participation in community project steering committee should not be restricted to individuals who are eligible to vote in elections—ensure that all residents are able to participate, regardless of status. Recruit participation from undocumented people, people with experiences with the criminal justice system, refugees, permanent residents, and youth.
- Compensate community steering committee members fairly.
- Follow guidance to promote accessibility when it comes to creating and running community project steering committees.
- Respect and understand a community's history in collaborating with developers and local government.
- Clearly define the scope of the committee's decision-making authority and influence.
- Establish local, issue-based implementation working groups.
- Establish conflict resolution processes to ensure a clear system to address issues. A professional facilitator can also help provide support for meetings.
- Establish a clear system for decision-making and voting in the committee (e.g., majority or two-thirds vote?), as well as other governance policies as needed.
- Establish scheduled reporting to community project steering committee on agreed-upon subject areas.
- Ensure Community Project Steering Committee is *provided with educational materials* and given adequate time to make decisions. See IE-5. Educate Community Members on Essential Topics Related to Project.

Examples

Community Steering Committee

As part of Transform Fresno's initial community engagement plan—a robust process required by the Transformative Climate Communities grant that calls for a high degree of community engagement and stakeholder involvement at all phases—the project created a 165-member community steering committee. Meetings were open to the public, and residents were encouraged to participate and become a voting member. Each member of the committee either worked, lived, or owned property in the Transform Fresno project area. The committee created and voted on the final list of projects in the Transformative Climate Communities grant—demonstrating a high degree of authority in pursuit of community-centered development. This body eventually evolved into the Outreach and Oversight Committee.

Outreach and Oversight Committee

As the Transform Fresno initiative progressed, the project formed an outreach and oversight committee to serve as an advisory body and as a resource for community collaboration and feedback. The outreach and oversight committee is charged with providing overall guidance on implementation and material changes to the projects developed under the Transform Fresno initiative. Importantly, this body provides feedback and guidance on major budget and programmatic changes. Members must have served as voting members on the original community steering committee, either work, live, or own property in the Transform Fresno Project Area, and must not have been part of a project partner organization. (Transform Fresno 2021)

Related Measures

- CCD-2. Conduct a Stakeholder Analysis and Develop a Community-Centered Outreach Plan
- IE-3. Elevate Voices of Underrepresented Groups in Project Direction and Outreach

IE-3. Elevate Voices of Underrepresented Groups in Project Direction and Outreach

Upon identifying stakeholders and researching community needs, ensure that the community project steering committee is representative of the communities the project impacts. Amplify voices of frontline workers, people of color, women, gender-expansive people, LGBTQIA+, people with disabilities, people living in poverty, and underresourced communities by empowering them with decision-making authority and incorporating their representation in a community project steering committee (or another format). Leverage community knowledge and available data to identify vulnerable and underrepresented groups in the project impact area and elevate their priorities. Act on communicated needs and concerns, and report back to the community on how their input have informed the project.

Key Question: How can project proponents help to uplift the voices of underserved, underrepresented, and marginalized community members in decision-making and project development processes?

Applicability

Applicable to all projects.

Scale and Timing

- Scale: Neighborhood/City and Project/Site
- Timing: Planning, construction, operations

Dimensions of Equity

The perspectives of underrepresented communities are often left unheard by government and land-use developers. Elevating their perspectives and acting on their concerns is an essential component of *racial justice and equity* work.

Implementation Considerations

- Robust and inclusive outreach efforts are necessary to reach, incorporate, and uplift marginalized communities.
- Research and respect the historical experiences different groups have had with local government and developers. Talk to residents and leaders to learn about community experiences during the 2008 recession or COVID-19, or with wildfires, policing, deportation, and other community traumas. Understand the history and consequences of redlining and racial covenants, if applicable.
- Avoid tokenism and do not expect *individuals* to speak on behalf of an entire group. Recognize that individuals have different perspectives.
- Use appropriate committee structure, especially for people engaged over longer periods of time. These can vary from informal to very formal. Examples include steering committees, regular outreach meetings, social media groups, and coffee klatches.

Example

Recognizing that racism is a public health crisis, King County, Washington, committed to addressing the needs of Black, brown, Indigenous, and people of color in its 2020–2021 budget and policy agenda. As part of its larger priorities, the proposed budget includes $1.6 million for a cross-functional community engagement team and a $1 million reserve for "intentional and meaningful community engagement to co-create anti-racist, pro-equity solutions *with* community" (King County 2020). It also includes $1 million to build an ongoing translation program to ensure that information is available in the six most-spoken languages in the county. To help develop policy and investments, King County also provided $200,000 to 24 organizations serving underrepresented and marginalized communities. The organizations will help to engage their communities to provide input and direction that will guide the county's priorities and anti-racist agenda.

Related Measures

- CCD-2. Conduct a Stakeholder Analysis and Develop a Community-Centered Outreach Plan
- IE-1. Prioritize Outreach to Communities of Color and Underserved Groups
- IE-2. Establish or Join a Community Project Steering Committee

- IE-4. Inclusive Community Meetings

IE-4. Inclusive Community Meetings

Community engagement should be inclusive to all people, regardless of their abilities and needs, and capture diverse values and perspectives. To increase the accessibility of community meetings, the following strategies should be considered.

- *Hold community meetings in familiar spaces*: Meet community members where they are by following a format that is appropriate for the local community and use existing community meeting spaces if possible. Here, it is important to use physical spaces and technological platforms with which community members are already familiar. Look for opportunities to become familiar with the community by attending community events and building long-term relationships with residents.
- *Make community meetings accessible via walking and public transit*: Limiting the time and resources needed to travel to community meetings can enhance participation and increase accessibility.
- *Hold community meetings during times convenient for working members of the community*: Consult with community members to find times that work best for them; weekends and evening are typically most suitable. Respect attendees' time and keep meetings productive and succinct.
- *Provide refreshments:* Meeting times may conflict with community members' opportunities to get food. Provide refreshments to help offset these inconveniences.

Photo Credit: Port of San Francisco, March 2019

- *Provide childcare:* Meeting times may be inaccessible for families, parents, and caregivers. Provide childcare to enhance engagement with these stakeholders.
- *Outreach and meeting materials are accessible:* Meeting materials should be in community members' primary language. Provide translation or interpretation services and conduct outreach in multiple languages to engage a larger group of stakeholders. Use accessible, non-technical language and provide explanations where appropriate. Ensure all materials and information are readily accessible for people with disabilities.
- *Provide monetary stipends/compensation:* Monetary compensation for attendees encourages community members' participation and can help offset costs of attending community meetings.

These recommended strategies are not definitive, and the project proponent is encouraged to create additional strategies in collaboration with community members to ensure accessible meetings suited for their local community.

Key Question: How can the project proponent ensure that all community members, regardless of their capabilities, needs, income, or other characteristics, are able to attend and fully participate in meetings?

Applicability

Applicable to all projects.

Scale and Timing

- Scale: Neighborhood/City and Project/Site
- Timing: Planning, construction, operations

Dimensions of Equity

Ensuring accessibility for community meetings enhances the project proponent's ability to reach stakeholders who are traditionally left out of land-use development and decision-making structures. This measure can help promote opportunities for *social resilience, self-determination,* and *equity* for these groups.

Implementation Considerations

- Build relationships with community members and respect community history: It is important to understand the local community's culture, values, political structures, demographic trends, history, and past engagement with the local governments and project proponents.
- Work with local leaders and skilled facilitators with established relationships with community to help organize community meetings.
- To avoid engagement fatigue, provide additional resources as identified by community members to support capacity and participation.

Example

The Neighborhood Mobility Plan for the communities of Thermal and Oasis is designed to meet the needs of residents by increasing active mobility options and enhancing transportation networks in the Eastern Coachella Valley. The plan seeks to promote accessibility, connectivity, and resilience by following a community-driven model of development working in partnership with agencies and other stakeholders. The plan includes several projects, including establishing a long-term network of bicycle and pedestrian infrastructure that connects residents to key resources. Over 70 miles of multimodal pathways—more than ten times the existing amount of pedestrian and bicycle infrastructure—is proposed.

Among other strategies, Riverside County held three community workshops to help formulate the community-based plan. In these workshops, residents identified barriers to walking, bicycling, and transit and offered suggested solutions such as design and operational changes and the development of public transit route and mode options. In addition, the County conducted a diverse set of engagement activities to increase participation opportunities, including stakeholder meetings, pop-up on-street demonstrations, and mobile research beacon deployments. At these events, residents learned about traffic devices and improvement options, and identified priority areas to site enhanced pedestrian, public transit, and bicycle infrastructure. Times and locations were chosen to maximize accessibility and community turn-out. For instance, mobile research beacon deployments occurred at a local market in Oasis on a Friday and at a church in Thermal on a Sunday. All workshops were conducted in Spanish, the primary language of residents, with English translations. Additionally, food and childcare were provided (Riverside County Department of Transportation 2018).

Related Measures

- IE-1. Prioritize Outreach to Communities of Color and Underserved Groups
- IE-3. Elevate Voices of Underrepresented Groups in Project Direction and Outreach

IE-5. Provide Education on Essential Topics Related to Project

This measure encourages project proponents to provide technical assistance and information on key issues related to the project. Aspects of a project may require a high degree of specialized or technical knowledge. Project proponents should work with CBOs and community members to identify specific topic areas for additional or supporting information. Project proponents should work with a local jurisdiction, agency, or specialized community non-profit to provide assistance and educational materials. For example, if residents have identified improving pedestrian safety and reducing traffic impacts as a priority, a local pedestrian and bicycle advocacy organization may provide education on available street design and traffic control options. Simple, non-technical language should be used to broaden reach.

Key Question: How can local jurisdictions and lead agencies help to build community capacity so that all members are equipped with the knowledge and expertise to make meaningful decisions about the project?

Applicability

This measure is recommended for projects costing $50 million or more.

Scale and Timing

- Scale: Neighborhood/City and Project/Site
- Timing: Planning, construction, operations

Dimensions of Equity

Providing educational materials to community members not only enhances their capacity for *self-determination* as it relates to making informed decisions, but also increases a community's social *resilience* and builds local capacity by investing in social capital.

Implementation Considerations

- Provide materials in community's primary language. Proponents are also encouraged to offer multilingual materials and translation and interpretation services.
- Avoid use of jargon or technical language wherever possible.
- Depending on the project, long-term educational services may be beneficial. Providing industry-specific information can ensure a community is well-informed about a certain practice or sector in the long run.

Examples

Sacramento Boards & Commission Leadership Institute

The Sacramento Boards & Commission Leadership Institute provides training and education to local community advocates from low-income communities and communities of color to help them successfully navigate the processes of local government and policymaking. The training equips community advocates with technical expertise as well as the language and cultural norms needed to participate in local boards and commissions. Topics covered include structural racism, land use and affordable housing, health equity, transportation justice, and more.

Santa Cruz Housing Conversation Kit

As a part of the City of Santa Cruz's 2017 housing community engagement efforts, the City launched a Housing Conversation Kit program, providing outreach kits to residents interested in engagement activities. The program distributed kits at its kickoff event as well as other community locations, including Toddler Time at the downtown public library, bookmobile stops in two affordable housing communities, the downtown farmers' market, a police department town hall meeting, and City Hall to YOU locations (pop-up events at different neighborhoods where citizens and city leaders and staff have the opportunity to discuss neighborhood-specific issues). Each kit included several cards with a provocative statement about housing to discuss, along with supporting information to provide a quick yet comprehensive overview of housing issues. More than 1,000 kits were distributed in both English and Spanish (City of Santa Cruz 2017).

IE-6. Conduct an Equity Assessment with Community Project Steering Committee

An equity assessment explores how a project addresses and performs across a variety of equity-related indicators. This type of assessment analyzes how a project impacts racial and ethnic groups, how it may enhance or exacerbate equity, and where positive outcomes are likely to be realized during project implementation or other phases.

Race Forward (2009) provides the following guide to conducting an equity assessment:

1. Identify stakeholders: Specify which racial/ethnic groups may be most affected by and concerned with this project.
2. Engage stakeholders: Identify and incorporate anyone missing from the engagement process. Ensure stakeholders from different racial/ethnic groups have meaningful opportunities for input and decision-making.
3. Identify and document racial inequities: Research how different racial/ethnic groups are advantaged and disadvantaged by the project. Gather qualitative and quantitative data to document such inequities.
4. Examine the causes: Critically study causes of inequities and any related trends. Explore how the project impacts or addresses such inequities.
5. Clarify the purpose: Re-examine the project goal and investigate how it might reduce or deepen disparities.
6. Consider adverse impacts: Comprehensively explore negative effects and unintended consequences related to the project. Consider approaches to prevent or minimize adverse effects.
7. Advance equitable impacts: Explore ways in which positive effects or trends can be enhanced through the project.
8. Examine alternatives or improvements: Research and recommend other strategies that might reduce racial disparities in a more meaningful manner.
9. Ensure viability and sustainability: Establish ongoing data collection systems and pursue accountability during all phases of project development.
10. Identify success indicators: Detail how success will be operationalized and measured. Specify indicators that are to be evaluated.

Working with a CBO and community members is essential to develop a legitimate and comprehensive equity assessment. Equity assessments may differ in their scope and processes depending on the project and community but developing a host of community-supported equity metrics for long-term monitoring is a necessary element.

Key Question: How will the project impact equity and related metrics in the local community? How could it improve?

Applicability

This measure is recommended for projects costing $50 million or more.

Scale and Timing

- Scale: Neighborhood/City and Project/Site
- Timing: Planning, construction, operations

Dimensions of Equity

Effective equity assessments can help a project proponent understand where racial disparities exist and how to prevent negative impacts and/or enhance *racial justice and equity*.

Implementation Considerations

- Promote community decision-making by allowing community members and CBOs to lead when conducting an equity assessment. They often have community-rooted knowledge that a project proponent might miss.
- Provide payment and other resources for community-based organizers and community members to do this work, much as a project proponent would hire a consultant; do not expect them to provide labor for free.
- Grant adequate time and resources to conduct an equity assessment early in the planning phase and dedicate resources for continuous monitoring of equity indicators throughout a project's development.

Example

As part of creating Oakland's 2030 Equitable Climate Action Plan (ECAP), the City of Oakland's 2030 ECAP Equity Facilitator Team—Oakland Climate Action Coalition, Environmental/Justice Solutions, and Blue Star Integrated Studio (the equity facilitator)—were charged with setting up an equitable community engagement process and ensuring that the final plan is equitable in its ability to help reduce disparities in Oakland. The equity facilitator reviewed draft 2030 ECAP language and developed the *Racial Equity Impact Assessment and Implementation Guide* (REIA). In the REIA, Oakland-specific data was collected to provide city staff with a framework to maximize equitable outcomes. The REIA outlines clear approaches to identifying frontline communities, avoid policy blind spots, mitigate or reverse equity gaps that limit access to resources, and monitor and evaluate equity outcomes for reporting back to frontline communities. Key recommendations issued include the following (Tobias et al. 2020):

- Create tailor-made approaches to identify frontline communities.
  - Collect and analyze existing quantitative and qualitative data to illuminate systemic root causes for disparities in climate vulnerabilities and outcomes.
  - Measure baseline conditions for frontline communities over time, noting any gaps and aspirational data needs.
  - Ground-truth assertions with frontline communities and acknowledge blind spots.
- Use Geographic Information Systems mapping to enhance data visualization and accessibility. Make use of community-based data reporting, such as data generated by frontline community members.
- Maximize equitable outcomes.
  - Invite and empower frontline communities to co-design ECAP equity implementing policies and programs.

  - Adopt recommendations from the REIA's Best Practices for Frontline Community Engagement over the 10-year implementation plan.
- Dedicate resources for monitoring and evaluation.
  - Track outcomes, relevant project locations, and where project benefits accumulate, along with demographics of beneficiaries.
  - Track benefits that reach the 25 most-burdened census tracts in Oakland as compared to the City as a whole.
- Streamline and increase communication between City departments implementing the ECAP.

Related Measures

- CCD-2. Conduct a Stakeholder Analysis and Develop a Community-Centered Outreach Plan
- A-3. Evaluate Project Performance with Community Project Steering Committee/Community Based-Organizations

Accountability (A)

Photo Credit: Port of San Francisco, July 2019

Previous process sections outlined strategies to ensure community goals and perspectives are addressed in project development. This section focuses on delivering and implementing community priorities and providing enforcement and accountability strategies for community members. Transparency is foundational in this pursuit and should be followed throughout all phases of project development. Additional measures in this section call for project proponents to create accessible avenues for community members to register their concerns. Measures also focus on empowering community members to evaluate project performance and oversee the enforcement of provisions. Ensuring community members have direct roles in overseeing project development is critical to building project legitimacy and community ownership.

Making use of open feedback loops is a helpful overarching strategy to incorporate community insight into any stage of project development and increase accountability. Open feedback loop processes can be used to build trust with community members and enhance community decision-making in project development. The description of an open feedback loop follows (Jackson et al. 2018).

1. Initial community conversation: Identify community and neighborhood priorities.
2. Co-design data collection: Determine how community members prefer to have their input collected. There are a range of options here, such as surveys and websites

where people can submit input. Co-design both the medium for data collection and the data focus areas.

3. Collect data: Collect community feedback.
4. Second community conversation: Meet with and assist community members to reach consensus on appropriate course-correcting actions in response to feedback collection.
5. Implement: Take course-correcting actions as recommended by consensus in the previous step. Keep community notified of changes and project progress. Track and document changes and results.

The feedback loop can be continued.

6. Co-design second data collection: Co-design a second round of data collection with community members. Data should assess how community members view course-correcting actions.
7. Second data collection: Ensure feedback from community members results in a representative capture of community priorities.
8. Third community conversation: Discuss with community members to determine if action was appropriate and if additional changes need to be made. Follow a similar feedback loop pattern.

Following equitable stakeholder identification and community engagement practices is essential to gather representative feedback from community members. Be sure to show community members how their feedback is influencing project development to build trust. Measures in this section provide additional strategies to ensure accountability in project development.

A-1. Use Participatory Budgeting

Participatory budgeting is a democratic process that allows community members to lead funding allocation for projects by giving them voting powers when deciding how to spend part of a budget. Participatory budgeting is typically used for public investments, and the process begins during the outset of plan and program development. By participating in the budgeting process at every stage, residents can shape project proposals in a way that brings project development closer in alignment with the lived experiences of the local community. According to the Participatory Budgeting Project, a standard participatory budgeting process empowers community members to generate ideas, vote on proposals, and fund winners by following these steps.

1. Design the process: A steering committee that represents the community creates the rules for partnership and engagement plan.
2. Brainstorm ideas: Residents share and discuss ideas for projects.
3. Develop proposals: Volunteer “budget delegates” develop the ideas into feasible proposals with technical assistance from experts.
4. Vote: Residents vote on the proposals that most serve the community’s needs.
5. Fund winning projects: The government or institution funds and implements winning ideas.

While the participatory budgeting process outlined above is commonly applied to public budgets, participatory budgeting can be applied to any budget. Overall, participatory budgeting democratizes decision-making power, enhances civic engagement, and tailors projects to community priorities.

Key Question: What would communities identify as top priorities for funding?

Applicability

Public agency-led plans and programs, grant-funded plans and programs.

Scale and Timing

- Scale: Neighborhood/City
- Timing: All

Dimensions of Equity

As a procedural equity tool, participatory budgeting opens opportunities for communities to lead investment in a variety of sectors, enhancing *community ownership* and *self-determination*. Community-led projects can achieve a range of outcomes from strengthening economic resilience to enhancing access to parks, green spaces, and community gardens. See the *Examples* section for case studies on participatory budgeting's impacts on equity.

Implementation Considerations

- Robust community engagement is essential to ensure that underrepresented communities have proper representation in a steering committee and have their voices amplified in decision-making settings.
- Participation should not be restricted to individuals who are eligible to vote in elections—ensure that all residents are able to participate, regardless of status. Recruit participation from undocumented people, people with experiences with the criminal justice system, refugees, permanent residents, and youth.
- Incorporating participatory budgeting during the earliest stages of project planning is essential to capture community priorities and foster collaboration.
- Ongoing participatory budgeting processes provide greater opportunities for community direction and collaboration.
- Private-sector proponents can make sure that their projects are aligned with community priorities identified by existing jurisdictional-scale participatory budgeting processes.
- Technical assistance should be provided to steering committee and community members; see IE-5. Educate Community Members on Essential Topics Related to Project.

- While participatory budgeting can work with any amount of money, larger allocations of funds will increase the likelihood for motivated participation and long-lasting project impact. The Participatory Budgeting Project recommends starting with at least $1 million per 100,000 residents for large municipalities, or $13 to $22 per resident. Many jurisdictions use between 1 to 15 percent of their annual budget. Smaller allocations can be just as worthwhile: in San Jose's Overfelt High School, the participatory budgeting process allocates $50,000 for 2,800 students.

Examples

Oakland

In 2017, Oakland launched its first participatory budgeting cycle that gave residents of City Council Districts 1 and 2 decision-making authority over how federal Community Development Block Grant funds should be spent over the next 2 years. A range of project proposals secured funding, such as programs to provide meals and health services to people who are unhoused and programs to improve infrastructure safety.

Vallejo

In 2012, the first city-wide participatory budgeting process in the U.S. was established in Vallejo. Vallejo stakeholders are tasked with developing project proposals and voting on projects that are sent to City Council for consideration as part of the annual City budget (City of Vallejo 2018). The participatory budgeting steering committee funds a range of projects such as educational programs and community garden improvement programs.

Resources

- The Participatory Budgeting Project provides resources and guides to how participatory budgeting can address issues such as affordable housing, transportation, climate resilience, and equity and inclusion.
- *Organizing Engagement* provides a guide to participatory budgeting.

Related Measures

- CCD-3. Conduct a Community Needs Assessment
- CCD-5. Establish a Community Benefits Agreement

A-2. Establish Incentive and Penalty Provisions for Community Priorities

Clear terms for enforcement are essential when pursuing accountability, and the use of penalties and positive incentives can help ensure project proponents deliver on commitments. These provisions apply to public projects where there is a contract between government and a developer or construction company. One example of a penalty is a clawback provision, or a recapture provision, which requires a project proponent to deliver on an agreed-upon goal, and, if they fail to do so, they must repay a certain amount of public funds. On the other hand, incentives provide additional funds (bonus) to a project proponent that meets or exceeds an agreed-upon goal. Agreed-upon goals can cover a wide range of outcomes such as the number of union jobs created, long-term capital investment, years in residence requirements, duration of construction, diverse contracting requirements, or other provisions. Incorporating these provisions into contract agreements helps ensure a project upholds obligations and provides taxpayers some protections for public funding.

Key Question: If the project proponent cannot deliver the agreed upon benefits, what redress will be available? Are the benefits being sought reflective of community priorities?

Applicability

Projects receiving public funds.

Scale and Timing

- Scale: Neighborhood/City and Project/Site
- Timing: Planning

Dimensions of Equity

Penalty and incentive provisions require a project proponent to deliver on an agreed-upon benefit, increasing accountability. Tailoring provisions to the local community's desired benefits and priorities leave this measure with the potential to impact *any/all* dimensions of equity depending on the context.

Implementation Considerations

- Define key terms, metrics, and expectations.
- Clearly establish project proponent's scope of work and define penalties and incentives for agreed-upon metrics and goals.
- Agree to a timeline for achieving agreed-upon metrics and goals.
- Incorporate into the project agreement or contract to ensure it is legally enforceable.

Examples

City of Chicago and Ford Motors

In 2000 Chicago, Illinois, and Ford Motors negotiated a $115 million incentive deal for a new Ford plant, under which Ford would develop an industrial park and the city would develop a 900-acre inter-model freight transfer center. The deal included clawback provisions that required Ford to create at least 500 full-time jobs by the end of 2006 and to maintain these jobs through 2011. Failure to meet these goals would require Ford to pay back a percentage of the financing proportionate to the percentage of jobs that were not created, and it must also repay the city for infrastructure and road improvements (Santacroce and Weber 2007).

UNIDAD and G.H. Palmer Associates

In December 2010, G. H. Palmer Associates unveiled plans to build a multi-million dollar residential and retail complex on a 9-acre site in South Central Los Angeles. The project proposal included the Lorenzo, a large private luxury housing and retail complex on the site of a hospital. Already struggling with health and environmental disparities, most local residents would not be able to afford the Lorenzo and were concerned over the replacement of a medical site with luxury housing. As a result, the UNIDAD coalition launched its Lorenzo campaign. With strong organizing from activists, community leaders, and community members, in early 2011 UNIDAD and Palmer Associates negotiated a ground-breaking fully private $9.5 million community benefits agreement. UNIDAD won several provisions, including a 7,500-square-foot community health clinic that would operate rent-free for its first 20 years, a $2.1 million contribution to the clinic, and affordable housing contributions, among others (Pastor 2015).

To help guarantee that the local community can realize the benefits won through the CBA, UNIDAD installed essential enforcement mechanisms, including $140,000 to fund CBA compliance monitoring. For instance, the CBA stipulates that if Palmer fails to meet its local hiring or at-risk hiring goals, the company would pay liquidated damages to the Community Benefits Fund at the value of $168 for each work-day by which performance fell short (Partnership for Working Families 2011). There are also similar protections for living wage provisions. UNIDAD also incorporated a crucial severability clause to bolster the entire CBA. This clause allows the remainder of the agreement to remain in full force and effect, should a court find any other term, provision, or condition of the agreement to be invalid, void, or unenforceable.

Strong legal capacity and an effective legal strategy were critical success factors for UNIDAD against a developer that had previously successfully sued the City of Los Angeles over affordable housing requirements. UNIDAD also benefited from its coalition members' seasoned history and experience organizing in South Central Los Angeles.

Related Measures

- CCD-5. Establish a Community Benefits Agreement

A-3. Evaluate Project Performance with Community Project Steering Committee/Community Based-Organizations

The project proponent should develop reports in collaboration with the community project steering community or CBO to evaluate progress at every stage of project development, centering around agreed-upon focus areas and data metrics. Essential data for a comprehensive evaluation includes indicators on demographic and geographic characteristics as well as personal experiences from communities in the project impact area.

Quantitative data and qualitative data rooted in community insight should be used to create metrics for project evaluation.

Potential Evaluation Metrics—Specific Metrics will Depend on Project Type

- Cost-benefits assessment: Compare societal benefits against anticipated costs, including not only financial costs and benefits but also costs and benefits for the environment, air quality, and public health, for example.
- Project performance:
  - Affordable housing units created.
  - Percent of contracts with local vendors and businesses from marginalized and low-income communities and communities of color.
  - Sustainability metrics and performance (e.g., support for transportation justice and air quality improvements).
  - Other agreed-upon targets, such as financial contributions to community groups (as agreed upon in a CBA for instance).
- Management:
  - Percentage of employees in management-level positions who come from local underrepresented racial and ethnic populations.
  - Percentage of employees in management-level positions who identify as women or gender-expansive people.
  - Percentage of employees in management-level positions who identify as LGBTQIA+.
- Staffing:
  - Percentage of employees in staffing positions who come from local underrepresented racial and ethnic populations.
  - Percentage of employees in staffing positions who identify as women or gender-expansive people.
  - Percentage of employees in staffing positions who identify as LGBTQIA+.
  - Percentage of employees making at minimum a living wage with benefits such as healthcare, paid time-off, and sick leave.
- Equity Assessment:
  - Analyze the distribution of positive and negative impacts associated with the project across different groups.

Potential Data Sources

- Quantitative Data:
  - Environmental and air quality data
  - Environmental justice screening tools
  - Social vulnerability screening tools
  - Census economic and social data
  - Jobs data
- Qualitative Data Collection Strategies:
  - Workshops
  - Surveys

  - Interviews
- Other:
  - Community-based participatory research methods
  - Community-level data collection

Ideally, project evaluation reports should be conducted by a third-party evaluator, working in conjunction with the community project steering committee. The topics covered in each report will vary depending on agreed-upon data metrics; however, each report should cover at minimum successful activities, takeaways, and areas for improvement.

Key Question: How has the project proponent delivered on its commitments and metrics? Where is the project exceeding targets, and where is the project falling short and in need of remedies?

Applicability

Recommended for projects with a budget of at least $250 million.

Scale and Timing

- Scale: Neighborhood/City and Project/Site
- Timing: All

Dimensions of Equity

Evaluating project performance with a community project steering committee centers the local community in determining the overall performance of a development project. This practice also helps to ensure accountability and compliance by identifying where projects fall short of their equity targets and allows project proponents to identify and act on community concerns. Furthermore, coupling project performance with accountability measures builds the local community's degree of *self-determination*.

Implementation Considerations

- Schedule reports to ensure transparency and accountability in project's operational plan.
- Ensure access to agreed-upon data metrics across a project's development.
- Coordinate project evaluation performance with accountability measures.
- Make results of project performance assessment publicly available.
- Conduct hypothetical scenarios and prepare for "what if" scenarios to enhance project adaptation.

Example

To ensure community oversight of the implementation and operations of the Kingsbridge National Ice Center, a community advisory council was created in the Kingsbridge CBA. This body is a working group of 11 community representatives with broad monitoring and decision-making authorities. For instance, the advisory council may request the project proponent to make capital improvements from funding allocated through an $8 million initial contribution fund (Partnership for Working Families 2015b).

The community advisory committee is also charged with monitoring and reviewing the developer's local hiring and training initiatives at least annually. The CBA requires that on a quarterly basis each employer notifies the community advisory council of the following.

- The number of targeted job applicants hired (those who are underemployed, unemployed, recipients of public assistance, previously incarcerated individuals, people with disabilities, veterans, young people, seniors, and members of minority groups).
- The number of independent contractors, full-time employees, and total employees employed during the prior quarter.

Employers must retain these records for at least 7 years and grant the community advisory council the authority to request and review these documents. If an employer fails to meet requirements outlined in the CBA, the council may direct an employer to take corrective action; the CBA includes a hiring corrective action plan. If an employer fails to complete the corrective action plan, the CBA grants the advisory council and each organization of the coalition the authority to seek an additional remedy available at court or in equity, including specific performance. In terms of the CBA's local procurement plan, the community advisory council also has the authority to appoint an independent monitoring agency to assess progress toward meeting targets.

Related Measures

- CCD-5. Establish a Community Benefits Agreement
- IE-6. Conduct an Equity Assessment with Community Project Steering Committee
- A-2. Establish Incentive and Penalty Provisions for Community Priorities

A-4. Establish Clear Points of Contact

A core tenet of transparency is creating reachable avenues for the public to contact project proponents. This measure calls for project proponents to establish clear, accessible hotlines, websites, social media, email, and physical locations/mailing addresses to expand contact options for the public to register complaints and ask questions. Furthermore, during early stages of project development, clear points of contact can broaden and deepen the reach of the project's community engagement strategy. Post clear information detailing channels for communication and ensure that public inquiries are responded to promptly.

Key Question: How can community members quickly and easily contact project proponents to share concerns and provide feedback?

Applicability

Applicable to all projects.

Scale and Timing

- Scale: Neighborhood/City and Project/Site
- Timing: All

Dimensions of Equity

Clear contact information can help address issues related to *public health, air pollution, walkability & bike-ability,* and boost the *social resilience* of the local community during different phases of project development.

Implementation Considerations

- Contact information and services may need to be provided in multiple languages based on demographics in the local community.
- Consider partnering with CBOs to help communicate contact information across the community.
- Follow up with community members who register complaints to evaluate how the project is addressing the concerns.

Example

Non-available.

Related Measures

- A-5. Public Disclosure of Project Commitments
- CE-3. Post a Clear, Visible Enforcement and Complaint Sign

A-5. Public Disclosure of Project Commitments

The project proponent will make publicly available all commitments to improve equity, diversity, health, climate change and resilience, and other benefits. This would apply for both projects with and without a community benefits agreement. Commitments should be included in a project proponent's agreement, other agreements, or other applicable documents, as well as maintained on a website. It should also include clear goals, performance metrics, timelines, contact information, and responsible parties. Project information, plans, potential impacts and benefits, and other information should also be included to help provide education and information. Translations should be available in the languages most widely spoken in the community.

Key Question: How can the public learn about project commitments and targets to help track and provide public monitoring on progress?

Applicability

Applicable to all projects.

Scale and Timing

- Scale: Neighborhood/City and Project/Site
- Timing: All

Dimensions of Equity

Public disclosure of a project's commitments, in simple and clear language, is important for accountability and transparency. Enhanced, widespread community knowledge and awareness of a project's commitments can help to support public monitoring, progress tracking, and oversight to ensure that commitments are met. This can lead to greater *community ownership and self-determination,* as well as greater equity and community empowerment.

Implementation Considerations

The project proponent should coordinate with the community steering committee to ensure that residents know where to find project commitments. An easily accessible location may be the website of the community benefits coalition or CBO. This should also be accompanied by updates on project progress toward metrics, as well as points of contact and channels of communication to address questions and concerns. In addition, relevant conditions of approval should also be included on the website to streamline information accessibility and transparency.

Example

Non-available.

Related Measures

- A-3. Evaluate Project Performance with Community Project Steering Committee/Community Based-Organizations
- A-4. Establish Clear Points of Contact

Outcome Measures

A new land use project can alter the existing community, for better or for worse. Wealthier, well-resourced communities have the power and capacity to influence the processes of local governments, planning commissions, and public hearings and are often able to alter or reject proposed projects based on their preferences. Due to historic and structural inequities, low-income, underresourced, and marginalized communities often lack access to these same opportunities or have their concerns ignored and overlooked. The outcome is that underresourced communities must expend more time and effort to access education, jobs, convenient mobility choices, safe homes, affordable and fresh groceries, and much more.

While structural inequities and racism should be addressed at the policy and plan level, it is possible and desirable for each individual project to strive to maximize its positive outcomes and benefits for the surrounding community. This is more so if a project is proposed for a community that experiences disproportionate air pollution, or lacks tree canopy, parks, high-quality housing, and other amenities that are critical social determinants of health. While the previous section focused on strategies to expand community participation and decision-making in the process of project development, this section recommends strategies for projects to improve their outcomes for the community. These outcomes range from the temporary – construction emissions – to long-lasting impacts, such as the provision of healthy neighborhoods, economic opportunities, inclusive community resources, green spaces, affordable housing, and protection against climate impacts. By incorporating these measures, projects can help to address chronic under-investment and help to build up healthy, livable communities throughout California.

Construction Equity (CE)

Photo Credit: Richard Masoner, February 2011

While construction is generally a temporary state, its impacts on communities can be consequential and long-lasting. The construction sector as a whole is responsible for negative impacts on community experiences with noise, access, air quality, and quality of life, especially in growing neighborhoods. Statewide, off-road vehicles—such as bulldozers, backhoes, and graders—are responsible for nearly a quarter of particulate matter (PM) emissions and a fifth of nitrous oxides (NOx) emissions from mobile diesel sources (CARB 2007). Construction also generates carbon monoxide, sulfur dioxide, fugitive dust, reactive organic gases, volatile organic compounds, and GHGs from disparate sources and activities such as on-road haul trucks, off-road heavy-duty equipment, soil disturbance, grading, asphalt paving, and the application of architectural coatings. As a result, mitigation and conditions of approval can be difficult to enforce, with multiple contractors and trades working across different construction phases. Equipment breakdowns and shortages, as well as unplanned delays, can lead to dirtier engines or dustier construction sites than originally anticipated in construction plans.

This section is intended to offer communities and lead agencies a non-exhaustive list of considerations for lessening the disruption and impacts of the construction period on communities, as well as empower communities to ensure laws are fairly enforced.

Key Indicators: While all communities can benefit from these measures, communities with sensitive populations and socioeconomic challenges would especially benefit. Relevant CalEnviroScreen indicators include: Asthma, Cardiovascular Disease, Low Birth Weight Infants, Poverty, Linguistic Isolation, Housing Burden, and Educational Attainment. Relevant Healthy Places Index indicators include: Above Poverty, Housing Habitability, Asthma Emergency Room Admissions, Coronary Heart Disease, Chronic Obstructive Pulmonary Disease, Heart Attack Emergency Room Admissions, Children, and Elderly.

Cross-Cutting Guidance

Construction sites are dynamic places, and it can be difficult for instructions and information to be disseminated to all relevant persons, or for a plan to foresee and appropriately address all issues. We recommend incorporating the following into any measures chosen.

- **Regular community check-ins**: Establishing a standard, open channel of communications is essential to allow the community to give the project proponent real-time feedback on the construction plan as it is implemented across different construction phases. The project proponent may also use the channel to communicate any changes. The feedback process should allow for additional enforcement as well as amendments to the construction plan, such as if nuisance issues become a problem. The community should be viewed as an ally in ensuring the project proceeds with minimal disruption to both the construction schedule and the community.
- **Construction equity requirements included in bid specifications and contracts**: Specific requirements, such as guaranteed bike lane access or speed limits for haul trucks, should be included in bid specifications and contracts. Contracts should also include financial penalties for non-compliance if contractors fail to adhere to policies that support public health and community priorities during construction.

CE-1. Create a Construction Plan with Community Input

This measure creates a construction plan that is responsive to community input, reflecting community concerns and priorities. The plan should include construction hours, duration, access closures, detours, noise, dust, parking, deliveries, lighting, emissions, truck routes, and other potential impacts and nuisances that may affect the community. The plan should also include agencies responsible for enforcing the plan and a point of contact in case aspects of the plan fail to be implemented or are ineffective. As noted by Jose Richard Aviles, "The construction phase tends to be the longest, most painful part of a project for the community—what would it look like for planners to build an engagement strategy for that phase?" (Aviles 2020).

Applicability

Projects involving construction.

Scale and Timing

- Scale: Project/Site
- Timing: Planning

Communities or Issues Addressed

Construction plans are often driven by what is most expedient for the project, and not necessarily what is best for the community. Plans also tend to be drafted in isolation of other nearby projects. In addition, communities may not be familiar with available enforcement options to reduce construction activity impacts. A construction plan developed jointly with the community can help to address community perspectives and concerns before any work takes place. While project proponents should research and identify any sensitive sites (such as schools, senior residences, or playgrounds) in advance, community participation can provide additional ground truthing and refinement of local needs, and express preferences in accommodating the construction process (for example, a shorter, more intensive construction process or a longer, less intensive one).

Dimensions of Equity

Community members are knowledgeable about their neighborhood and can help direct traffic and impacts away from sensitive areas, improving *public health* and minimizing disruptions to daily life. Increasing community participation in construction planning supports greater *self-determination*.

Implementation Considerations

Construction plan discussions with the community need to present meaningful choices that reflect community priorities. Jurisdiction staff and the project proponent should be thoughtful about these issues, and, especially for detours, hours, and duration, present a range of options for discussion. If only one plan is presented and community input would not change the plan, this measure cannot be utilized.

Construction plans should include the following: set construction hours, duration, access closures, detours, allowable noise, dust, parking, deliveries, lighting, emissions, truck routes, and other potential impacts and nuisances. Heavy-duty routes can be planned to avoid residential neighborhoods and sensitive land uses such as daycares, schools, and senior residences. It should also include penalties for violations.

It is strongly recommended that these outcome measures be combined with the *Process Measures* in this chapter, especially the *Inclusive Engagement* measures, so that the construction plan may be effectively discussed with the community. This is especially important for larger projects, multi-year projects, and/or projects that impact the public right-of-way (i.e., sidewalks, bicycle lanes, and streets).

In areas with nearby populations, the plan should pay particular attention to PM emissions, such as from dust and diesel exhaust. Most air districts provide guidance related to dust control and reducing diesel particulate matter.

Example

LA Metro's Purple Line extension required street closures and night work. Regular meetings with the community resulted in changes to the project practices, such as sound training, sound blankets, and moving loud work to the daytime. The construction schedule also changed during the COVID-19 pandemic, when it was deemed preferable to close Wilshire Boulevard continuously during the lockdown for a shorter duration instead of intermittent closures over a longer period.

Resources

- *Planning Healthy Places*: The Bay Area Air Quality Management District (BAAQMD) provides best management practices to reduce emissions as well as exposure for construction (pages 25–26) in this guidebook for addressing local sources of air pollutants in community planning.
- The Sacramento Metropolitan Air Quality Management District provides best management practices for various construction phases.
  - Basic Construction Emission Control Practices (Best Management Practices)
  - Enhanced Onsite Exhaust Controls
  - Enhanced Fugitive PM Dust Control Practices

CE-2. Ensure Active Modes Access During Construction

The project will maintain pedestrian, cycling, and transit access along street frontage during construction. Any pedestrian detours will not require crossing the street. Bus stop relocations should be no more than two blocks away, with clear signage and a map at the original stop directing passengers.

Applicability

Projects with construction that infringe upon the public right-of-way.

Scale and Timing

- Scale: Project/Site

- Timing: Construction

Communities or Issues Addressed

Construction projects often temporarily close sidewalks and bike lanes, forcing vulnerable users into dangerous situations in the vehicle lanes or creating burdensome detours. Closures are often not coordinated with other projects, leading to dangerous or incomplete active transportation networks. This measure seeks to maintain safety and convenience for active transportation users for the duration of construction.

Dimensions of Equity

Ensuring safe, sustainable modes maintains *active transportation/walkability and bike-ability.* Communities with low vehicle ownership rates and limited mobility options are often put into dangerous situations due to construction sites, leading to possible traffic injury or inconvenient, ill-marked detours. Maintaining transit stops also ensures *transportation access*.

Implementation Considerations

The project should ensure construction deliveries do not create safety conflicts with pedestrian and cycling paths of travel. A solid barrier should be used if the pedestrian or cycling path is in-street. Construction workers often use on-street parking, which can cause conflicts with transit stops and local business. If the project is replacing a vacant lot, look for desire paths, which indicate existing routes used by the community; these travel patterns should be taken into consideration when designing both the construction access plan as well as circulation patterns after the project is operational.

Example

For a construction project on Broadway, the City of Oakland required the placement of protective barriers for both sidewalks and bike lanes rerouted into the street (Rudick 2020). Unlike in many construction projects, the contractors provided K-rail to the left of the bike lane, providing cyclists a physical barrier from vehicle traffic. Additional dividers for the rerouted walking path protected pedestrians from both bicycles and construction equipment, providing greater safety for users.

The City and County of San Francisco provides clear guidance on sidewalk closures, transit station access, and bike lane access during construction. Contractors are required to provide, at minimum, a 4-foot wide clear path of travel on any sidewalk at all times, and any projects that cannot do so requires a special permit (San Francisco Municipal Transportation Agency 2012). If pedestrians must be routed into the parking lanes, a barrier must be used. San Francisco also requires that construction projects not block or impede any transit operations or movements into transit stops. Contractors may submit a request for a temporary bus stop relocation, and they must provide signs and may be required to install temporary benches.

CE-3. Post a Clear, Visible Enforcement and Complaint Sign

The project will have conspicuous signs at the fence line listing hotline numbers for potential nuisance complaints and agency responsible for enforcement. The sign should be in clear, plain language (example: Dust problems? – Call Air District at xxx, Construction before 6am or after 8pm? – Call City at xxx, etc.).

Applicability

Projects with construction.

Scale and Timing

- Scale: Project/Site
- Timing: Construction

Communities or Issues Addressed

Enforcement of nuisance issues—which includes excessive dust, noise, light, pollution, or other inconvenience or annoyance impacting other people—tend to be complaint-based. Ensuring that all communities have knowledge of expected parameters of construction and access to reporting resources is necessary to minimize disruption and harm during the construction process.

Dimensions of Equity

Providing clear contact information and a means of solving a problem related to construction can increase *transparency* and *accountability* and increase community members' positive interactions with and trust in local government.

Implementation Considerations

Provide translations in communities where other languages are widely spoken, which may be reflected in CalEnviroScreen's Linguistic Isolation indicator and the American Community Survey and should be reviewed with community members during construction plan development, as many languages are not represented in surveys. Larger projects, or projects on multiple street frontages, will need multiple signs. Include multiple methods of contact for each enforcing agency, such as phone, email, social media, or website.

Example

The City of Los Angeles provides a list of good neighbor construction practices, containing requirements regarding street access, street closures, noise, debris and cleanliness, and allowed construction hours. The City also provides the agency responsible for enforcement for each requirement (Los Angeles Department of Building and Safety 2015).

CE-4. Portable Indoor Air Filtration for Nearby Residents During Construction

The project proponent will provide indoor air filtration for the duration of the construction project to potentially impacted residents and businesses. The project may either upgrade or equip heating, ventilation, and air conditioning (HVAC) systems to use MERV-13 or higher air filters capable of at least 0.5 air exchanges per hour, or provide California-certified portable air-cleaning devices. Residential users should be provided with at least one air-cleaning device per occupied bedroom, with sufficient air flow to complete at least two air exchanges per hour. Residents will be trained on their use, optimal placement, and are encouraged to move the air-cleaning device(s) to where they will be breathing. High-efficiency, appropriately sized portable air-cleaning devices can remove 30 to 60 percent of air particles, and in some cases up to 90 percent (CARB 2017).

Applicability

- Projects using diesel on-road trucks with a gross vehicle weight rating over 14,000 pounds using an exemption from the California Air Resources Board's (CARB) Truck and Bus regulation (such as Low-Use Exemption or a Governor's Emergency Order).
- Projects in locations with harmful soils.
- Projects where construction activity is likely to cause dust to impact adjacent or nearby occupied land uses.
- Projects involving demolition or extensive site preparation.

Scale and Timing

- Scale: Project/Site
- Timing: Construction

Communities or Issues Addressed

Even with carefully selected measures, construction activity can still impact nearby residents due to the amount of equipment involved, especially for large projects or in areas where residents are downwind of construction. Construction emissions can also have a greater impact on low-income residents, who are more likely to live in older homes or apartments, with more air leakages that leave them exposed to outdoor air quality. Renters, who may be more likely to be low income, also have less control over their building conditions or access to the HVAC system. This measure acts as an additional line of protection, filtering dust, diesel exhaust, and other PM generated by the project. Consider using this measure in areas with particularly harmful soils, such as areas with naturally occurring asbestos, lead contamination, or Valley Fever spores.

Dimensions of Equity

Providing indoor air filtration to impacted residents improves *public health* and can also mitigate indoor *air quality* impacts.

Implementation Considerations

This measure requires windows to be closed to be effective, so may be less effective in locations with mild climates or for buildings without HVAC systems. Resident training is key for success; all training and educational materials should be available in multiple languages based on community input and available data. Replacement filters need to be provided in sufficient quantities to last through the construction phase. The project proponent should also consider providing assistance throughout the construction phase with maintenance and filter replacements. Air filters may increase utility bills for residents, so a stipend may be appropriate.

This measure is not a replacement for emission and nuisance-control practices and should complement local and state regulations, mitigation measures, and conditions of approval.

Example

For construction projects built under the UC Davis Sacramento Campus 2020 Long Range Development Plan update, the prime construction contractor will implement air pollution exposure reduction measures for nearby residents in areas where projected cancer risks exceed 10 per million. UC Davis will provide financial assistance for residents to purchase up to two MERV-15 air filters per year or a portable home air cleaner if the home lacks a compatible HVAC system. (UC Davis 2020.)

Resources

- U.S. Environmental Protection Agency's (U.S. EPA's) *Guide to Air Cleaners in the Home 2nd Edition*
- CARB's List of CARB-Certified Air Cleaning Devices
- *Planning Healthy Places*: This resource from BAAQMD provides guidance on air filtration use to reduce exposure for sensitive receptors.

CE-5. Air Quality Monitoring and Response Plan

The project proponent will commit to fence-line monitoring of air pollution during the construction phase and will take corrective action to modify or limit construction activities if pollutant levels exceed the ambient air quality standards. Community input is critical to determine preferred response and redress actions in advance, so that when air quality standards are exceeded, the project proponent can immediately implement corrective actions. Potential redress actions include eliminating idling of diesel-powered equipment; suspension of excavation, grading, and demolition activities when wind speeds or the daily air quality index (AQI) exceeds a certain threshold; limiting simultaneous occurrence of multiple construction phases; lowering speed limits; adding more freeboard in haul trucks; and increasing watering of exposed surfaces, such as unpaved access roads or graded areas, ideally with recycled or reclaimed water.

Applicability

- Locations with harmful soils near other occupied land uses.
- Construction includes demolition, simultaneous occurrence of two or more construction phases, extensive site preparation, or extensive material transport.

Scale and Timing

- Scale: Project/Site
- Timing: Construction

Communities or Issues Addressed

This measure may be particularly applicable in communities already disproportionately burdened by air pollution, as based on their indicators in CalEnviroScreen or the Healthy Places Index. Some projects, such as landfill remediation, necessitate disturbing soils that may put nearby receptors at risk.

Dimensions of Equity

Continued air monitoring at a construction site, particularly if the data is available in real-time to the public, can increase *transparency* and *accountability* for land use development projects, while also supporting *public health*.

Implementation Considerations

An air quality monitoring plan should consider target emissions for monitoring as well as meteorological data. The plan should ideally also include a publicly accessible platform to share real-time as well as historical air quality data and connect to other local air quality monitoring efforts. If real-time data will not be available, the plan should work with the community to determine preferred reporting intervals and delivery formats. Multiple monitors may be required for appropriate coverage. Monitoring should begin before construction activities start to understand baseline air pollutant levels. Once construction begins, monitoring should be active both during and outside of core construction hours to establish a control for comparison. The plan should also set action levels at which construction activities are altered or limited. Community input (see *Inclusive Engagement*) and consultation with the local air district are necessary to make these determinations.

Example

City of Folsom Clean Closure Work Plan: Corporation Yard Landfill

The City of Folsom conducted a clean closure (removal of waste to another location) of a 4-acre landfill in their corporation yard. The environmental document required that an air monitoring specialist, independent of the contractor, would implement a monitoring program for methane, total VOCs, hydrogen sulfide, dust, metals, asbestos, and meteorological parameters during construction. The plan included actions that the contractor would take if air quality levels degraded below appropriate levels.

BNSF Sangamon Right-of-Way Air Monitoring Plan

BNSF (a railroad) conducted removal activities along South Sangamon Street in the City of Chicago, Illinois. An Air Quality Monitoring Plan was created to monitor for fugitive dust from project activities. The plan committed to real-time air monitoring and the implementation of additional fugitive dust mitigation measures if PM2.5 concentrations exceeded set action levels.

Resources

- CARB's Community Air Protection program includes resources on how to develop and implement a community-driven air monitoring program.
- *Planning Healthy Places* and *Warehouse Projects and Best Practices and Mitigation Measures to Comply with the California Environmental Quality Act*: These resources, from BAAQMD and the Office of the Attorney General, respectively, contain construction best practices and example construction ordinances that can be consulted for potential response actions if air quality standards are exceeded.

CE-6. Provide Funds to Businesses Impacted by Construction Activities

The project will provide financial assistance to businesses impacted by construction activities and consequently see a decline in revenue. Financial assistance may be limited to fixed operating expenses, such as payroll, rent or mortgage, utilities, and insurance.

Applicability

Projects where access to businesses are restricted during construction—typically, public transportation projects.

Scale and Timing

- Scale: Project/Site
- Timing: Construction

Communities or Issues Addressed

Small and local businesses typically have less available operating capital than their national counterparts and are typically less able to withstand temporary loss-of-business due to construction impacts. Many small businesses also have limited ability to transition to online sales or to increase marketing as a response strategy to construction disruptions.

Dimensions of Equity

Small and local businesses provide community identity, gathering places, and services. Small businesses also return more money into the local economy. Keeping small businesses afloat during the construction period helps to ensure the new project will benefit from an intact neighborhood and supports local *economic resilience* with the continuity of employment opportunities.

Implementation Considerations

Funds can be provided to businesses based on a percentage of their losses and may be capped at a certain amount. Some small businesses may not have sufficient record-keeping to demonstrate years of sales or income, so strict documentation requirements may exclude some impacted businesses.

Example

The Los Angeles Metro operates a Business Interruption Fund that provides financial assistance to small businesses located in areas impacted by transit construction projects. The financial assistance covers fixed operating expenses such as utilities, rent or mortgage, payroll, insurance, and other documented expenses. Funding is limited to $50,000 or 60 percent of operating expenses, whichever is less. Businesses must have at least 2 years of continuous operating history, be solvent, provide financial records, and be in good standing with all tax and licensing authorities. Information is available in English, Spanish, Korean and Japanese, based on the demographics of the construction location. Six months after grant award, 94 percent of recipient businesses remained open, and 1 year after receiving the grant, 85 percent of businesses remained open.

Public Health and Air Quality (PH)

As established by extensive research and residents' lived experiences, low-income communities and communities of color are disproportionately burdened by air pollution, with lasting health impacts.

Marginalized communities are more likely to be located near highways, railyards, warehouses, ports, oil and gas facilities, and other industrial sources—or rather, these industrial facilities are more likely to be placed in and near communities of color. Over half (57 percent) of facilities covered by California's cap and trade program are in or within a half mile of disadvantaged communities, including 15 out of 20 refineries, 5 out of 9 cement plants, and 65 percent of other combustion sources – including facilities that produce a range of toxic chemicals (OEHHA 2017). Across the U.S., Black communities are exposed to 1.5 times more particulate matter 2.5 (PM2.5) than the population average, and communities of color 1.3 times more (Mikati et al. 2018). Communities of color with higher levels of racial isolation also experience higher levels of ozone and PM2.5 (Bravo et al 2016), as well as exposure to airborne toxics and its associated cancer risks (Morello-Frosch and Jesdale 2006). The severity of discrimination appears even at the particle level: Black, Latinx, Asian, and low-income populations were up to 150 percent more exposed to toxic components of PM2.5, including aluminum, sulfates, vanadium, nickel, nitrates, and zinc, than white populations—even in areas that meet federal air quality standards (Bell and Ebisu 2012).

Toxic air outside the home translates into toxic air inside the home. Low-income residents and residents of color are more likely to live in homes with elevated indoor levels of NOx, PM2.5, and compounds such as benzene, chlorinated chemicals, and lead as result of aging and dilapidated housing conditions, air leakages, inadequate or non-existent ventilation systems, smaller living spaces, and other challenges (Adamkiewicz 2011). Moreover, poor housing conditions and the lack of ventilation/HVAC systems can translate into exposure to hazardous levels of wildfire smoke – an increasingly urgent issue as California endures catastrophic wildfires year after year. Wildfire smoke can be up to 10 times more harmful to human health than ambient PM2.5, leading to significant increases in hospital admissions (Aguilera 2021). Low-income and outdoor workers, such as in the agricultural and construction industries, especially undocumented people, are particularly at risk of wildfire smoke and are often overlooked by local, state, and federal disaster response and relief programs.

A lifetime of breathing polluted air, coupled with systemic disparities in healthcare, transportation, housing, education, access barriers, green spaces, and resource availability, has consequences. Long-term exposure to PM2.5 is far deadlier – up to three times more – for Black, Asian, Latinx, and low-income populations than the general population (Di 2017). Race matters more than wealth: Even at higher income levels, Black people had higher risks of deaths from PM2.5 than the general population or lower-income white people, suggesting that systematic racism in the siting of polluting sources is at play (Di 2017). Extreme heat and the climate crisis will only make matters worse, as mortalities associated with PM2.5 increases with warmer temperatures (Kioumourtzoglou et al. 2016). Extreme heat itself is an environmental justice issue: low-income communities and communities of color are more likely to lack tree canopy, parks, and green spaces, and are more likely to experience urban heat island (UHI) effects and extreme heat. Heat, in turn, is linked to heat strokes and potential fatalities, cardiac arrests, and other health impacts.

These tragic disparities have magnified and exacerbated the impact of COVID-19 on marginalized and underserved communities. A nationwide study found that for every 1 microgram per cubic meter increase in long-term PM2.5 exposure, COVID-19 fatality rates increase by 11 percent (Wu 2020). Black, Latinx, and Native persons are hospitalized at three to four times the rate of white persons and have fatality rates about 2 to 2.5 times greater (CDC 2021). Decades of segregation and structural racism have resulted in poverty, pollution exposure, underserved neighborhoods, and a lack of access to healthy food, healthcare, and green spaces—all of which have left communities of color at far greater risk to COVID-19 and other health and environmental disasters (Pirtle 2020).

Recent research finds that inequities in PM2.5 exposure are increasing—not decreasing—in the U.S. *despite* the progress made in stricter vehicle emission standards, air pollution regulations, and cleaner electricity production. From 2000 to 2016, predominantly white populations saw improvements in air quality, compared to no improvements in predominantly Black communities (Jbaily 2020). While California's cap-and-trade program has helped to reduce the gap in air pollution exposure between disadvantaged communities and the rest of the state, it has not completely eliminated this gap, which has returned to near-2008 levels by 2017 (Hernandez-Cortes and Meng 2020). This suggests that unless equity and environmental justice are intentionally centered in policies and programs, frontline communities will not see the co-benefits of cleaner air and improved public health because of GHG reduction programs. As such, it is critical that new development in California attempts to implement measures to improve public health and air quality outcomes for vulnerable and underserved communities.

Key Indicators: These measures are relevant to communities that experience elevated air quality impacts, AB 617 communities, and communities with greater socioeconomic vulnerabilities. Relevant CalEnviroScreen indicators include PM2.5, Diesel PM, Ozone, Asthma, Cardiovascular Disease, Low-Birth Weight, Poverty, and Unemployment. Relevant Healthy Places Index indicators include Above Poverty Level, Clean Air–Diesel PM, Clean Air–Ozone, Clean Air–PM2.5, Asthma, Asthma–Emergency Room Admissions, Coronary Heart Disease, Chronic Obstructive Pulmonary Disease, Heart Attack Emergency Room Admissions, Active Transportation, Obesity, Children, Elderly, Outdoor Workers, and Race/Ethnicity.

Cross-Cutting Guidance

Most measures in this section focus on urban greening, which begins a multi-generational commitment of maintenance and care. Often if a tree becomes a problem or gets in the way, it is removed. As such, it is critical that the right planting goes in the right location with the right support and protection. It is recommended the user incorporate the following into PH-1 and 2.

- **Input from the community**: Community preference and concerns must be addressed for the plantings to be used and loved. Sight lines, access, security, lighting, allergens, odors, droppings, shade, and community character should be discussed.
- **Input from jurisdiction and agency partners**: To forestall potential conflicts, utilities, Caltrans, and local departments (e.g., transportation, fire, parks, planning, and urban forestry) should have access to and input on landscaping and greening plans. The landscape plan must also be cross-checked with signage and billboards, as trees will likely be felled if they encroach upon the view shed. Appropriate space must be given to prevent sidewalk and pavement buckling, as well as allowing the plantings to mature to their full potential.

- **Maintenance and redress**: There must be clear ownership of the maintenance responsibility, understanding of maintenance expectations, and appropriate redress if the vegetation fails. This can include replanting, adding high-albedo coating to unshaded pavements, providing portable air filtration devices, or other measures.

It should also be noted that measures addressing public health are not limited to this section. There are substantive public health benefits from many GHG mitigation measures in Chapter 3, chiefly via air pollution reduction, such as through building electrification, building decarbonization, renewable energy generation, and reductions in vehicle emissions. Critically, however, the health benefits associated with increased physical activity as a result of active transportation overshadow the health benefits associated with improved air quality from reduced or cleaner vehicle emissions (Maizlish et al. 2017). Physical inactivity is one of the leading factors in cardiovascular diseases, such as heart disease, diabetes, and cancer. Increasing active transportation to just 20 minutes per day could save over 8,000 lives annually, improve health, and reduce years of life lost and disability (Maizlish 2016). What's more, historically underserved and marginalized communities are often disproportionately burdened by chronic disease as a result of structural inequities and often lack access to sidewalks, bike lanes, transit service, and parks. Thus, measures that facilitate Californians to walk, bike, and ride transit as part of their daily routine should be prioritized to improve public health and reduce health disparities. To see measures that support active transportation, please turn to Chapter 4.

PH-1. Establish Vegetative Barriers to Reduce Pollution Exposure

If designed, planted, and maintained correctly, a thick barrier of trees, bushes, hedges, and/or shrubbery can decrease air pollution and protect public health. Vegetative barriers achieve this by intercepting PM, as well as taking up ozone, NOx, and other air pollutants through their leaves. Well-designed roadside vegetation barriers can reduce downwind particulate matter by as much as 50 percent, black carbon by 27 percent, and NOx by 20 percent (Deshmukh 2018). To maximize effectiveness, vegetative barriers can be combined with a solid wall barrier (Tong 2015); however, use of impenetrable walls should be considered carefully to avoid creating barriers that discourage walking or biking to destinations in or near a neighborhood.

Applicability

Projects within 1,000 feet of the following:

- Major roads such as highways, freeways, or arterials.
- Major stationary sources as defined by the local air district.
- Railyards and railways.
- Locations with high volume of diesel trucks, or other sources of pollution.

Scale and Timing

- Neighborhood/City and Project/Site
- Construction and operations

Communities or Issues Addressed

This measure is particularly applicable for AB 617 communities and other communities disproportionately burdened by poor air quality. Because it takes time for vehicle fleets to become cleaner, vegetative barriers can reduce air pollution for projects that are located near busy roads and freeways. They can also help to block pollution from new land uses that will be a source of emissions and provide protection for projects that serve sensitive users (e.g., daycares or senior residences).

Dimensions of Equity

In addition to improving *air quality*, vegetative barriers can help to reduce noise and beautify the environment. In addition, they can help to reduce the UHI effect through evapotranspiration and shading, contributing to *climate resilience*. If native species are selected, they can also support local biodiversity and habitat. Finally, vegetative barriers can help to reduce stormwater and improve groundwater infiltration.

Implementation Considerations

It is critical to properly design and plant vegetative barriers to effectively block and uptake air pollution. Vegetative barriers should be tall, thick, and have sufficient density of leaves to block air flow (Baldauf 2017). U.S. EPA has developed minimum recommendations for constructing roadside vegetation barriers to improve near-road air quality, including ensuring a minimum thickness of 10 meters (33 feet); for examples of vegetative roadside barriers meeting these minimum recommendations, please see illustrations on pages 13-16 in the Sacramento Metropolitan Air Quality Management District's *Landscaping Guidance for Improving Air Quality Near Roadways*.

Vegetative barriers should not seasonally shed leaves or have other gaps – vegetative barriers that are porous or have large gaps can result in unchanged or higher levels of air pollution downstream. Studies suggest that plants with small leaves, complex leaf shapes, and/or rough leaf surfaces are the most effective at air pollution reduction (Barwise and Kumar 2020). In addition, regular maintenance, pruning, and care is important to keep the vegetative barrier alive, and these costs should be factored in during the design phase. If possible, drought-tolerant or native species should be selected.

While there are ranked lists of species most effective at air pollutant removal (Yang 2015), the project proponent should consult with the regional urban forester, local tree foundations, master gardeners, CBOs, neighborhood associations, and other groups to select plant varieties preferred by residents and suitable to the local climate. Species selection should not include tree species that emit high amounts of reactive organic gases or allergenic pollen to avoid additional, substantial burdens for nearby residents, especially those with asthma or other respiratory conditions.

Vegetative barriers adjacent to freeways can consider the inclusion of a solid wall barrier or sound wall, but a wall along arterial and collector roads may create barriers to walking and biking around the community, reducing network connectivity.

Inclusive community engagement is a critical part of this measure: community participation can determine preferences and priorities around preferred species, barrier design, and barrier placement. Consult the *Community-Centered Development* and *Inclusive Engagement* sections for measures on understanding local priorities and community outreach.

Example

Approved in 2014, McKinley Village is a 328-unit residential development in the City of Sacramento, closely bounded by an interstate highway to the north and the Union Pacific Railroad tracks to the south. Project residents are located within 500 feet of the highway—CARB's recommended minimum distance for siting new sensitive receptors—which averages 159,000 vehicles per day (City of Sacramento 2014). To reduce air quality impacts, the project includes a 30-foot-wide barrier consisting of a sound wall with landscaping adjacent to the freeway and an 8-foot-wide landscape buffer adjacent to the railroad tracks (City of Sacramento 2013). The vegetation for both barriers includes a mix of evergreen, deciduous (which are *not* recommended for vegetative barriers), and coniferous trees such as pines and redwoods. When initially planted, the vegetative barrier was incomplete due to temporary signage advertising the sale of homes.

Resources

- CARB: *Strategies to Reduce Air Pollution Exposure Near High-Volume Roadways*
- Sacramento Metropolitan Air Quality Management District: *Landscaping Guidance for Improving Air Quality Near Roadways*
- U.S. EPA: *Recommendations for Constructing Roadside Vegetation Barriers to Improve Near-Road Air Quality*

PH-2. Increase Urban Tree Canopy and Green Spaces

The project will go above and beyond local requirements and standards and plant additional trees along streets and public spaces in underserved and low-income communities, which disproportionately lack tree canopy, parks, and green spaces in comparison to wealthier, whiter neighborhoods. To achieve equity in tree canopy, additional tree planting should be focused on neighborhoods with the fewest trees. Trees are estimated to remove over 1 million tons of air pollution in California in 2010, with associated health benefits of $446 million dollars in terms of avoided health costs (Nowak 2014). Yet with the disparity in urban tree canopy between communities, these benefits fail to accrue to low-income residents and people of color, who disproportionately experience the impacts from respiratory conditions, hospital admissions and emergency room visits, lost workdays, and fatalities. By increasing tree canopy and park spaces in underserved communities, the project can contribute to reductions in air pollution and extreme heat, while creating a more inviting environment for walking and biking, improving all dimensions of public health.

Numerous studies have documented the association between income, race, and tree canopy coverage, which in turn leads to inequities in air pollution and extreme heat exposure. Formerly redlined communities have nearly 50 percent less tree canopy than formerly greenlined communities (Locke et al. 2021). Across the U.S., 94 percent of formerly redlined communities are hotter than their non-redlined neighbors, by as much as 12.6 degrees Fahrenheit (°F) in some cases (Hoffman et al. 2020). An analysis of heat disparities in urban California found a 4.7°F difference between the poorest 10 percent of neighborhoods and the wealthiest 10 percent, with the greatest difference of 6 to 7 °F in Los Angeles, the Inland Empire, Palm Springs, and Latinx communities (Dialesandro 2021). The disparity in tree canopy and green spaces leads to higher fatalities during heat waves, exacerbated cardiovascular conditions, higher energy bills, poorer air quality, lower home values, and other impacts.

Applicability

Applicable to all projects.

Scale and Timing

- Neighborhood/City and Project/Site
- Trees can be established during the construction or operations phase but should be determined in the planning stage in conjunction with the community.
- The environmental review phase should include opportunities to mitigate noise/air quality impacts through the installation of trees.

Communities or Issues Addressed

This measure should be prioritized for neighborhoods that lack tree canopy, or projects that are located near busy roads, freeways, industrial land uses, and other sources of pollution. Projects located in communities with a high percentage of impervious or paved surfaces should also consider increasing tree canopy, green spaces, greenways, and other green infrastructure.

Dimensions of Equity

Trees improve *air quality* by removing PM, NOx, ozone, and sulfur dioxides, with the greatest health and environmental benefits from PM reduction. By reducing air pollutant concentrations in outside air, trees in turn also reduce indoor air pollution, with trees planted outside the home linked with a 50 percent or more reduction in indoor PM (Maher 2013). Similarly, urban trees, as well as cooler air temperatures, have also been linked with improved academic performance in schools – a benefit that could extend to future *economic resilience* (Kuo et al. 2018; Park 2018). Indeed, trees can cool cities by up to 10°F, with the greatest cooling occurring when canopy cover exceeds 40 percent (Ziter 2019). This cooling effect means that homes in neighborhoods with high tree canopy levels can save on air-conditioning bills during the summer—by up to 30 percent in Sacramento as one example (Akbari 1997).

In addition, urban trees and parks can help to create a more comfortable environment for walking, biking, and exercise, improving people's overall *health* and encouraging *active transportation.* Urban greening can also help provide pleasant public spaces for community residents to meet and socialize. Public spaces and strong neighborhood connections have been linked with greater *social resilience* and decreased fatalities during the 1995 Chicago heat wave as documented by Eric Klinenberg in *Heat Wave: A Social Autopsy of Disaster in Chicago*. By listening to community members on desired spaces for greening, tree planting can support *community ownership* of their neighborhood and built environment. Finally, trees, parks, and green infrastructure can help to enhance overall *climate resilience,* through contributing to groundwater recharge, stormwater absorption, and biodiversity support.

Implementation Considerations

Community input and preferences should be centered in any tree planting efforts. Because an increase in tree canopy is associated with small increases in property value (Donovan 2021), gentrification is a concern, and CBOs and residents should have full input and decision-making authority on tree selection, siting, and maintenance. The project should work with neighborhood associations, CBOs, and other stakeholders throughout the process. Local tree foundations and forestry organizations can provide advice about species selection, but generally a diversity of species will be more resilient against pests, invasive species, and climate change. Heat- and drought-tolerant trees are more likely to be adaptable to future climate conditions and ensure long-term survivability. If urban cooling is a goal, growth rate and canopy size should be considered. Finally, allergen and biogenic volatile organic compound production are additional factors to consider.

Example

On June 17, 2021, the City of San Francisco broke ground on the India Basin Shoreline Park. The project will create a park that directly serves the priorities of San Francisco's historically overlooked and underserved southeast communities by remediating an abandoned industrial site, which will then be combined with two existing open space areas. Upon completion, the 10-acre waterfront park will offer the 35,000 nearby residents a restored shoreline, accessible, expanded park space, gardens, natural habitats, walkways, a public plaza for local events and markets, and an ecological education area. The park is led by a collaborative partnership with the Bayview Hunters Point community, the A. Philip Randolph Institute, the Trust for Public Land, and the San Francisco Parks Alliance (City and County of San Francisco Office of the Mayor 2021).

Resources

- Tree Equity Score: Based on the existing tree canopy cover, population, income, unemployment, race, age, and temperature, this tool identifies the amount of tree canopy cover needed for urbanized census tracts to reach tree equity.
- Vibrant Cities Lab: A wealth of resources, research, toolkits, and case studies related to urban forestry and all its accompanying benefits.

Related Measures

- Inclusive Engagement (IE) measures

PH-3. Highly Rated Air Filtration

This measure requires a project proponent to install MERV-13 or higher-rated air filtration systems, and for vulnerable populations such as schools and nursing homes, MERV-14 or higher air filters. Highly rated air filters clean the air that enters the building, reducing resident exposure to air pollution and wildfire smoke. Independent of efforts to reduce air pollution sources, filters can help protect people from the air pollution that already exists, removing 50 to 99 percent of particles (CARB 2017). In addition, they can reduce air pollution generated indoors (e.g., from cooking, candles, consumer products, or smoking) as well as allergens that trigger respiratory ailments.

This measure requires the project be constructed with an HVAC system that accepts MERV-13/14 or higher filters, and has a permanent label affixed to the HVAC system that indicates a MERV-13/14 or higher filter must be used as a condition of approval for the project.

Applicability

Applicable to all projects.

Scale and Timing

- Scale: Project/Site
- Timing: Project construction, but filters must be changed regularly during operations

Communities or Issues Addressed

Low-income and underserved communities are often disproportionately impacted by particulate pollution and toxic air contaminants. Indoor air filtration can reduce impacts from these pollutants. In addition, seasonal issues, such as wildfire smoke, wood-burning appliance use, dust storms or certain airborne allergens, can be reduced inside, giving respite to breathers. This is especially important in communities without regular access to health care providers, and for projects located near major sources of pollution such as highways, trucking routes, railyards and railroads, or industrial sources.

Dimensions of Equity

While a combination of regulations and lower-emissions technology (e.g., renewable energy or electric vehicles) is gradually lowering air pollution levels throughout California, air filtration represents an immediate improvement to indoor *air quality* and can address allergen issues as well. This is especially important in communities burdened with high levels of air pollutants. With wildfires increasing across California, air filtration is also a *climate resilience* solution, and may become necessary in areas where air pollution has not historically been an issue. While all properties can benefit from cleaner indoor air, projects in places with high traffic and high PM can especially benefit from this measure.

Implementation Considerations

Filters work best when windows are closed, so this measure will be less effective in mild climates where windows are kept open most of the year, or in places without air conditioning. Education is necessary to ensure effective use.

While filters typically need replacing at least once each year, major wildfire events or location in high-use areas, such as near major roads, may necessitate more frequent replacement.

Because the filters are only effective when the HVAC fan is engaged, energy bills may be higher than normal. Seek to use the most efficient and durable systems. Operating the HVAC system on fan-only mode, instead of with air-conditioning, will have lower energy costs.

Example

Non-applicable.

Resources

- U.S. EPA: *Guide to Air Cleaners in the Home 2nd Edition*
- CARB: List of CARB-Certified Air Cleaning Devices

Related Measures

- CE-4. Portable Indoor Air Filtration for Nearby Residents During Construction

PH-4. Create Healthful, Sustainable Indoor Spaces

People spend nearly 90 percent of their time indoors, making indoor air quality and chemical exposure critical to human health. Yet indoor air quality can be two to five times worse than outdoor air quality (U.S. EPA n.d.). Building materials and interior furnishings are the main source of indoor air pollutants and other toxics. Paints, flooring, composite and manufactured wood, fire retardants, insulation, adhesives, binders, sealants, and other materials can off-gas and release a wide range of chemicals hazardous to human health. These include volatile organic compounds (VOCs) – including formaldehydes – benzene, xylene, styrene, per- and poly-fluorinated chemicals (PFCs, such as polyfluoroalkyl substances), and fibers. The U.S. EPA estimates that VOC levels can be as much as ten times higher indoors than they are outside (U.S. EPA n.d.).

In addition to reducing chemical exposure, ventilation is also a key component of indoor air quality. As building energy efficiency improves, the tightness of the envelope seal also improves, potentially creating stagnant air inside, which can result in higher indoor humidity and concentrations of carbon dioxide, VOCs, and other chemicals.

This measure calls for the project to:

- Use certified non-toxic, low-toxic, and/or low-emissions building materials, wherever feasible, including in paints, sealants, finishes, adhesive products, carpets, insulation, flooring, flooring materials, wood products, furniture, and more.
- Include operable windows and provide training and guidance on the proper operation and maintenance of ventilation systems to optimize indoor air quality. Ensure good ventilation when paints, sealants, adhesives, and similar products are being applied.
- Projects with an operational component should use low- or non-toxic cleaners and other chemicals, which can benefit the health of building staff and occupants.

Some material certification systems undertake a lifecycle analysis of the environmental footprint of building materials and products. Thus, building materials should ideally be sustainable, natural, or made of recycled or renewable materials, which are also likely to have less impact on people and the environment during the manufacturing process. If possible, materials and products should be sourced locally.

Applicability

All

Scale and Timing

- Scale: Neighborhood/City and Project/Site
- Timing: Planning, construction, and/or operations

Communities or Issues Addressed

Using non- or low-toxic or low-emissions building materials can improve public health for both building occupants as well as construction workers. People with respiratory conditions or existing health conditions, seniors, and children are particularly vulnerable.

VOCs are linked with a range of short- and long-term health effects, ranging from irritation of the eyes, nose, and throat; to nausea, headaches, and loss of coordination; to long-term damage to the liver, kidneys, and central nervous system. As a carcinogen, formaldehyde is a particular VOC of concern and can be found in a range of composite wood products. Other indoor air contaminants, such as toluenes and xylenes, which are emitted from laminated lumber products, have high levels of toxicity to the liver, blood, and nervous systems (Khoshnava et al. 2020). In addition, PFCs are commonly used in building materials such as carpets and furniture to repel stains, water, and corrosion, but they are linked to health impacts such as high cholesterol, testicular and kidney cancer, reduced vaccine effectiveness, and thyroid disease (Fletcher et al. n.d.).

Used in pipes, flooring, and other building materials, polyvinyl chloride (PVC) generates high levels of dioxins and vinyl chloride throughout its production and disposal cycle and is a critical environmental justice issue: Most of the United States' PVC manufacturing plants – including the world's largest – are located in low-income Black communities in Texas and Louisiana, including Louisiana's Cancer Alley, a stretch between Baton Rouge and New

Orleans home to 150 refineries, plastic plants, and chemical facilities (CHEJ n.d., UN 2021). Dioxins are highly toxic and are linked with cancers and harms to the reproductive and immune systems, while vinyl chloride is a known carcinogen (WHO 2016).

Using low- or non-toxic materials is beneficial for all projects but especially so for residential projects, healthcare facilities, and schools. Notably, for businesses and commercial projects, studies have found improved productivity, decision-making skills, and a 26 percent improvement in cognitive function for workers in green-certified buildings with low levels of VOCs, low levels of carbon dioxide, and low- or non-toxic building materials (MacNaughton 2017). Workers and occupants of these green buildings also report fewer symptoms of sick building syndrome and better sleep.

Dimensions of Equity

The use of low- or non-toxic building materials can improve *public health* for people across the lifecycle of the building. By displacing toxic materials, it can reduce chemical exposure during the material manufacturing, building construction, and operational phase for workers, nearby residents, and building occupants. If the building materials are sourced locally or recycled locally at their end of life, it can also help to support local *economic resilience*.

Implementation Considerations

There are various third-party certifications for low- or non-toxic building materials, with some certifications extending to cover lifecycle analysis, material sustainability, end-of-life producer responsibility, sourcing, and more. Note that each material or product type may have its own specific chemicals of concern, and there is not one single certification system, rule, or solution. Thus, ensuring a completely low-toxic building throughout all its components can be challenging and costly. The project should work with community members and stakeholders to understand priorities, goals, and toxins of highest concern. Examples of intrinsically low-VOC materials include glass, concrete, stone, ceramic, adobe, tile, plated or anodized metal, clay brick, and unfinished or untreated solid wood. Some low- or non-toxic materials may be more expensive than others, and understanding community priorities will be important to determining trade-offs and alternatives.

Note that many California air districts have VOC limits for paints, adhesives, sealants, and other architectural coatings. Projects are advised to check with their local air district for the most up-to-date limits.

Example

Kaiser Permanente has adopted a safer products policy prohibiting a wide range of toxins and carcinogens from its building materials as well as medical products. Specifically, Kaiser has prohibited the use of PVCs in flooring, carpet and carpet backing, handrails, signage, and more; the use of per- and poly-fluorinated chemicals in building materials, finishes, furniture, and fabrics; and upholstered furniture with chemical flame retardants. This is not only good for health but also lower cost overall: the use of PVC-free flooring not only reduces staff, patient, and visitor chemical exposure but also lowers the total cost of ownership, including cost and time for maintenance (Health Care Without Harm 2019). In addition, Kaiser's commitment across its facilities also helps to expand the market and product availability for low- and non-toxic building materials.

Resources

Certification systems

Below is a non-exhaustive list of established certification systems and programs for sustainable building materials. As interest in healthful indoor environments grows, the number of available environmentally friendly, non-toxic building materials is also likely to increase, while their cost is likely to decrease.

- **Declare:** The Living Future Institute's Declare program provides a clear label for building materials and products, detailing their place of final assembly, component ingredients (including toxics), VOCs, responsible sourcing certification for forestry products, and end-of-life options. The program includes construction materials, furnishings, paints, finishes, and more.
- WELL Building Standard: WELL certifies buildings based on how their design features and operational protocols support human health and well-being. WELL focuses on 10 areas, including air quality, materials, and thermal comfort, and is performance-based, with certification based on onsite testing.
- **Build it Green:** This pioneering California nonprofit organization focuses on environmentally friendly buildings that support occupant health. They offer a green product rating and also rate single- and multifamily homes for their environmental, health, and energy efficiency components.
- **Greenguard:** This independent, third-party organization certifies low-emitting building materials, paints, and products, with all results in a searchable database.
- **GreenSeal:** GreenSeal certifies products based on rigorous lifecycle analysis. Their directory includes paints, sealants, finishes, and adhesives, as well as a wide range of commercial/industrial cleaners and detergents.
- **CARB Airborne Toxic Control Measures Phase II and Toxic Substances Control Act Title VI:** To reduce exposure to formaldehyde in furniture, flooring, and cabinets, choose products that are certified CARB Airborne Toxic Control Measures Phase II compliant or Toxic Substances Control Act Title VI compliant.

Other resources

- **Healthy Buildings For Health:** This resource hub from the Harvard T.H. Chan School of Public Health translates research and studies on healthy buildings to actionable recommendations for all. The hub contains guides for healthy homes, schools, workplaces, and materials, as well as for COVID-19, climate change, and more.
- **CARB Formaldehyde Factsheet:** Overview of formaldehyde and strategies to reduce formaldehyde exposure.

Related Measures

- IEP-4. Use of Locally/Regionally Manufactured Products and Materials

PH-5. Provide Equitable Food Access and Food Justice

California is the United States' largest producer of fruit and vegetables, but more than 4.7 million adults and 2 million children suffer food insecurity, experiencing inconsistent or limited access to sufficient or nutritious foods (California Food Policy Advocates 2019). The situation is worsening: the percentage of households reporting food insecurity increased by 22 percent during the first 3 months of the COVID-19 pandemic (UCLA 2021). Even when food is available, it may not be healthful. Counties with a higher percentage of people of color often have fewer healthful food options and more unhealthful options (Union of Concerned Scientists 2016). As a result, residents must often travel further and spend more time and money to access fresh produce. Thus, expanding access to healthful food is integral to public health and food justice, especially for low-income, historically underresourced communities.

While food access is a multifaceted issue, land use plays a key role in shaping access and availability. This measure calls for project proponents to incorporate strategies or solutions to support equitable food access as part of their project. Strategies include increasing opportunities for residents to grow their own food, adding or retaining locations to purchase food, and facilitating access to existing food sources.

For instance, projects can incorporate space and improvements for urban agriculture or community gardens, including through the transformation of vacant lots into urban farms. Also rising in popularity, vertical farming grows produce in stacked layers by controlling light, temperature, water, and sometimes carbon dioxide – thus, optimizing plant growth while taking up little space. Adopting local policies to support the growing of food crops in front yards and other practices can increase food access.

Projects can also expand the number of refrigeration units at existing or new convenience or neighborhood markets to facilitate the provision of fresh, healthful foods. Space, equipment, or funding for farmers markets, farm stands, mobile food banks, or local CBOs dedicated to food justice are also eligible. Larger efforts, such as the recruitment and construction of grocery stores, are also welcome.

Increasing access to existing food sources can also further food justice. Examples include expanding eligibility or hours to existing food programs (e.g., school nutrition programs) or facilitating travel (e.g., via microtransit or carshare) to existing retail locations.

Applicability

All

Scale and Timing

- Scale: Neighborhood/City and Project/Site
- Timing: Planning

Communities or Issues Addressed

Expanding healthful foods access can reduce food insecurity and the incidence of chronic health conditions, such as high blood pressure, high cholesterol, heart disease, type 2 diabetes, cancer, and obesity. Many low-income and underserved communities are disproportionately burdened by these diseases as a result of structural inequities and redlining that have left neighborhoods with limited access to healthful foods but a far higher density of fast-food outlets and convenience stores (Union of Concerned Scientists 2016). Children are particularly vulnerable to food insecurity and poor nutrition, as it can affect development and mental health. Poor nutrition has even been linked with COVD-19 outcomes, as a plant-based diet is associated with a lower risk of COVID-19 infections and less serious symptoms if infected – with the beneficial effects particularly significant for residents in areas of high socioeconomic deprivation (Hampton 2021).

Dimensions of Equity

Providing access to nutritious food supports *public health*. In addition, enhanced access to affordable food and agriculture facilitates greater *economic and social resilience*. Community-based urban agriculture can support *community development* by creating an opportunity to network, organize, and strengthen social capital, civic involvement, and community empowerment (Meenar and Hoover 2012).

Implementation Considerations

The project should involve community members, CBOs, and other stakeholders in the planning and decision-making process to uplift community expertise and to avoid inequality, displacement, or gentrification. Consulting with community members is also essential in order to identify food options that are needed and desired, including culturally appropriate foods. Consider collaborating with a CBO to identify these needs and provide resources to community members. Such resources may include community-led cooking or canning workshops, gardening events, seed and crop swaps, and recipe bulletins.

When considering spaces to grow produce, especially in underresourced communities, specific health risks such as soil, water, and air pollution should be analyzed and mitigated first. For instance, vegetables grown in soil with high lead concentrations will uptake lead, which poses negative health effects, particularly for children (Horst et al. 2017). Appropriate training, garden planning, and infrastructure can help mitigate some of the environmental pollution risk.

Examples

The City of Santa Clara approved a farm-to-table, mixed-income development that will combine affordable housing with a 1.5-acre regenerative farm in a dense, urban environment. In addition to 36 townhomes, the housing will include 165 units for low-income seniors and veterans and 160 market-rate units with 10 percent reserved for moderate-income households. The farm will produce up to 20,000 pounds of hyper-local fruits, vegetables, herbs, and nuts per year, which will be available to purchase at steep discounts for residents. Landscaping outside the farm will also include food plants and habitat for native birds and insects. The project will also provide publicly accessible open space and recreational opportunities (Peters 2021).

The City of Richmond worked with the Richmond Food Policy Council to support agricultural initiatives by simplifying the process for submitting paperwork, lowering permitting fees, eliminating certain zoning requirements, and promoting community gardens as spaces for social and education activities (Barhoum 2016). The Contra Costa County Food Bank hosts a mobile food pantry, which provided food to one in eight people in Contra Costa and Solano Counties in 2015 (Barhoum 2016). Similarly, the Regional Environmental Council in Worcester, MA, provides fresh produce through their mobile farmers markets rotating through different residential, medical, cultural, or religious centers, while providing standing farmers markets at parks from Monday to Saturday.

The community of Southeast Bakersfield lost its only supermarket in 1995. Using $100,000 of public funds, the City of Bakersfield conducted demolition and site prep work on a burned-down motel located at California and Union Avenues (both of which host bus lines) in 2000 and started recruiting supermarkets. FoodMaxx opened for business on the site in 2006 (Wenner 2016).

Resources

- USDA Food Access Research Atlas and Food Environment Atlas: These atlases help to map food access indicators and data, and food environment indicators (store proximity, food prices, food and nutrition access), respectively, at the census tract level. They can help to determine if the proposed project is in a neighborhood facing food access or food insecurity challenges.
- The California Health and Human Services Open Data Portal offers California-specific data sets on food affordability, fruit and vegetable consumption, food assistance program participation, and the retail food environment.
- Food policy councils are made up of local food system stakeholders and provide suggestions on how to improve the food system. The Food Policy Network Directory lists local food policy councils throughout California.

Related Measures

- IC-5. Designated Space for Community-Based Organizations, Disadvantaged Businesses, and Community Assets
- IC-8. Enhanced Access to Community Resources

Inclusive Economics and Prosperity (IEP)

On August 28, 1963, more than 200,000 people gathered for the Washington March for Jobs and Freedom to call for a sweeping civil rights bill that would, among other goals, desegregate schools, eliminate discrimination in all employment, and provide training and placement for unemployed workers. Recognizing the centrality of economic empowerment to achieving racial justice, demonstrators marched in response to the segregation and structural racism that left Black workers facing low wages, poor mobility, unequal pay, and widespread discrimination. And yet, while much progress has been made, the dream of freedom and economic empowerment has not yet been fully realized. Systemic racism, as expressed by unfair housing, education, public safety, labor and healthcare policies, has continue to produce unjust outcomes in life expectancy, wage disparity, employment, and other indicators of prosperity. Historic disenfranchisement and exclusion from higher-paying jobs and homeownership, for example, has left communities of color unable to accumulate and pass on wealth between generations that can help to support a higher degree, a test prep course, or the ability to take on an unpaid internship. The mean and median wealth of Black families in the U.S. was only 15 percent that of white families in 2019—or $24,100 compared to $188,200 (Bhutta 2020). The wage gap between Black and white workers continues to increase year on year, and between 2000 and 2018, wage growth for white and Latinx workers was about four times faster than for Black workers (Gould 2019). Black workers with university and advanced degrees experienced significantly slower wage growth than white or Latinx workers at the same education levels.

Although these issues are challenging and complex, the development of land use projects can help to gradually address these issues through the adoption of inclusive contracting and hiring practices that prioritize residents from historically marginalized and underserved communities. By providing internships, apprenticeships, and other opportunities, project proponents can help open doors and potentially change lives.

Key Indicators: Relevant CalEnviroScreen indicators include Poverty, Education, and Unemployment. Relevant Healthy Places Index indicators include all Economic and Education indicators, Homeownership, and Hardship Index.

Cross-Cutting Guidance

Many contracting and hiring processes, especially in the public sector, are resource-intensive for potential applicants and favor large enterprises or well-resourced individuals. If the measures below are simply appended to existing processes, root causes of exclusion are not addressed and can lead to tokenism or the proponent asking for the measures to be removed as infeasible. We recommend incorporating the following into any measures chosen.

- **Evaluate existing contracting, recruiting, and hiring practices**: The organization should evaluate their vendor lists and applicant pools from recent recruitments to identify additional outreach or modification of application requirements needed to increase local and diverse applicants. Consider partnering with CBOs or non-profits to provide technical assistance or increase the diversity of the applicant pool.
- **Plan for inclusion at the beginning**: Local small businesses need small, specific contracts. If the organization cannot bid contracts individually, the application process for the general contractor needs to include detailed, community-driven plans to meet local and diversity hiring targets, and appropriate redress if they fall short.
- **Create an inclusive workplace**: Worker productivity, growth, and retention occur when people can bring their authentic selves to the workplace. Pay equity, training, gender-neutral parental leave, employee resource groups, mentoring, and culturally inclusive dress codes, holidays, and organizational culture all can help people feel more welcome, supported, and included within an organization.

IEP-1. Local Labor and Apprenticeships (Construction)

To encourage economic development for the local community, the project will commit to hiring locally and provide apprenticeship and training opportunities for residents during the construction phase of the project. Local hiring can help to channel some of the economic value of development directly to the community in which it is building, helping to partially counter the potential effects of gentrification and neighborhood change. An apprenticeship program can help workers from low-income, vulnerable, marginalized, underresourced, or underrepresented backgrounds to gain work experience in the construction industry, and eventually accreditation and certification.

Applicability

All projects with construction.

Scale and Timing

- Neighborhood/City and Project/Site
- Construction

Communities or Issues Addressed

Communities that are economically disadvantaged or low-income, based on median annual household income, CalEnviroScreen socioeconomic indicators, or Healthy Places Index economic indicators.

Dimensions of Equity

This measure can support local *economic development* and *job training* by providing opportunities to residents as well as members from underrepresented, marginalized, and vulnerable communities, and communities that face barriers in accessing jobs.

Implementation Considerations

This may be most feasible for larger projects above a certain price threshold (e.g., $2.5 million). The project can set targets for both overall local hiring as well as specifically for apprenticeships for workers from the local community, economically disadvantaged communities, communities of color, individuals who are unhoused, formerly incarcerated, or from underrepresented backgrounds, LGBTQIA+ people, and women. The project should establish quarterly or annual reporting to document progress toward these targets.

Example

In 2012, Los Angeles Metro adopted a construction career policy and a project labor agreement for federally funded, and some locally funded, projects with a construction value greater than $2.5 million. For federally funded projects, the project labor agreement set targets of 40 percent participation (based on work hours) for construction workers from economically disadvantaged areas, 10 percent participation for disadvantaged workers, and 20 percent participation for apprentices. For locally funded projects, the targets are 40 percent participation from local targeted workers and community area residents, 10 percent participation from Los Angeles County residents, and 20 percent participation from apprentices, with 50 percent of all apprentice hours coming from local targeted workers. Los Angeles Metro provides project labor agreements, contractor resources and forms, reports, and other helpful documents.

Related Measures

- IEP-2. Local Labor and Apprenticeships (Operations)
- IEP-3. Contract with Diverse Suppliers

IEP-2. Local Labor and Apprenticeships (Operations)

To encourage economic development for the local community, the project will commit to hiring locally and provide internship and training opportunities for residents or residents from marginalized and underresourced communities during the operations phase of the project. Ideally, partnering with local education providers can offer additional training and accreditation for workers. Local hiring can help to channel some of the economic value of development directly to the community, helping to partially counter the potential effects of gentrification and neighborhood change. An internship program can help workers from low-income or marginalized, underrepresented, and underresourced backgrounds to gain work experience and eventually accreditation and certification.

Applicability

All projects with employees.

Scale and Timing

- Neighborhood/City and Project/Site
- Operations

Communities or Issues Addressed

Communities that are economically disadvantaged or low-income, based on median annual household income, CalEnviroScreen socio-economic indicators, or Healthy Places Index economic indicators.

Dimensions of Equity

This measure can support local *economic development* and *job training* by providing opportunities to residents. It can also help to increase opportunities and training for individuals who face barriers in accessing employment, as well as members from underresourced and marginalized communities. Local employment also reduces the need for transportation expenditures, which, when combined with housing, make up half of the average U.S. household budget; thus, this measure can help to reduce cost burdens for households (U.S. DOT 2015).

Implementation Considerations

This may be most feasible with large projects or institutions, such as healthcare providers. However, smaller projects can partner with existing programs or educational institutions to provide internship opportunities. The goal of these programs is to develop local employee talent for the project while creating opportunity and building capacity for residents.

Examples

Eighty percent of jobs at hospitals require 2-years of training or less. East Bakersfield High School (a public Title I school) created a Health Careers Academy with local hospitals, governments, healthcare providers, and veterinarians to provide hands-on experience and training as well as college-prep courses to provide youth early engagement in the healthcare field.

Cristo Rey, a private high school network serving mostly low-income students of color, includes a corporate work-study program as part of its curriculum. Local employers can bring on students to intern 1 day per week in return for sponsoring half their tuition. Through 4 years of high school, the student learns about different careers, develops job skills, contacts, work experience, and builds professionalism.

Many larger projects also include local hiring and training provisions, such as the $4.2 billion Los Angeles Sports and Entertainment District development (the Staples Center).

Related Measures

- IEP-1. Local Labor and Apprenticeships (Construction)

IEP-3. Contract with Diverse Suppliers

The project proponent will contract with diverse supplier(s): disadvantaged business enterprises (DBE); women-owned business enterprise (WBE); minority-owned business enterprise (MBE); disabled veteran-owned business enterprise; and/or LGBTQIA+-owned business enterprise.

This measure calls for proponents to contract with diverse suppliers, as defined above, for at least 15 percent of contracting dollars. Diverse suppliers are essential components of the health and sustainability of the economy. They employ people, provide wages, and contribute to social and community development. Project development offers important opportunities for equitable contracting practices by engaging with diverse suppliers.

Applicability

All projects with contracting needs.

Scale and Timing

- Scale: Neighborhood/City and Project/Site
- Timeframe: All

Dimensions of Equity

Utilizing inclusive contracting practices by partnering with diverse suppliers is an important strategy to direct funds to historically marginalized communities. Contracting with diverse suppliers provides important opportunities for *jobs/training* and *economic resilience* for women, people of color, disabled veterans, and/or LGBTQIA+ people.

Business ownership is a potent tool to help vulnerable communities accumulate assets and wealth. However, challenges for diverse suppliers arise on multiple fronts. Minority- and women-owned business enterprises typically have lower rates of utilization and face systemic barriers in contract procurement. The net worth for families of color is typically only a fraction of the net worth of white families—limiting access to financial institutions and causing their businesses to often rely on family and friends for initial growth capital. Discrimination in lending practices restricts initial access to capital and other financial resources for diverse suppliers. Gaps in capital between minority-owned businesses and their white counterparts are heavily influenced by disparities in credit scores (Fairlie 2020). Low levels of access to bank loans, credit services, and other financial resources affect minority-owned businesses in the long-run as well. Studies have found that businesses started by Black founders do not converge with their white-owned counterparts as they age. Additionally, minority business owners typically have fewer relationships with prime contractors, making it less likely they will be asked to become a sub-contractor.

Project proponents can help advance *racial justice* and equity by addressing systemic barriers and discrimination in lending, contracting, and business ownership. Promoting contracts with diverse suppliers provides these businesses with opportunities for capacity development and business growth. Not only do inclusive contracting programs help enhance individual diverse suppliers, but they work toward closing wealth and resource gaps impeding the well-being of children, families, and communities—contributing to greater *social resilience*. Studies have shown that regional economies that invest in their diversity are economically better off. Thus, active engagement with diverse suppliers is essential for sustainable economic prosperity.

Implementation Considerations

- The low number of certified diverse suppliers can be a barrier for this measure. Additionally, a complex network of certification programs contributes to a significant burden for diverse suppliers to receive third-party verification. Due to this reason, while third-party verification is recommended, it is not required to satisfy this measure.
- Establish data-reporting systems to share the following:
  - Race and gender data and hours worked for all employees under contractor(s) and subcontractor(s). These requirements help identify specific instances of discrimination in hours allocation.
  - Breakdown of dollar amounts the proponent spends on diverse suppliers.
  - Contract allocation (Edelman et al. 2017):
    - Percentage and absolute number of contracts awarded to all diverse suppliers.
    - Percentage and absolute number of businesses in each diverse supplier category (DBE, WBE, MBE, etc.) that have contracts with the proponent.
    - Number of diverse suppliers that win a contract with the proponent for the first time. This data reveals insights on the proponent's outreach performance for smaller diverse suppliers.
- Targeted outreach and technical assistance (Edelman et al. 2017):
  - Invest in staff dedicated to outreach and technical assistance objectives.
  - Provide support and guidance to diverse suppliers for business registration, certification, bidding, and contracting processes.
  - Conduct contract and business development workshops—particularly in low-income communities and/or communities of color.
  - Partner with non-profit organizations and CBOs to increase access to responsible capital and legal services for diverse suppliers.
  - Advertise contracting opportunities in spaces familiar with diverse suppliers. Circulate advertisements in small business media, and publications of minority and women's business organizations.
  - Meet with diverse suppliers prior to bid or proposal deadlines to explain scope of work.
  - Provide feedback to diverse suppliers who did not win a bid.

   - Provide skills and information training to diverse suppliers. Due to high barriers to entry, disadvantaged businesses may have limited capacity in certain fields including high-cost construction requirements, materials, technologies, and skills.
- Use online contract monitoring tools to track contract progress and goals.
- Make use of best-value contracts. They are negotiated contracts between a contractor and owner and include a range of considerations such as expertise, financing, quality, and past performance.
- Pay sub-contractors promptly—they are often the last ones paid and least able to afford the wait.
- Ensure payment through contract compliance.
- Unbundle large projects to make them accessible to smaller DBEs with different levels of capacity.
- Structure bid pools based on contractor size. This allows small contractors to compete rather than with large contractors.
- Use an accessible online sub-contracting system.
- Identify portions of work during the planning phase that could be substituted for diverse suppliers.
- Build a diverse supplier contact list to share with other proponents. (Fairchild et al. 2018)

Examples

Kingsbridge Armory, New York

Contracting with minority- and women-owned business enterprises is an explicit provision in the Kingsbridge Armory CBA. Specifically, the CBA calls for each employer of the development project to award 25 percent of the funds spent on employees performing construction of the project to MBEs and WBEs located in the Bronx. Each employer is also required to include this provision in any contract or agreement with any third party that will operate its business at or provide services to the Kingsbridge Armory project (Partnership for Working Families 2015b).

Los Angeles International Airport, California

In 2004, a coalition of CBOs and labor unions entered a CBA as part of the Los Angeles International Airport's (LAX) $11 billion modernization plan. The agreement is between the LAX Coalition of Economic, Environmental, and Educational Justice and Los Angeles Worlds Airports (LAWA). The original agreement includes a MBE, WBE, and small business utilization and retention program to increase participation in the planning, construction, operation, and maintenance of LAX. To pursue these goals, LAWA agreed to conduct targeted outreach to small businesses, MBE, and WBE within the project impact area. These businesses were also included in pre-bid conferences and "meet the general contractor" events. LAWA also agreed to unbundle construction projects into smaller bid sizes to help ensure fair competition. Additionally, LAWA agreed to help with access to bonding, insurance, procurement and other types of capacity-related assistance where necessary. Importantly, the CBA also called for LAWA to coordinate with the City of Los Angeles Mayor's Office and other relevant business and finance organizations to assist in identifying or developing a low-interest working capital revolving loan program (Partnership for Working Families 2004).

Resources

Third-Party Certification Sources and Clearinghouse

- Caltrans California Unified Certification Program Disadvantaged Business Enterprise Certification
- Women, minority, LGBTQIA+, and disabled veteran-owned businesses:
  - CPUC GO 156 CPUC Supplier Diversity Program Clearinghouse
  - Southern California Minority Supplier Developer Council/National Minority Supplier Development Council Certification
  - Western Regional Minority Supplier Development Council/National Minority Supplier Development Council
  - US Small Business Administration: Service-Disabled Veteran-Owned Small Business Program
  - US Small Business Administration: Women-Owned Small Business/Economically Disadvantaged Women-Owned Small Business Program
  - CA Department of General Services: Disabled Veteran Business Enterprise Certification Program
  - US Small Business Administration: 8(a) Business Development Program

Related Measures

- CCD-5. Establish a Community Benefits Agreement

IEP-4. Use of Locally/Regionally Manufactured Products and Materials

Buying locally manufactured products and materials in both the construction (e.g., forestry products) and operations (e.g., food) provides employment opportunities for community members as well as supporting California tax revenues. Local procurement also reduces emissions for transportation, especially for bulk materials such as construction aggregate. Different parts of California also have different capacity for manufacturing and producing products and materials, so the guidelines below should be tailored to local conditions. In general, the preference is to first source materials from within the commute shed of the project location (offering local employment opportunities), followed by within the region or adjacent counties, followed by sourced within California.

Applicability

Applicable to all projects.

Scale and Timing

- Scale: Project/Site
- Timing: Project construction

Communities or Issues Addressed

Tradable sectors of the economy (where output can be sold to other states and nations) bring income into an area, and typically support non-tradable sectors of the economy (such as retail, healthcare, and service) through the multiplier effect. Money spent with local businesses on locally made goods is more likely to flow to other sectors of the local economy (e.g., upstream through product supply chain or horizontally through employees), than money spent at national-level chains and retailers. In addition, local businesses support local jobs and pay local taxes, which in turn support municipal and state services. Keeping project dollars local by purchasing from local providers strengthens economies and can reduce transportation emissions.

Dimensions of Equity

Investment in local tradable industries improves *economic resilience* and creates additional opportunities for residents. The use of local forestry products made of biomass from forest restoration projects can help to increase *climate resilience* by reducing the risk of catastrophic wildfires, thus also reducing GHG emissions.

Implementation Considerations

Beyond aggregate, paving, and forestry products, consider other products the project would use, such as machinery, fabricated metals (bike racks and hardware), plumbing, interior furnishings, ceramics, electrical vehicle support equipment, etc. Product sourcing should also consider sustainability and recyclability and support the circular economy whenever possible. Paving products, for example, can contain recycled materials. Wood products can use biomass removed from forest thinning and management practices, sustaining local jobs as well as helping to increase resilience. Currently, California imports 100 percent of its engineered wood from out of state, but the use of locally produced cross-laminated timber products, for example, can simultaneously support local industry in rural California, develop beneficial uses for biomass removed from forest restoration and thinning, and reduce GHG emissions by offsetting the use of steel and concrete as construction materials (LHC 2018).

The project can also go a step further to ensure that its products and materials are not only locally sourced but are free of toxic chemicals and components that may affect the health of construction workers and building occupants (see Measure PH-4, *Create Healthful, Sustainable Indoor Spaces*). Additionally, project proponents can also look for materials that are locally recycled or salvaged.

Example

The City of Pasadena has a First Buy Local Initiative that offers informal bid procedures for purchases under $25,000 and formal competitive procedures for purchases exceeding that threshold. Both the informal and formal procedures have a 5 percent bonus in evaluation score for local businesses and a 5 percent bonus for small businesses. Supporting strategies include outreach, engagement, and working groups to reach local businesses (City of Pasadena 2010).

Related Measures

- PH-4. Create Healthful, Sustainable Indoor Spaces

Resources

- Made in California Program: A directory of over 2,000 small- and medium-sized companies that make their products in California, with the ability to filter by county, region, or category.
- CA Made Program: The Governor's Office of Business and Economic Development's made in California certification and label.

IEP-5. Higher Wage and Working Condition Standards

The project will go above and beyond standard requirements on wages and working conditions. Since 1979, worker productivity has grown 3.5 times faster than worker pay, while cost of living – especially housing – has escalated dramatically, driving income inequality (Economic Policy Institute 2021). In addition, there are notable pay gaps in gender and race, with Asian and white people making more than Black and Latinx people and men making more than women (Patten 2016). The rise of independent contractors (the "gig" economy), labor deregulation, and increasing costs of benefits have further led to the deterioration of working conditions (Livni 2019). While projects may promise job creation as a core benefit, communities may be rightfully concerned that employment opportunities generated by project construction and operation may not pay wages commensurate with the local cost of living or provide safe working conditions and meaningful employment opportunities.

For this measure, the project would ensure minimum wage and/or labor standards. During construction, project labor agreements and prevailing wage and skilled and trained workforce requirements are typical mechanisms to ensure fair wages and working conditions. Living-wage standards, skilled worker or training requirements, or union labor agreements can help achieve these goals for operational projects. These requirements can also be adopted jurisdiction-wide for specific workers or industries, such as prevailing wage requirements for publicly funded construction projects, or New York City's delivery worker bills that required restroom access, mileage limits, and other working condition improvements for app-based delivery workers.

Finally, the project will include accountability measures to implement existing labor standards that may be overlooked or difficult to enforce. For example, to protect outdoor workers from wildfire smoke, California Code of Regulations, Title 8, Section 5141.1 requires employers to provide enclosed workspaces, relocate work sites, change work schedules or work intensity, and/or provide respirators such as N95 face masks when the AQI for PM2.5 exceeds 151. Projects would need to create policies and procedures in advance, such as designating staff to monitor daily AQI, stockpiling sufficient respirators, and instructing staff and supervisors on appropriate work intensity. These additional accountability measures should be focused on likely hazards, such as extreme heat, or regulations that are commonly violated in the industry or community.

Applicability

All

Scale and Timing

- Scale: Neighborhood/City and Project/Site
- Timing: Construction and operations

Communities or Issues Addressed

Projects may increase demand for low-wage service workers, workers in industries with limited regulations, or other laborers that operate with inherent power differentials that can lead to exploitation (e.g., undocumented workers or workers whose immigration status is dependent on the employer). Ensuring fair wages and safe working conditions empowers these employees and communities. Workers also benefit from lower allostatic load and increased residential and transportation choice (McEwen and Gianaros 2011).

For example, half of the families in California's construction sector are on state safety net programs, considerably higher than the state average of one-third for all working families (Jacobs and Huang 2021). A skilled and trained workforce provision, which requires a percentage of workers to graduate from apprenticeship programs, can improve safety and wages (Office of Disability Employment Policy 2021).

Dimensions of Equity

By implementing wage and working conditions standards that go beyond requirements, proponents can directly support *economic resilience* and *social resilience* for workers. This measure also has the potential to benefit the resilience of the broader community when coupled with local hiring and contracting provisions. With deep wage disparities across race and gender, prevailing wage standards can help advance *equity*. Enhanced labor standards can also help combat labor exploitation and provide safer environments, critical for *climate resilience*.

Implementation Considerations

Accountability measures are necessary to ensure the project is consistent with promises, and measures need to be carefully crafted to survive challenge. Community benefit agreements, project labor agreements, and developer agreements may be more defensible than mitigation measures or conditions of approval.

Examples

The Los Angeles Sports and Entertainment District Community Benefits Agreement (Staples Center) set a goal that 70 percent of the jobs created by the project would pay the City's living wage.

The Oakland Army Base project included employer hiring agreements that required living wage compensation and a focus on hiring disadvantaged workers.

Related Measures

- CCD-5. Establish a Community Benefits Agreement
- IEP-1. Local Labor and Apprenticeships (Construction)
- IEP-2. Local Labor and Apprenticeships (Operations)

Inclusive Communities (IC)

Photo Credit: Franco Folini, November 2003

Many communities in California have been intentionally designed to exclude people, often by race, income, or disability (Othering & Belonging Institute 2018). This reality created the need for people, especially marginalized communities, to create supportive social networks within the built environment to fulfill needs such as childcare, education, employment, and identity (Payne et al. 2009). As projects are built in new and established communities, care must be taken to ensure that all Californians can be included in the housing and jobs that the project brings. An inclusive community is one in which all residents can live, work, play, and meet their daily needs, and which shares, uplifts, and affirms the stories and identities of its marginalized and historically excluded communities.

Key Indicators: Many communities would benefit from these measures. That said, relevant indicators in CalEnviroScreen include: Education, Linguistic Isolation, Poverty, and Unemployment. Relevant Healthy Places Indicators include: Above Poverty, Employed, Median Household Income, Auto Access, Park Access, Retail Density, Supermarket Access, Tree Canopy, Disabled, Cognitively Disabled, Physically Disabled, Children, Elderly, Hardship Index, California Qualified Opportunity Zones, and Race/Ethnicity.

Cross-Cutting Guidance

Standard development processes are rooted in exclusionary practices. Designing inclusive communities requires intentionality and collaboration, ideally prior to the formal entitlement process. It is recommended the user consider the following:

- **Early community engagement:** Community members are experts on their neighborhood and can help identify which suite of measures and implementation pieces have the most benefit for the community. Refer to the *Community-Centered Development* section for measures on community needs assessments and asset mapping to help identify needs and gaps, and the *Inclusive Engagement* section for engagement recommendations.
- **Continued engagement during operations**: As communities evolve, and as climate and economic disruptions may occur, community needs change. Demographic, socio-economic, and environmental changes may require the project to flexibly address what it means to create an inclusive community. Relationship building between community members and the project, as well as regular community engagement events, can help anticipate some of these changes.

IC-1. Invests in Local Arts and Culture to Affirm Community Identity

During development, a community's identity can often be erased and threatened with gentrification. Support for and investment in local arts and culture help to preserve a sense of community in the wake of neighborhood change. Art can help contribute to advancing human dignity, inspiring and mobilizing social change, healing and mental health, expressing a community's identity, history, and vision for itself and its place in the world, building community capacity, and improving its public spaces and infrastructure (Cleveland 2011). Additionally, access to representative arts and cultural spaces may be a community need identified through community needs assessments or other community-based outreach. Collaborating with CBOs and local groups is imperative to ensure proper and appropriate investment.

The project proponent, working with local community groups, will invest at least 1 percent of the total project cost in local arts and culture projects, programs, or other initiatives. This could manifest as murals, heritage walks, arts education, artist-in-residence and artist-in-training programs, cultural district designation, youth-led arts, arts programs for people who are incarcerated, a performing arts pavilion in an onsite plaza, sponsorship of local artists and groups, or other priorities identified by community members.

Applicability

Applicable to all projects.

Scale and Timing

- Scale: Project/Site or Neighborhood/City
- Timing: Planning, construction, or operations

Communities or Issues Addressed

"During challenging and turbulent times, artists have been on the forefront of expressing our community's demand for change… It is imperative that we amplify their voices by supporting their work as they memorialize and mark this moment," noted the Saint Paul and Minnesota Foundation (SPMF 2020). The arts can narrate the unique people, culture, history, and issues of a community to both the members of the community and the wider world.

Art is a core part of a community's articulation of its past, present, and future, and it is crucial to provide greater space and support to artists from low-income and marginalized communities and communities of color, which have often been overlooked in arts funding programs. Arts organizations serving communities of color generally have far smaller budgets and greater financially instability than their counterparts in white communities (PolicyLink 2017). Through this measure, a project proponent can thoughtfully support artists from underresourced backgrounds, while contributing to community development and creative placemaking.

Dimensions of Equity

By uplifting artists from marginalized and underrepresented communities, inclusive art projects can help to enhance community *self-determination* and support community ownership over art, art-making, and public spaces. Providing support and spaces for Black, Indigenous, and People of Color (BIPOC) artists can help to further *racial equity*. Art commemorating civil rights leaders, community figures, and traditional cultural practices can help a community tell its story, benefiting *social resilience*. Community-centered art training and education can also help to increase individual wellbeing, civic participation, and engagement with community initiatives (Bennett 2014). Finally, arts projects can also help to contribute to creative placemaking and *enhance economic development* by drawing visitors.

Implementation Considerations

While art can benefit an individual project, the intent of this measure is to ensure the wider community benefits as well. This can take the form of not only supporting individual public works of arts (e.g., a sculpture, mural, a performance, or festival) but also supporting local artists, sponsoring art programs, and providing training and arts education for underserved, vulnerable, and marginalized communities. "Successful creative placemaking projects are not measured by how many new arts centers, galleries, or cultural districts are built. Rather, their success is measured in the ways artists, formal and informal arts spaces, and creative interventions have contributed toward community outcomes," writes ArtPlace, a collaboration between foundations and federal agencies to support and fund art as placemaking and community development (Axel-Lute 2017).

Community spaces should be respected, and artists should come from and be representative of the community. Community arts groups, coalitions, and CBOs should take the lead in identifying artists, programs, and initiatives to support, as well as implementation and program design. Artists and art groups from underresourced and marginalized communities should be prioritized, especially Black, indigenous, people of color, youth, and seniors. Local artists should be involved.

Examples

The City of Berkeley's Public Art on Private Development Program requires either an onsite, publicly accessible artwork valued at 1.75 percent of construction costs, an in-lieu fee at 0.8 percent of costs, or a combination thereof.

Public projects in San Francisco are required to contribute 2 percent of projects costs for art through the San Francisco Arts Commission. As part of its multibillion rebuild of its sewer system, the San Francisco Public Utilities Commission is working to channel art funds to neighborhoods directly impacted by the rebuild. This includes a focus on Bayview-Hunters Point, San Francisco's historic Black community and home to the city's largest wastewater treatment plant (PolicyLink 2017).

Resources

- The **Americans for the Arts** provides example ordinances that set aside percentages to fund arts projects.
- **ArtPlace** provides toolkits, resources, research studies, and more to help community planners, local governments, and artists to support art in community development. ArtPlace has developed an interactive tool that provides research and case studies on how arts and culture can support equitable community development, focusing on 13 benefits, such as ensuring cultural continuity, healing trauma, and building power.
- The **Federal Reserve Bank of San Francisco's** November 2019 issue of *Community Development Innovation Review* focuses on the role of arts and culture, with articles examining how the arts can impact community wellbeing, transforming vacant space, social resilience, community empowerment, economic development and more.

IC-2. Adopt Design Standards

The use of an inclusive design standard or certification system can encourage sustainable, equitable development, while also providing inspiration and examples to other project proponents. Today there exists a range of comprehensive international and national design standards and frameworks that help to guide and promote sustainable design throughout the project planning, construction, and operations lifecycle, but not all of them address equity.

Below are some of the key features of each of the design standards that can be incorporated to increase equity.

- The Living Future Challenge is the most comprehensive of all global design standards, aiming to be "socially just, culturally rich, and ecologically restorative" (International Living Future Institute 2021). Their standards can be implemented at the product, building, or community scale, and are based on performance and operations, not just certification at completion of construction.

  - The Living Building Challenge includes elements focusing on indoor air quality; equitable and public access to non-building infrastructure and roads such as gardens, paths, and benches; equitable treatment; just business practices; accessibility; and urban agriculture.
  - The Living Community Challenge encompasses these same elements, as well as broader features that can build equity in an entire community: local food programs, community hubs, shared public spaces, community resilience and disaster planning, and more. They also provide a framework for affordable housing and biophilic design.
- Enterprise Green Communities (EGC) is a design standard specifically for new or rehabilitated affordable housing projects. The goal is to develop affordable housing that is healthy, sustainable, safe, resilient, and comfortable. Standards focus on a healthy indoor living environment, zero energy, active mobility, emergency management and resilience, and universal design. There are also recommendations for affordable housing development in rural, suburban, and tribal communities. Unlike many other design standards, EGC covers the cost of certification, making it more accessible for affordable housing developers.
- Active Design Guidelines: Developed by the Center for Active Design in 2010, the Active Design Guidelines aim to support public health through developing streets, buildings, and public spaces that encourage walking, biking, recreation, and active living. The guidelines can help improve pedestrian and bicycling infrastructure and amenities (e.g., lighting and crosswalks) in communities where they have historically been neglected. They can also to help to increase access to neighborhood destinations while simultaneously addressing physical activity and public health. There are additional supplements for affordable housing, safety, and schools.
- LEED: The U.S. Green Building Council's LEED rating system has introduced Social Equity Pilot Credits, which are designed to address equity throughout the lifecycle of the building process, from construction to operations. The credit includes community engagement, evaluating existing needs and disparities, workforce development, supply chain sustainability, accessibility, and more.
- Universal Design: Universal design is the principle that the built environment can be accessed and used by all people regardless of age, ability, disability, or size, meeting the needs of all without the use of individual modifications and adaptations. Universal design is inclusive by nature and aims to be equitable, flexible, and intuitive and require low physical effort. This supports equity by expanding accessibility to all users.

Applicability

All projects with construction.

Scale and Timing

- Neighborhood/City and Project/Site
- Timeframe: Planning, construction, and operations

Communities or Issues Addressed

Due to the comprehensive nature of these design standards, they are beneficial to all communities and issues.

Dimensions of Equity

Because this measure encompasses a range of design standards, some of which are holistic and systematic in approach, it can help to address almost all dimensions of equity, depending on the specific standards implemented.

Implementation Considerations

The process of pursuing certification may be costly for some projects, but individual elements can be pursued or combined across systems to increase equity, resilience, and sustainability. The project should consider local goals and priorities, as well as community input, needs assessments, and plans, in selecting which design standard, or combination of standards, would be most appropriate. Of all the design standards, ECG specifically focuses on affordable housing and may be the most accessible for all projects.

Examples

Working with an interdisciplinary team of planners, health experts, community groups, and agencies, Sacramento County developed and adopted its own iteration of the Active Design Guidelines, Design 4 Active Sacramento. This has been codified into an array of zoning and housing codes, ensuring that active design for health is centered in Sacramento County regulations.

Seattle's International Chinatown District is exploring multiple ways to adopt Living Community Challenge principles, include a community-led de-paving effort, community gardens, public gathering spaces, a greenway, and stormwater mitigation. Numerous other case studies and examples, including many in California, can be found on the Living Future website.

IC-3. Promotes Accessibility

The project will increase ADA access beyond code requirements and design for people with autism as well as other neurological or sensory processing conditions. Open spaces and amenities are available to all; the project will incorporate Universal Design to create environments that are accessible to anyone. Universal Design explicitly calls for constructing environments that are designed with everyone in mind, regardless of their age, size, or ability.

Applicability

Applicable to all projects.

Scale and Timing

- Scale: Project/Site or Neighborhood/City
- Timing: Construction

Communities or Issues Addressed

People with physical or neurological conditions or limitations may have difficulties navigating and using traditionally designed projects. Designing for accessibility supports all users, making a more open, inclusive built environment. Features that benefit neurodivergent populations also reduce stress and confusion for neurotypical users, while features aiding those with mobility devices also help those with carts or strollers. These features also enhance independence. For example, Universal Design facilitates aging in place, allowing seniors to defer or delay leaving their homes and communities for institutionalized care.

Dimensions of Equity

Designing for accessibility in all spaces creates a more welcoming environment for all, supporting greater inclusion and independence for individuals of all abilities. Accessible transportation can improve *mobility choice* and transportation justice, while accessible housing design can help improve *public health*, mental wellbeing and confidence, and enhance *economic* and *social resilience.*

Implementation Considerations

The project proponent should consider not only how the target market would use the project, but how anyone could use the project. For example, a subdivision of two-story single-family homes should include an option for a bedroom and bathroom on the ground floor to accommodate occupant injury, residents who cannot navigate stairs, or seniors. Grab bars in bathrooms and wide doorways and hallways facilitate aging and mobility devices. A nearby quiet garden with water feature can create a place to recover from overstimulation.

Resources

- The **Center for Excellence in Universal Design** provides an excellent primer on universal design.
- A City for Marc provides a toolkit and resources for urban design that is inclusive of people with autism and other neurosensory conditions.
- The American Association of Retired Persons' Center for Aging in Place provides a checklist for developing senior-friendly communities supportive of aging-in-place.

IC-4. Enhanced Open and Green Spaces

Low-income communities often lack equitable access to parks and green spaces. By supporting park and open space development in underserved communities, the project proponent can help increase space for residents to exercise and socialize, increasing social resilience and reducing the UHI effect. Especially as COVID-19 has highlighted the need for outdoor spaces in which to safely exercise and socialize, the disparities in park access between wealthy and low-income communities have become particularly stark.

Under this measure, proponents of residential projects will contribute their Quimby requirements and other park impact fees, plus an additional 25 percent or more in acreage-equivalents, to a Quimby plan area in the bottom quartile of a jurisdiction based on aggregated CalEnviroScreen score, or on the project if in a disadvantaged community. These additional funds may be given to the local jurisdiction or local open space CBOs. Commercial and industrial projects would make a similar additional contribution based on equivalent dwelling units.

Applicability

Applicable to all projects.

Scale and Timing

- Scale: Project/Site
- Timing: Construction

Communities or Issues Addressed

This measure can help communities that currently lack park access or have low tree canopy or a high percentage of impervious spaces. Low-income or underresourced communities should be prioritized. Relevant indicators include Park Access, Tree Canopy, Impervious Surface Cover, and Urban Heat Island Index as part of the Healthy Places Index.

Dimensions of Equity

Parks, greenbelts, and green spaces are linked with not only improved *air quality* and lower temperatures in the park itself, but also in their greater surrounding areas, supporting *climate resilience* (CARB 2017). In addition, parks and other public spaces help to support greater *social resilience.* Increasing access to public green spaces will also help to encourage *active transportation, mobility,* and *public health*.

Implementation Considerations

Commercial developments that are not able to develop public spaces or open spaces on site may be able to consider an offsite alternative, ideally within the same community. The development of parks in low-income and marginalized communities may lead to rising housing costs, and eventually gentrification and displacement. To address this potentiality, project proponents should work closely with CBOs and community members to understand community priorities and needs, as well as to plan, site, design, and develop the park. Project proponents, local jurisdictions, housing advocates, and community groups should also work together to determine appropriate anti-displacement strategies, such as local hiring measures in the *Inclusive Economics and Prosperity* section or housing measures in the *Anti-Displacement and Housing* section.

Example

The 1985 San Francisco Downtown Plan required that publicly accessible open spaces be provided for all construction projects, at the rate of one square foot of open space per 50 square foot of building space. As a result, as of 2009, 27 open spaces have been developed, including urban gardens, walkways, and public plazas (SFPD 2011). In addition, commercial developments were required to contribute $2 per square foot of building space to a dedicated park fund that would be used to acquire and develop parks downtown. As of 2009, nearly $11 million has been collected and used to develop parks on existing public parcels. As a result, most of downtown is now within a quarter mile of a neighborhood-serving open space.

Resources

- Greening without Gentrification: This policy brief analyzes 26 parks-related anti displacement strategies targeted for different audiences, finding that early implementation and community engagement are key.

Related Measures

- PH-2: Increase Urban Tree Canopy and Green Spaces

IC-5. Designated Space for Community-Based Organizations, Disadvantaged Businesses, and Community Assets

Designating space in a development project for a CBO, a community asset, or a disadvantaged business can contribute to local economic development, social wellbeing and resilience, education, health, capacity building, and other benefits. A CBO or local non-profit can provide services, resources, events, and activities for residents. Community assets should help to address existing needs and disparities in the community and provide needed services. Examples include community centers, health clinics, elderly care sites, grocery stores providing healthy, affordable foods, local businesses, and childcare facilities. Disadvantaged businesses can include businesses owned by women, people of color, veterans, LGBTQIA+ people, and other underrepresented groups, as well as small, locally owned businesses. In addition, or as an alternative approach, the project proponent could also consider offering discounted rent or mortgage, in-kind donations, or other support. By designating space for these organizations, the project can help to expand local opportunities and enhance the overall economic and social wellbeing of its surrounding community, which would in turn enhance its long-term prospects.

Applicability

Commercial or mixed-use developments in urban, rural, and suburban communities.

Scale and Timing

- Scale: Project/Site
- Timing: Operations

Communities or Issues Addressed

This measure can help to support local businesses and community needs in low-income and underresourced communities.

Dimensions of Equity

Locally owned businesses recirculate a greater share (50–80 percent) of their revenue to the local economy as compared to chain businesses (14–30 percent), because of greater spending with local labor, contractors, supply chains, and locally made goods (ILSR 2016). Other studies show that sales at local businesses generate more than twice the amount of local economic activity and 2.6 times more jobs, than sales at chain businesses (ISLR 2016). Thus, supporting local businesses will help keep money in the local economy, supporting *local jobs,* tax revenue, and *economic resilience.*

Implementation Considerations

Community input is crucial to the success of this measure; the project should consult existing community plans, needs assessments, asset mapping, and other available community documents to identify unmet needs and priorities. If existing research is insufficient, the project should partner with a CBO or conduct listening sessions to understand local desires. By designating space to support community needs, the project can help gain local support and drive additional traffic and visits to project sites, increasing overall economic benefits.

Example

La Fenix, a new housing development by BRIDGE Housing and Mission Housing Development Corporation in the Mission District of San Francisco, provides 100 percent affordable housing in combination with dedicated spaces for CBOs and community assets. On the first floor, neighborhood-serving spaces include a childcare center operated by Mission Neighborhood Centers, art studios, an art gallery from Acción Latina, and a bicycle repair workshop (City and County of San Francisco 2021). These services are open to not only onsite residents but also the surrounding neighborhood.

Related Measures

- CCD-3. Conduct a Community Needs Assessment

IC-6: Create Non-Standard Commercial or Retail Spaces

National-level chain businesses typically require larger building footprints and standard retail environments, high ceilings, and storage. These retail spaces typically have greater difficulty accommodating locally owned and small businesses. As retail and dining trends evolve in the twenty-first century away from big-box stores and chains, commercial developments can incorporate more non-standard retail spaces within their projects to respond to emerging business types (e.g., pop-up and to-go only food vendors, start-ups). By being smaller and thus more affordable to rent and operate, non-standard retail spaces can reduce operating costs and better accommodate the needs of small and independent businesses, first-time business owners, and businesses owned by members of low-income, underserved, and underresourced communities. This can help to spur new business creation, especially by those who may lack initial capital, as well as social benefit businesses. In turn, this can help to support local economic development, social wellbeing and resilience, capacity-building, and other benefits.

Applicability

Commercial or retail projects.

Scale and Timing

- Scale: Project/Site
- Timing: Operations

Communities or Issues Addressed

Commercial or mixed-use properties, especially those in underserved communities.

Dimensions of Equity

Non-standard retail spaces can encourage new small businesses and help drive *economic development,* entrepreneurship, and creativity. Smaller spaces with lower rents reduce barriers of entry for people with less capital or lower credit. As non-standard retail spaces are more likely to be occupied by independent locally owned businesses, they are likely to return more economic value to the community. Locally owned businesses recirculate a greater share (50–80 percent) of their revenue to the local economy as compared to chain businesses (14–30 percent), because of greater spending with local labor, contractors, and locally made goods (ILSR 2016). Other studies show that sales at local businesses generate more than twice the amount of local economic activity, and 2.6 times more jobs, than at chain businesses (ISLR 2016). Thus, supporting local businesses will help to ensure that money stays in the local economy, supporting *local jobs*, tax revenue, and economic resilience.

Implementation Considerations

Offering a range of retail spaces can help commercial and mixed-use developments diversify the retail environment, support new business development, and attract a wider range of uses and customers. Buildings with low ceilings and alley-fronting spaces will usually be avoided by national retailers, preventing local businesses from being outbid. Small, street-facing retail spaces can help increase foot traffic and create more walkable, engaging neighborhoods. The project proponent should work with local business improvement districts and community coalitions to conduct outreach to potential tenants from underresourced and marginalized communities.

Example

As malls have closed around in the U.S., several of them are being redeveloped to accommodate smaller retailers, while downtown revitalization efforts around the U.S. have also highlighted the popularity of smaller street-facing shops in dense, walkable communities. The popularity of markets, converted shipping containers, and food halls such as Los Angeles's Grand Central Market and San Francisco's Ferry Building also point to the success of establishments focused on non-standard retail and their ability to develop and support new businesses, including from underrepresented business owners. In San Francisco, La Cocina opened the first woman-led food hall that will provide retail spaces for women- and immigrant-owned restaurants, offer economic opportunities and jobs, and serve as a model for anti-gentrification and conscious development in the Tenderloin, one of San Francisco's most disadvantaged neighborhoods.

Related Measures

- IC-8. Enhanced Access to Community Resources

IC-7. Equal Access to Building Amenities

Mixed-income multi-family developments should provide equal access to all building entrances, amenities, lobbies, and other shared facilities for affordable housing units. Affordable housing units should also be built to the same energy efficiency and other design standards as the baseline market-rate units.

Applicability

Mixed-income residential projects with common areas.

Scale and Timing

- Scale: Project/Site
- Timing: Operations

Communities or Issues Addressed

Affordable housing units are sometimes excluded from amenities in multi-family housing complexes, such as use of the clubhouse, community room, pool, or other shared amenities. This leads to segregation under which affordable housing residents are treated as second-class citizens, and families must explain to children why they cannot enjoy the same the pool or playroom as other residents.

Dimensions of Equity

Equal access to building facilities can help build *social resilience* and integration in the community. This can also support greater physical and mental *health* for residents.

Implementation Considerations

Shared, equitable access should include all amenities that are available to market-rate units at no additional cost but can exclude priced amenities such as parking. Affordable housing units should be provided the same keys to all secured amenities (e.g., bike rooms, laundry, gyms) as market-rate units. Take into account the needs of large families, those living with disabilities, and children when designing facilities and building access.

Example

Designed by Dutch architectural firm OMA, the Avery in San Francisco combines world-class architecture and a LEED gold rating with mixed-income housing. Of the 548 housing units, 149 are permanently affordable and will be designated for families earning up to 50 percent of area median income, which would be $64,050 or less for a family of four (City and County of San Francisco Office of the Mayor 2020). Shared building amenities include a fitness center, pool, roof garden, outdoor terrace, business and technology lounge, media room, and resident community garden. The Avery also includes public art, including works by local artists.

IC-8. Enhanced Access to Community Resources

The project will enhance and expand access of marginalized and underserved communities to resources such as additional green spaces, food, recreation areas, healthcare facilities, childcare facilities, elder care facilities, schools, broadband internet, and financial services. This measure promotes the diversification of accessible economic and social activities. The project can also expand transportation access to existing resources, such as by improving access to transit stations, sidewalk and bike lane improvements, or other improvements to the active transportation infrastructure. The project should directly address the identified needs of the community and help to support the creation of a healthier, more equitable, and more resilient environment for the people who live and work in the project area.

Applicability

Applicable to all projects.

Scale and Timing

- Scale: Neighborhood/City and Project/Site
- Timing: Planning, operations

Communities or Issues Addressed

As a result of redlining and other historic policies, low-income communities and communities of color have been neglected by investment and development, and as a result lack ready access to facilities such as grocery stores, health, recreation, and other services that support healthful living. For example, predominantly white communities in Los Angeles have 3.2 times and 1.7 times more supermarkets than predominantly Black and Latinx communities, respectively (NYLSRJP 2012). At the same time, low-income communities often have higher than average shares of fast-food restaurants and convenience stores supplying only processed foods. As a result, residents often face fewer choices, pay more, and travel further for fresh produce, groceries, and other services. Rural communities, as well, lack access to many of the same facilities, in addition to high-quality broadband internet, which often puts rural residents at a disadvantage for remote work, school, healthcare, and social connections.

Dimensions of Equity

Depending on the specific needs in each community, this measure can address a range of equity dimensions, including *public health, education, climate resilience*, *air quality, social resilience, jobs,* and more. By directly addressing community needs, this measure can also improve a community's *self-determination* and *equity*.

Implementation Considerations

The project proponent should build on community engagement and outreach efforts to understand community needs, priorities, and challenges. Partnering with a local CBO can help to identify existing community needs without conducting a separate needs assessment. Other resources, such as adopted community plans, a community health needs assessment, Healthy Places Index, or CalEnviroScreen can help to inform the process. The project proponent should then work with residents and local organizations to develop strategies to address the identified needs through the provision of space, infrastructure, transportation access, programming, or other solutions. Consider creating a new social or economic use, such as one that is not available within a half-mile, to enhance the local community's access to diverse activities.

Example

In its request for proposal for a 700,000-square-foot mixed-use development in East Harlem, the New York City Economic Development Corporation requested that 50,000 square feet be set aside for local businesses and 30,000 square feet for community facilities (ISLR 2016).

Related Measures

- IC-5: Designated Space for Community-Based Organizations, Disadvantaged Businesses, and Community Assets

Anti-Displacement and Housing (AH)

Photo Credit: Mark Hogan, May 2012

Housing, equity, and climate resilience are deeply linked – especially in California. As a result of skyrocketing rents, 79 percent of extremely low-income households and over half of very low-income households in California pay more than half their income for housing, compared to 7 percent of moderate-income households (California Housing Partnership 2020a). According to the Bay Area Equity Atlas, renters who are Black, Latinx, Native American, and/or women are more likely to be rent-burdened (Bay Area Equity Atlas 2021). Black residents are less likely to own their home, and for those that do, they are more likely to have their home be systematically undervalued during appraisals—by as much as $164,000 in the San Francisco Bay Area—when compared to similar homes with similar neighborhood amenities and school districts, which in turn undermines wealth and equity building for families (Levin 2020). With home ownership being one of the primary means of generational wealth accumulation and transfer among middle-class Americans, decades of segregation and redlining have exacerbated intergenerational poverty for Black communities and other communities of color. For the U.S., homeownership rates for Black residents are about 30 points lower than those of non-Hispanic whites, and for Latinx residents, about 25 point lower (U.S. Census 2021).

High housing costs and the lack of affordable housing have other widespread impacts, contributing to the number of unhoused residents in California, higher poverty rates, and greater vulnerability to sudden shocks and emergencies. Unaffordable housing also pushes residents into aging, potentially unsanitary homes that may be more exposed to temperature extremes. Housing costs may force residents to live at great distances from their work and school, resulting in long commutes that reduce time available for family life and exercise, deteriorating physical and mental health. Thus, expanding affordable and workforce housing near job centers can also help to decrease GHG emissions, not only in cities but also in mountain towns and rural communities, where second homes and short-term rentals have exacerbated housing shortages for local residents.

The measures in this section provide recommendations to increase affordable housing in California, protect tenants, and develop additional forms of community-owned housing or supportive housing. There are many strategies and actions to support affordable housing and anti-displacement at all levels of actions, from state- and regional-level policy change to direct advocacy and assistance for tenants; the measures here are by no means comprehensive and focus on actions that may be implemented at the project level, or by the project working together with the local jurisdiction.

Key Indicators: Relevant indicators in CalEnviroScreen include Housing Burden, Poverty, and Unemployment. Relevant indicators in Healthy Places Index include Above Poverty, Employed, Homeownership, Housing Habitability, Low-Income Homeowner Severe Housing Cost Burden, and Low-Income Renter Severe Housing Cost Burden.

Cross-Cutting Guidance

While California continues to pass laws that streamline the development of affordable housing, at the time of writing rising rents, land values, and construction costs have made safe, affordable housing even more challenging. The following are recommendations to support and enhance all measures in this section.

- **Early community engagement**: Early community engagement, including with CBOs and housing advocates, is essential to these measures. Projects including affordable housing may find challenges during entitlement, and early, collaborative engagement with the community can result in a better project. Community engagement also helps to identify important housing considerations for people with children, people living with a disability or medical condition, people coming from an underserved background, and large or multigenerational families.
- **Creative financing:** Standard project financing may require a rate-of-return that may be incompatible with these measures. Patient capital, tax credits, use of non-standard parcels, grants, or other finance vehicles may be appropriate.

AH-1. Support Community Land Trusts

Under this measure, the project proponent would either set aside land or provide a donation to a local, existing community land trust (CLT), a non-profit organization that owns land in trust for the community. The size of the land or donation should depend on project size and community characteristics and be determined in consultation with the local CLT and residents living in the project area.

First developed by civil rights activists, CLTs provide a shared model of land and home ownership that takes land off the market rollercoaster of appreciation and speculation. While some CLTs have other goals, most focus on the provision of housing through affordable rentals or long-term leases as an alternative to traditional home sales. Unlike housing funded by low-income house tax credits, CLT housing will not revert to market rate after 30 years and will remain permanently affordable. Under the CLT lease model, homeowners will only earn a portion of any appreciation in property value when they leave, and the rest goes back to the CLT, helping to preserve long-term affordability (Community-Wealth.org n.d.). A true multi-benefit solution, CLT-stewarded homes are often built more sustainably and are maintained in better condition than typical low-cost rental housing, helping residents to live in a healthier environment, build wealth, and support climate resilience and racial justice.

Applicability

All projects in jurisdictions with a local community land trust. While CLTs are most common in cities, they can also be found in suburban and rural communities in California, such as the Bolinas Land Trust and Humboldt Land Trust. CLTs can also steward community-owned farms and green spaces for conservation.

Scale and Timing

- Scale: Project/Site or Neighborhood/City
- Timing: Planning

Communities or Issues Addressed

CLTs can be particularly effective for neighborhoods at risk of displacement or gentrification by placing control of land and housing directly with the community. CLTs may also be an effective solution for rural communities where tourism is changing the market dynamics of real estate. It is recommended that projects consult with CBOs, residents, housing advocacy organizations, and the lead agency to understand if they are in a community at risk from gentrification. Regional or local studies may help to identify vulnerable communities. The Urban Displacement Project provides detailed maps for the San Francisco Bay Area (including Sacramento), Los Angeles, and San Diego on neighborhoods at risk of displacement and gentrification. A nation-wide effort from the University of Minnesota similarly maps displacement and the concentration of low-income residents in economically declining neighborhoods.

Dimensions of Equity

Community land trusts can directly alleviate the high *housing burden* for low-income residents and communities of color, reducing housing costs and the risk of becoming unhoused, providing fair lending practices, and enabling occupants to build up wealth and home equity. These improvements can slowly reverse decades of racial inequity in home ownership, and lead to greater economic stability and resilience. In turn, *economic resilience* often confers greater ability for *disaster response and recovery* at both the household and neighborhood level. The cascading impacts of climate disasters, high housing costs, and systemic racism not only place communities of color directly in the path of the disaster—as with Hurricane Katrina—but they are also less likely to receive assistance from the Federal Emergency Management Agency post-disaster (National Advisory Council 2020). By increasing economic stability—starting with housing—CLTs can play a valuable role in climate resilience. With hundreds of thousands of Californians displaced by wildfires in recent years—and likely more to come—increasing community-owned, permanently affordable housing is critical to aid recovery efforts.

In addition, market-supplied housing units available to low-income renters are often in unsanitary and unsafe conditions, leaving residents exposed to air pollution, extreme heat, mold, and other climate and health hazards. In contrast, CLT homes generally are better maintained and often have energy efficiency and weatherization improvements, helping residents with utility savings and reducing GHG emissions. CLTs also contribute to *climate and social resilience* of the community through stewardship of parks, urban gardens, and other green spaces; many CLT homes incorporate renewable energy, green infrastructure, active transportation, and other sustainable elements.

Finally, CLTs help to build community power and support *community ownership*, *self-determination*, and participation by providing residents a say in land use planning and decision-making in the neighborhood.

Implementation Considerations

This measure is particularly applicable for housing or commercial developments that may contribute to rising rents and housing prices in the project area. As such, engagement with and input from organizations and stakeholders that are representative of the project area are especially important. Project proponents are recommended to consult with the CLT and community stakeholders on the ideal location, size, and other characteristics of the land to be donated. In areas without an established community land trust, project proponents could consider contributing to seed funding or start-up funding that could be held by the lead agency to support nascent efforts.

Examples

In its home renovations, the Community Land Trust Association of West Marin makes energy efficiency and weatherization improvements and installs induction cooktops, hybrid water heaters, grey water recycling, and other sustainability features. It also built California's first new passivhaus, which are highly efficient and uses minimal energy, instead relying on passive heating and cooling from the environment. The Beverly/Vermont Community Land Trust in Los Angeles exercises land stewardship to create permanently affordable, sustainable, and low-impact housing in pedestrian-centered neighborhoods, including the Los Angeles Eco Village.

Resources

- The California Community Land Trust Network is a group of over 25 community land trusts across California, helping to support new and existing CLTs.
- The Grounded Solutions Network provides a resource library containing toolkits, case studies, reports, and decision guides to support CLTs and other inclusive housing policies.

Related Measures

- AH-6. Support the Formation of Collective Ownership Models: Limited-Equity Housing Cooperatives or Mutual Housing Associations

AH-2. Promote Affordable Housing in Transit-Rich Areas

Increasing affordable housing in transit-areas can help support wealth-building, mobility, and economic resilience for low-income residents, while also reducing GHG emissions and improving air quality. As a result of high housing prices in California, many low-income households live far from work or school, commuting hours from the outskirts of urban areas and job centers. Yet the trade-off is that transportation expenses—the cost of car ownership, maintenance, and operations—may erode or negate any savings on housing costs. Households in auto-dependent neighborhoods spend 25 percent of household income on transportation costs, but in neighborhoods with a variety of mobility options, including transit, transportation drops to 9 percent of budgets (HUD 2014). Affordable housing near transit, thus, can help save residents money as well as time. Data from the California Household Travel Survey shows that low-income households drive 25 to 30 percent less when living within a half mile of transit, and 50 percent less when living within a quarter mile of frequent transit, in comparison to households at the same income level living far from transit (Transform and California Housing Partnership Corporation 2014). This reduction in vehicle miles traveled can translate into savings in gas, vehicle ownership, and maintenance costs—which range from $6,000-$12,000 per year (HUD 2014).

In selecting sites and locations, multi-family affordable housing projects should opt for locations within a half-mile of existing transit stations and implement transit-supportive measures such as limiting onsite parking supply, building safe and comfortable bike lane and sidewalk connections to transit, and providing subsidized transit passes for residents. Cities and counties that own land within a half mile of transit stations should prioritize these locations for affordable housing development.

Applicability

Urban communities with a robust, frequent transit network.

Scale and Timing

- Scale: Neighborhood/City and Project/Site
- Timing: Planning

Communities or Issues Addressed

This measure would help to support low-income residents, particularly those who are unable to drive, whether for reasons of income, ability, or age. Nationally, only about 18 percent of people earning less than $35,000 per year own a car (HUD 2014).

Dimensions of Equity

By reducing both housing and transportation costs for low-income households, affordable housing near transit can help to build *economic resilience*. In addition, transit can free up *mobility choices* and destination access for residents, especially for families with multiple working adults, school-age children, and only one vehicle. Decreased auto usage can also reduce GHG emissions, improve *air quality,* and support walking and *active transportation,* supporting *physical health* for residents.

Implementation Considerations

Strategies to help incentivize affordable housing include increasing density allowances, eliminating or reducing parking requirements for transit-oriented development (saving on costs while enabling increases in building footprint), and establishing a transit-oriented development fund. Because transit is typically viewed as a neighborhood amenity, proximity to transit typically increases market rates by up to 20 percent for residential properties and 23 to 120 percent for commercial properties (National Center for Sustainable Transportation 2017). Thus, it may be possible for proponents to subsidize affordable housing units with market-rate housing and commercial leases.

Potential funding programs to support affordable housing near transit include the Strategic Growth Council's Affordable Housing and Sustainable Communities Program, the California Department of Housing and Community Development's Transit-Oriented Development Housing Program and Infill Infrastructure Grant, and regional funding sources such as the Bay Area Transit-Oriented Affordable Housing Fund.

Example

Recognizing that transportation costs are a significant burden for low-income families, San Jose-based First Community Housing chooses to not only site its affordable, sustainable housing developments near transit stations, but also to provide free, annual Valley Transportation Authority (VTA) Eco Passes to all residents at its 14 properties in Santa Clara County (FCH 2014). The passes provide unlimited trips on bus and light rail services operated by VTA. Surveys and studies show a high utilization rate for the Eco Pass, ranging between 40 and 90 percent across the housing developments. Not surprisingly, housing sites closest to light rail stations had the highest utilization rates. Between 29 and 76 percent of residents also reported choosing public transportation over driving for specific trips. Many residents commented on the helpfulness of the Eco Pass, noting that their families relied primarily or solely on transit for their mobility needs. Benefits for residents include more affordable commutes, a greater likelihood of walking (and thus increased fitness), and financial savings on vehicle operations and maintenance costs. Public benefits include reduced GHG emissions, air pollution, and traffic.

In addition, the studies also conducted parking counts, finding that 17 to 63 percent of parking spaces were always free at the housing sites. This, in turn, helped to convince the City of San Jose to reduce its parking requirements for senior housing from 1 per unit to 0.67—a significant savings for developers, as parking construction costs between $15,000 to $50,000 per space in Silicon Valley. What is more, First Community Housing is analyzing the potential of converting some of the excess parking spaces into low-impact designs, featuring pervious pavers, bioswales, and raingardens. These solutions—the direct outcome of supporting transit access by low-income residents—thus can also benefit climate resilience by reducing paved surface areas and the UHI effect, filtering stormwater, and supporting native habitat.

Resources

Transform's GreenTrip Connect tool allows residential multifamily developments in California to estimate how affordable housing can help to reduce vehicle miles traveled and GHG emissions. While it does not specifically focus on projects located near transit stations, users can set the project location near transit and determine the effects of increasing affordable housing units, reducing parking spaces, and providing subsidized transit passes and rideshare program membership, in comparison to the city or county average. GreenTrip Connect will also estimate residential savings in terms of transportation costs and developer savings for avoided parking spaces.

AH-3. Protection for Existing Tenants of Redevelopment Projects

Redevelopment or rehabilitation of existing housing developments can be more sustainable than new construction, while also helping to provide more energy efficient, healthier, and improved housing conditions for residents. When existing affordable or low-income housing developments are redeveloped, the project should aim to help protect existing tenants and avoid displacement. The scarcity of affordable housing makes it challenging for residents to find alternative, equivalent housing near their workplace, family, or school. Residents in affordable housing units may also have fewer resources to enable them to relocate to another region or city, and relocation generally disrupts existing social networks and communities.

To avoid displacement, the project proponent can adopt the following best practices.

- Right to return: Existing residents should have the right to return to the affordable housing site after redevelopment and/or the first right of refusal.
- Relocation assistance: Existing residents should be offered fair compensation or relocation assistance and funding if they must vacate their homes temporarily during construction, or permanently. Relocation assistance programs should aim to ensure existing residents are equipped with the necessary resources, support, and information throughout the moving process.
- Temporary housing: The project proponent should endeavor to provide temporary housing near the original site at similar costs and quality.

Applicability

Projects involving the removal or demolition of existing housing units.

Scale and Timing

- Scale: Project/Site
- Timing: Planning, operations

Communities or Issues Addressed

Existing tenant protections can be particularly effective for affordable housing developments in neighborhoods at risk of displacement or gentrification, as well as rural communities where the market dynamics of real estate are evolving. The project should consult with CBOs, residents, housing advocacy organizations, and the lead agency to understand if they are in a community at risk from gentrification. Regional or local studies may help to identify vulnerable communities. The Urban Displacement Project provides detailed maps for the San Francisco Bay Area (including Sacramento), Los Angeles, and San Diego on neighborhoods at risk of displacement and gentrification. A nation-wide effort from the University of Minnesota similarly maps displacement and the concentration of low-income residents in economically declining neighborhoods.

Dimensions of Equity

Providing protections for existing residents can help to maintain a community's social fabric and network, helping to build and maintain *social resilience*. These protections can also help to buffer residents from high real estate costs and scarcity, reducing the risk of becoming unhoused and reducing housing burdens. Housing stability in turn translates into *economic resilience* and generates greater preparedness for disaster response and recovery at both the household and neighborhood level.

Implementation Considerations

An unplanned relocation from one's residence on another party's timeline is always disruptive and rarely easy. The project proponent should communicate all plans and timelines with residents in the existing development as early as possible, seek resident feedback, and work with residents to address issues and concerns. Households should receive a case manager to assist with the relocation process. If providing temporary housing, the project proponent should also develop clear options as early as possible and present them to residents for feedback. Permanently displaced residents should receive additional assistance and benefits.

Example

The Sacramento Housing and Redevelopment Agency (SHRA) is demolishing and rebuilding the 1940s-era, low-income Dos Rios housing project into a larger mixed-income housing development, renamed Marisol Village. The redevelopment process will fully replace the 218 very-low-income and low-income units and add another 280 affordable workforce and higher-end units. During the demolition and construction process, the proponent will provide relocation assistance for residents to relocate for at least 24 months. A case manager was assigned to each family to assist with relocation to either another SHRA-managed housing project or other alternatives with housing vouchers. If any residents are permanently displaced, they will receive permanent relocation assistance and benefits. While all 218 low-income units will be replaced, only the first 140 units in the initial phase will be offered to former residents. They will retain the same rents, set at a percentage of income. Other project additions will include a bike trail, community garden, 500 trees, a park, and electric vehicle car share. The project is funded by several federal and state grants, including a Transformative Climate Community grant from the Strategic Growth Council, and will be fully complete in 2024.

AH-4. Incorporates Permanent Supportive Housing

The needs of certain underserved groups are often overlooked when developing housing units. Specifically, people who are currently or formerly unhoused, people living with a mental illness, people who want support with substance use issues, people who are living with chronic medical conditions or disabilities, the elderly, people with young children, people living with large families or multigenerational households, and members of the LGBTQIA+ community can benefit greatly from having onsite services. Permanent supportive housing helps to meet these needs by combining affordable housing with case management and permanent supportive services designed to help people remain permanently housed. For instance, supportive housing projects can allocate space for a community center where residents can engage with health programs, mental health services, job-seeking assistance, educational classes, and childcare services. Services are to be provided permanently, and all tenants may live in their homes and use services if they meet the basic obligations of tenancy. The types of services provided may vary depending on the local community's demonstrated needs and priorities, with the primary goal of keeping tenants housed.

Applicability

Residential projects.

Scale and Timing

- Scale: Project/Site
- Timing: Operations

Communities or Issues Addressed

For everyone, a stable home is foundational. For some of the most vulnerable groups in the state, affordable housing coupled with support services is a necessity. From mental health services to childcare, when it comes to maintaining housing and living in a healthy environment, onsite, multi-disciplinary services help tenants address a variety of challenges. For instance, in Santa Clara County, a study found that 86 percent of unhoused individuals randomly assigned to a permanent supportive housing program remained housed and needed fewer emergency psychiatric services (Kurtzman 2020). Similarly, a comprehensive literature review of permanent supportive housing found significant reductions in use of medical emergency services and mental health crisis services, hospitalizations, substance use, and days incarcerated, as well as increases in quality of life, social network size, and use of outpatient medical services (CSH 2020).

Notably, because of the reductions in use of emergency and crises services, permanent supportive housing is far less costly than traditional spending on services for the unhoused. In Orange County, individuals in permanent supportive housing had 78 percent fewer ambulance transports and 100 percent fewer arrests in comparison to those who are unhoused. As a result, costs per capita for permanent supportive housing residents were 50 percent lower ($51,587) than for the unhoused ($100,759), with higher benefits for individuals who are more unwell (Snow and Goldberg 2017). As this number totals nearly $300 million in Orange County annually, permanent supportive housing can provide substantial savings for public agencies and non-profit organizations.

Dimensions of Equity

By directly addressing challenges for underserved groups, supportive housing services have the potential to enhance a community's *affordable housing* quality, *public health*, and *social resilience*, boost *employment*, and address key determinants of *poverty*.

Implementation Considerations

- Leverage expertise of local CBOs to help develop supportive housing and/or to become service providers at the project site during operations.
- Ensure that housing and services are affordable, with tenants paying no more than 30 percent of their income toward rent/utilities/services.
- Collaborate with CBOs and community groups to determine specific needs.

Example

Permanent supportive housing has a proven record in helping unhoused residents. In Orange County and Sacramento, Jamboree Housing operates six permanent supportive housing developments, providing homes to over 475 residents who had been unhoused (Jamboree 2021). The housing properties provide units of different sizes, as well as veteran-designated and Mental Health Services Act (MHSA) Housing Program-dedicated units. One of the properties is California's first 100 percent MHSA property. Three of the developments are integrated into standard affordable housing, but all offer onsite services including 24/7 full-service clinical services, vocational training, life skills training, support groups, and community alliances, referrals, and liaisons. In Irvine, one property, Doria, is developed in conjunction with the Irvine Community Land Trust and provides both affordable workforce housing and permanent supportive housing within an upscale master-planned community – exemplifying integrated housing across all income classes. The outcomes include significantly reduced hospitalizations for both physical and mental conditions, reduced incarceration and contacts with the criminal justice system, higher housing retention rates, and improvements in health, financial stability, work skills, and education.

AH-5. Make Housing Units Permanently Affordable

This measure calls for the project proponent to ensure affordable housing units are permanently affordable for low-income residents. Many affordable housing units in California eventually flip to market-rate as affordability restrictions expire. The project proponent should pursue strategies to guarantee affordable housing is maintained.

Permanent affordability can be achieved by engaging with alternative housing models (*community land trusts* and *limited-equity housing cooperatives*) and deed restrictions.

In creating long-term affordable housing units, the project proponent, government agency, or nonprofit subsidizes homeownership for low- and moderate-income homebuyers by investing public and/or private funds to reduce the purchase price of the housing unit. Homebuyers then agree to requirements to preserve the affordability of the unit for future families. These requirements can take the form of resale price restrictions (typically a specified percentage of any increase in value, plus the original cost of the property and any additions they have made), and a requirement to sell to other low- or moderate-income households.

Applicability

Residential projects.

Scale and Timing

- Scale: Project/Site and Neighborhood
- Timing: Planning, operations

Communities or Issues Addressed

The California Housing Partnership (2020b) estimates that even before COVID-19, 1.3 million low-income households in California lacked access to affordable homes. Increasing and preserving affordable housing supply is an utmost priority for the state.

Dimensions of Equity

Enhancing a community's stock of affordable housing has important implications for *economic resilience, social resilience, public health,* and *poverty* levels.

Implementation Considerations

- To preserve affordable housing, project proponents should consider other alternative housing models, especially those that *support collective ownership* and *community land trusts.*
- Partner with local CBO to manage affordable housing programs and consider the following strategies (Stromberg and Stromberg 2013):
  - Provide pre- and post-purchase education for potential homebuyers.
  - Provide financial counseling.
  - Provide other homeownership assistance services.
- Important considerations for deed restrictions.
  - Important considerations when using deed restrictions to limit resale prices:
    - Specify required length of affordability and affordability level.
    - Determine how resale price will be calculated.

    - » Specify the entity (typically a public agency) entitled to the difference between the sales price and the restricted resale price if an income-qualified buyer cannot be found.
    - » If there are restrictions for local workers, ensure the program is eligible to all people who work in a certain geographic area, including immigrants.
  - Design deed restriction programs to prevent the conversion of housing units to market rate in the event of foreclosures.
    - » This event occurs when the deed restriction is placed in a subordinate position to the interests of the primary lien holder (issuer of the primary mortgage) which allows a deed restriction to be cancelled under a foreclosure.
    - » Detail protections for buyers if the price of the housing unit declines.
    - » Determine the treatment of capital improvements as well as deferred maintenance at resale.
- Detail provisions for repayment of any secondary financing benefiting a public agency.
- Specify owner-occupancy requirements and/or restrictions on rentals.
- Detail property transfer process.
- Outline involuntary sale or transfer procedures.
- Outline processes for the addition of parties to title by marriage or domestic partnership.
- Detail hazard insurance and property tax requirements.
- Identify provisions for subordination of the agreement, refinancing, and home equity loans.
- Buyer's consent to the option to purchase.
- Detail default events that trigger the Option to Purchase or foreclosure.
- Define the affordability rate of housing units: Detail the income levels targeted (e.g., 80 percent area median income [AMI], 60 percent AMI, 30 percent AMI) and the number of units allocated to each income level. (Marshall, Kautz, and Higgins 2006)

Examples

The Vail, Colorado, Housing Department found that 90 percent of sales from locally owned homes were purchased by a second home/vacation property owner. Vail also found data demonstrating that these second homes and vacation properties are rarely purchased by residents, revealing a housing market trending toward pricing out local wage earners. To address this problem, the Vail Town Council and the Vail Local Housing Authority launched the VailInDEED program in 2017. This program uses taxpayer funds to purchase deed restrictions to protect and preserve existing housing for use by residents. Since its launch, the program has secured approximately 140 new deed restrictions for the Vail community. In total about 270 Vail residents have been assured of the affordability of their homes (Urban Land Institute 2020).

Grappling with a similar challenge of rising housing costs limiting availability for local workers, Placer County is developing a similar program, as 90 percent of homes in eastern Placer County—by Lake Tahoe—are owned by second homeowners. Due to launch in 2021, the Workforce Housing Preservation Program will pay homeowners to deed restrict their homes so that only local workers can purchase or rent them (County of Placer 2021). Participants must work at least 30 hours a week at a job within 20 miles of the deed-restricted residence; income eligibility is capped at 120 percent of the average median income, or about $103,000 for a family of four. The income and geographic limits are higher in eastern Placer County due to its significantly higher housing costs.

Related Measures

- AH-1. Support Community Land Trusts
- AH-6. Support the Formation of Collective Ownership Models: Limited-Equity Housing Cooperatives or Mutual Housing Associations

AH-6. Support the Formation of Collective Ownership Models: Limited-Equity Housing Cooperatives or Mutual Housing Associations

This measure calls for proponents to build and operate housing units as limited-equity housing cooperatives, mutual housing associations, or resident-controlled units. These collective ownership models serve as effective strategies to center the needs of residents and have the potential to bolster a community's stock of affordable housing.

Limited-Equity Housing Cooperatives

In a limited-equity housing cooperative, residents form a corporation and share ownership of a building. Cooperative members pay dues and work together through democratic decision-making to reach mutual goals. Limited-equity housing cooperatives can offer permanently affordable homeownership opportunities for low- and moderate-income families. Under this system, residents are shareholders of their cooperative, and they purchase a share of stock in the cooperative entitling them to occupy one housing unit, instead of directly buying the housing unit. Restrictions on share resales ensures that affordability is maintained from one resident/shareholder to the next.

Mutual Housing Associations

Mutual housing associations are non-profits that have a board that includes residents, future residents, and representatives of the public and private sectors. They manage their own developments and work toward goals of expanding affordable housing supply, providing public goods by investing in the local neighborhood, and ensuring quality of life for residents. Residents lease housing from the mutual housing association.

Applicability

Residential projects.

Scale and Timing

- Scale: Project/Site or Neighborhood
- Timing: Planning, operations

Communities or Issues Addressed

Increasing the supply of affordable housing with collective ownership structures can help alleviate the declining stock of affordable housing across California. Collective ownership structures help make housing affordable for low-income people by removing property from the speculative real estate market.

Dimensions of Equity

Collective ownership structures help improve the *economic resilience* of residents and democratize residential decision-making power which enhances *community ownership* and *self-determination*.

Implementation Considerations

- Organize ownership structures in collaboration with prospective low- and moderate-income residents. Tailor the ownership structure based on community capacity and priorities. For instance, consider a merger between a community land trust and a limited-equity cooperative for a more robust shared equity model.
- Consider partnering with CBOs or existing community land trusts to manage resident recruitment/community building and to provide housing support services. Limited equity housing cooperatives require strong fiscal and organizational support to succeed. Leverage existing experience from local community organizations to ensure sustained support.
- Resident participation is fundamental for a cooperative's success. Ensure real estate educational resources are provided and residents are supported.
- For limited equity housing cooperatives, develop a workable limited equity formula to determine affordable share purchase and resale prices in the long term.

Examples

Limited Equity Housing Cooperatives

Originally completed in 1985, Dos Pinos is a limited-equity housing cooperative on a 4-acre parcel in the Senda Nueva neighborhood of North Davis. The cooperative has approximately 60 units and is governed by an elected seven-person Board of Directors. To become a voting member of the cooperative, a person purchases a share or membership certificate in the cooperative housing corporation. This share grants the person the exclusive right to occupy one dwelling unit in the cooperative and sign an occupancy agreement. Residents pay a monthly carrying charge that covers the cooperative's general operating costs.

Shares cannot be resold for more than the maximum transfer value (MTV) for that unit. MTV is equivalent to the sum of the following: the value of the share at time of purchase, annual increases in the share's value over the span of a member's residency, and the depreciated value of any permanent improvements (which are approved by the board) made during residency. When a member notifies the Board of their intent to move out, Dos Pinos has the right of first refusal to re-purchase the share. If Dos Pinos does re-purchase, it sells it to the next person on a waiting list.

A study from the Urban Institute found that Dos Pinos has effectively provided affordable homeownership opportunities since its formation. Across 276 sales, the Dos Pinos cooperative's median share price provided homeownership opportunities for households with incomes below the area median. Additionally, during a period when the Sacramento area's housing market underwent substantial appreciation, the cooperative units at Dos Pinos were successful at retaining and in some instances increasing their affordability (Temkin et al. 2010).

Mutual Housing Association

In 1988 Mutual Housing was incorporated as a partnership between neighborhood residents, business representatives, housing advocates, and local government in Sacramento. The locally controlled nonprofit owns and operates 1,071 homes, including communities designed and built by Mutual Housing on vacant infill lots and other communities built from rehabilitated housing stock.

The nonprofit provides residents numerous supportive programs such as a digital literacy program, which provides free Internet access to all residents and offers trainings at onsite computer labs. Mutual Housing also offers various community-specific financial capability programs that provide financial mentoring, group workshops, peer lending circles, and youth financial coaching.

Mutual Housing provides leadership development support to resident leaders to help them identify needs for additional programs to uplift vulnerable individuals and address community-specific gaps. Examples of such activities include community gardening and nutrition, after-school tutoring, English and citizenship classes, disease prevention, and senior exercise classes. Importantly, resident leaders also serve on Mutual Housing's board of directors (Mutual Housing 2021).

Community Land Trust/Limited-Equity Housing Cooperative Hybrid

Established in 1989, the Lopez Community Land Trust uses the ground lease mechanism of CLTs coupled with the limited equity cooperative model of housing to serve the rural island community of Lopez Island, Washington. The hybrid organization is structured as a nonprofit and acquires land and develops housing for residents earning no more than 120 percent of the area median income.

Homes are owned by the limited equity housing cooperative, which leases the underlying land from the CLT. Prospective homeowners purchase shares from the cooperative (granting them the right to occupy homes), sign an occupancy agreement, and become voting members of the cooperative. Importantly, the housing cooperative holds both the title to the property and the mortgage, with residents making monthly payments to the cooperative to cover their share of the mortgage, property taxes, and other maintenance fees. This set up allows the Lopez Community Land Trust to offer housing to people who may not have the credit history needed to secure a mortgage on their own, as many underserved communities lack access to quality banking and credit infrastructure.

Because the cooperative is directed by residents, there is the inherent risk that members might vote to opt out of affordability restrictions. The CLT protects against this risk by incorporating affordability protections into both the ground lease and the occupancy agreement to help ensure lasting affordability. The CLT also provides supportive services such as first-time homebuyer classes, homeownership counseling, and training in cooperative governance (U.S. HUD OPD&R 2012).

Resources

The California Center for Cooperative Development supports cooperatives across California with start-up, management, and technical assistance, and provides education on how cooperatives can generate economic growth and home ownership in low-income and underserved areas.

AH-7. No Net Loss of Affordable Housing Units/One-For-One Affordable Housing Policies

This measure encourages proponents to preserve affordable housing stock by replacing all affordable units demolished on a one-for-one basis. This strategy is designed to result in a no net loss of affordable housing units for each of the very low-, low-, and moderate-income levels. No net loss/one-for-one replacement strategies ensure that the total number of affordable units within a community does not decline over time and help safeguard against the acquisition and conversion of low-income units into luxury units.

Applicability

Residential projects redeveloping affordable housing.

Scale and Timing

- Scale: Neighborhood/City
- Timing: Planning, construction

Communities or Issues Addressed

The conversion of existing affordable housing units into condominiums and luxury housing presents a clear threat to the already dwindling affordable housing supply.

Dimensions of Equity

As strategies to preserve *affordable housing* supplies, no net loss/one-for-one policies serve as valuable assets to the overall *social resilience* of the local community.

Implementation Considerations

- Build affordable housing replacement units prior to the demolition of existing affordable units.
- Provide strong relocation assistance to help displaced residents find housing.
- Consider Enhanced Infrastructure Financing Districts to help finance the construction/rehabilitation of public and certain types of private infrastructure.
  - Funding from enhanced infrastructure financing districts can help subsidize the development of moderate-, low-, and very low-income housing units.
- Ensure that housing units are *permanently affordable*.

Example

In its redevelopment of the 1940s-era Dos Rios public housing project into mixed-income housing, SHRA has committed to fully replacing the 218 very low-income and low-income units that will be demolished. In addition, it will add 280 affordable workforce and higher-end units. While all 218 low-income units will be replaced, only the first 140 units in the initial phase will be offered to former residents. They will retain the same rents, set at a percentage of income.

Related Measures

- AH-3. Protections for Existing Tenants of Redevelopment Projects

Climate Resilience (CR)

Photo Credit: m., June 2010

Environmental justice communities are at far greater risk to the compounding impacts of climate change than other California communities. As recently experienced during California's catastrophic wildfires, communities of color and low-income communities have been on the frontlines of climate change and extreme weather, living in neighborhoods more likely to flood, living in older homes in high wildfire-risk areas, working jobs that leave them exposed to wildfire smoke—and critically, lacking access to resources, disaster relief, and other assistance needed to bounce back and recover. While it is true storms and wildfires do not differentiate in their destructiveness, wealthier communities are often better protected with infrastructure, live in more resilient homes, and have access to information systems, transportation options, insurance, savings, and other resources that enable them to access information, evacuate quickly (to a hotel or another area), and to recover and rebuild. Marginalized communities, on the other hand, may not receive critical emergency alerts, or may not receive it in a language they know, and may have functional or access needs that slow down evacuations. Without documentation and insurance, residents may have a difficult time accessing state or federal disaster relief assistance and may not be able to recover losses. For example, after the Thomas fire in Ventura and Santa Barbara counties, local immigrant rights and environmental justice groups provided essential services to communities not served by recovery efforts, which focused on privileged communities. These services included providing access to emergency information in Spanish and Indigenous languages; farmworker labor protections; and a private disaster relief fund for undocumented immigrants ineligible for federal aid.

The greater risks and exposures of environmental justice communities are not just the outcome of present-day decisions, however, but rather have their roots in historic decisions. Homes in formerly redlined neighborhoods are 25 percent more likely to be flooded today. As a result of low-income communities and communities of color being designated as risky for lending in the 1930s, they are now truly at risk of climate hazards. While cities invested in sewers, levees, and other infrastructure in formerly greenlined, predominantly white neighborhoods, systemic racism that drive investment decisions left poorer communities and communities of color exposed. Unfortunately, the floods, wildfires, storms, and other disasters California faces today have the potential to be much more severe and destructive.

Thus, it is critical that new growth and development takes place in a way that enhances resilience in the surrounding community, particularly in neighborhoods that have faced systemic disinvestment and racism in the past. By building in a way that enhances climate resilience and adaptive capacity, new growth has the potential to protect its neighborhood—as well as itself—from future impacts of climate change. A project's resilience is tied to its surrounding community; if a commercial building is surrounded by flooded roads, its employees cannot come to work, and nor can it receive deliveries or welcome customers. Recognizing that the long-term resilience of a business or a project is inherently dependent on its surrounding community can help to encourage project proponents to undertake improvements and investments to build overall responsive capacity to floods, wildfires, poor air quality, drought, extreme precipitation, sea-level rise, and other climate hazards.

It should be noted that most of the climate adaptation and risk reduction measures, of which many address equity and vulnerable communities, are in Chapter 4, *Assessing Climate Exposures and Measures to Reduce Vulnerabilities*. Chapter 4 provides guidance on evaluating climate risks, exposures, and vulnerability, and provides measures to increase resilience. This section provides a more detailed description on three particular risk reduction measures that can be incorporated as part of project design and land use planning at the jurisdictional level.

Key Indicators: Many factors increase both physical and socio-economic vulnerability to climate change impacts. Relevant CalEnviroScreen indicators include: Ozone, PM2.5, Cleanup Sites, Asthma, Cardiovascular Disease, Housing Burden, Linguistic Isolation, Poverty, and Unemployment. Relevant Healthy Places Index indicators include: Above Poverty, Employed, Median Household Income, Automobile Access, Park Access, Tree Canopy, Clean Air – Ozone, Clean Air – PM2.5, Homeownership, Housing Habitability, Asthma, Coronary Heart Disease, Chronic Obstructive Pulmonary Disease, Disabled, Cognitively Disabled, Physically Disabled, Extreme Heat Days, Wildfire Risk, Population in Sea Level Rise Inundation Area, Children, Elderly, English Speaking, Outdoor Workers, Air Conditioning, Impervious Surface Cover, Urban Heat Island Index, and Race/Ethnicity.

Cross-Cutting Guidance

For an issue as big as climate resilience, it is imperative that local jurisdictions take the lead, leveraging their resources and tools to facilitate local action to deal with this global problem. It is recommended that users consider the following actions.

- **Adopt ordinances that facilitate resilience**: Whether requiring enhanced air filtration for publicly owned assembly buildings or adopting an Urban Agricultural Incentive Zone (California Government Code section 51040 et seq.), the jurisdiction should adopt policies that further resilience.
- **Understand community priorities**: Each community is likely to have their own vulnerabilities and exposures to climate impacts, as well as their own strengths and adaptive capacities. Outreach is critical to understand how climate hazards and changing conditions will impact each community, and the highest priority resilience measures.

CR-1. Adapt and Re-Use Vacant Lots for Green Infrastructure

As precipitation extremes are likely to increase because of climate change, stormwater inundation, localized flooding, and even severe flooding will become a greater risk for many communities. Coastal communities may also be at risk of king tides and storm surges that lead to localized flooding. Greening vacant lots and brownfields in cities can help manage stormwater and reduce UHIs, while also providing other community and social benefits based on specific designs and community goals. This measure can be especially beneficial in underserved communities where investment in traditional grey infrastructure is lacking. While grey infrastructure focuses on directing water away from the city, green infrastructure approaches the city as a sponge, with hundreds of points to absorb and hold water (Newman 2019). This can be considered a form of "urban acupuncture", a concept developed by UC Berkeley architecture professor Nicholas de Monchaux, treating many disparate locations across the urban environment to turn brownfields and vacant lots into public green spaces that can provide additional benefits such as job training, healthy foods, and social wellbeing (Maclay 2016).

Some 17 percent of land in U.S. cities are vacant, with many vacant lots being oddly shaped, small, disjointed, or having less-desirable locations. These lots are challenging to develop for commercial purposes. As such, there is significant potential to repurposing them for regenerative and climate-resilient purposes. Vacant lots can be adapted into urban gardens, bioswales, rain gardens, cisterns, small parks, and other community-serving green spaces.

Project proponents should be encouraged to contribute a small percentage of project costs to redeveloping adjacent or nearby vacant lots into climate-resilient green infrastructure. This can help to benefit the project itself by reducing stormwater run-off, beautifying the neighborhood, reducing the UHI effect, and discouraging crime.

Applicability

Projects located in urban and suburban areas.

Scale and Timing

- Scale: Neighborhood/City and Project/Site
- Timing: Construction

Communities or Issues Addressed

This measure is applicable for communities that experience localized flooding or stormwater surges or have a high amount of paved surfaces and high UHI effect.

Dimensions of Equity

Transforming vacant lots into gardens, parks, and other green infrastructure can support improved *air quality* and reduced UHIs. Improvements can also be planned to incorporate cisterns or detention ponds to capture stormwater, providing *climate resilience* against both drought and flooding. Community gardens can also help to boost food security and encourage *community ownership*, as well as economic opportunity if combined with pop-up markets or food businesses. The use of native plants or pollinator-friendly plants can also support biodiversity and habitat. Turning vacant lots into cared-for spaces can also help to decrease littering and crime, and encourage more civic engagement, recreation, and *social resilience.*

Implementation Considerations

There are numerous ways for vacant lands to be transformed and designed to fit a variety of climate challenges as well as community goals. The project should work closely with community members, stakeholders, and coalitions on site selection and design to ensure alignment with local priorities and goals.

Examples

In de Monchaux's analysis of transforming vacant parcels for climate resilience in the Los Angeles River Basin, a crowdsourcing and community engagement effort identified over 700 candidate sites. The analyzed improvements included drought-resistant landscaping, stormwater retention and filtering, shade trees, and shade gardens. The study estimated that all the proposed improvements together could absorb a million gallons of stormwater and save 13.1 gigawatt-hours of electricity through UHI reductions (Maclay 2016). A single site alone could save 980 kilowatt-hours of electricity a year. In another analysis focusing on the City of San Francisco, de Monchaux estimates that the city could save the millions that it currently spends on sewer work and stormwater management costs by transforming 1,500 vacant and under-used sites.

On the implementation front, Ron Finley, the self-styled "gangsta gardener," and L.A. Green Grounds helped turn dozens of unused and vacant lots in South Central Los Angeles—an area with many fast food outlets but little fresh food—into productive food gardens (Weston 2020). The gardens help to cultivate community ownership and youth engagement, in addition to fresh produce.

Resources

Various tools exist to help calculate and compare benefits across various sites. These include the following.

- Landscape Performance: This compendium of resources from the Landscape Architecture Foundation contains a toolkit, case studies, and resources to help evaluate the benefits of nature-based solutions. The resources can be filtered by benefit (stormwater management, access and equity, habitat, economic development, et cetera) or by feature (food garden, permeable paving, play equipment, et cetera). The toolkit library contains calculators and tools from a range of leading organizations to help quantify the ecological benefits.
- Center for Neighborhood Technology, Green Values Stormwater Management Calculator: This easy-to-use calculator can estimate the stormwater management benefits of a wide range of green infrastructure solutions. It provides both national defaults as well as customizable values for land use types, and calculates volume of stormwater captured, runoff volume, costs, and benefits such as reduced energy use, air pollutant reduction, and increased real estate value.
- Compared to vacant lots, brownfields will require additional remediation; the *U.S. EPA's Climate Smart Brownfields Manual* offers a guide to planning, environmental assessments, and remediation for brownfields, with the ultimate goal of redeveloping to include green infrastructure, community-owned open space, and other climate-resilient uses.

Related Measures

- IC-4. Enhanced Open and Green Spaces
- IC-8. Enhanced Access to Community Resources

CR-2. Support the Development and Operations of Community Resilience Centers

Climate-exacerbated hazards and disasters are likely to compound existing vulnerabilities, challenges, and hazards for both individuals and communities. With increasing extreme weather events, wildfires, and other worsening natural disasters, it becomes critical to develop and establish local resilience centers that can support the needs of the surrounding community—as well as potentially evacuees—at short notice, and for potentially extended periods of time.

Local jurisdictions and project proponents can assist in this effort by anticipating how its structures and land uses can be adapted to serve as resilience centers or provide emergency services. Commercial developments or multi-family residential developments with a public space or community room could consider ensuring that they are equipped with MERV-13 or higher rated air filtration systems, for example, to serve as a clean air center during wildfire smoke events. Larger developments could consider onsite solar PV systems coupled with battery storage to provide emergency power. Multi-family developments should identify residents that have electric-powered medical devices at home or would require interpretation or mobility assistance during emergencies. Disaster preparedness training, supplies, and other capacity-building activities are also important components of developing a community resilience center.

Additionally, local jurisdictions and projects could also partner with established CBOs to develop facilities that can serve as resilience centers or hubs, as part of a community benefits agreement (see *CCD-5. Establish a Community Benefits Agreement*). This could entail retrofitting an existing community center, place of worship or religious center, school, or cultural hub with air filters, cool roofs, building weatherization, and/or back-up power. This approach has the benefit of establishing the resilience center in a space already known and comfortable to the community.

Applicability

Urban, rural, and suburban communities.

Scale and Timing

- Scale: Neighborhood/City and Project/Site
- Timing: Construction, operations

Communities or Issues Addressed

This measure is applicable for all communities, but particularly those that are marginalized and may have fewer resources or less capacity to respond to unexpected disasters or hazards. Existing and projected climate hazards should also be considered using Cal-Adapt.

Dimensions of Equity

By helping to develop and establish community resilience centers, the project proponent can help to support overall *climate resilience* and community well-being during severe weather, extreme heat, wildfire smoke events, and other disasters and hazards. This can in turn help to mitigate and reduce the burdens of *disaster response* and recovery. In addition, community resilience centers can help to support *public health, equity, social resilience,* and *community ownership* and *empowerment*.

Implementation Considerations

Implementation specifics will depend on the location of the project, the surrounding community's existing challenges and needs, and the existing and future climate hazards likely to arise. Generally, partnering with an existing CBO can assist in understanding and identifying existing opportunities and vulnerabilities. A community benefits agreement can also help determine implementation specifics. In addition, creative, non-traditional community outreach and engagement strategies are critical to ensure that community members are aware of and use the resilience centers.

Example

The City of Berkeley's community resilience center program provides emergency supplies, tools, resources, and training to organizations to serve as hubs before, during, and following disasters. The organizations, which include multifamily housing complexes, a community college, and community-based, youth, religious, and cultural organizations, help to provide information and engagement with their audience and membership, and will help to support the community during emergencies.

Related Measures

- CCD-5. Establish a Community Benefits Agreement

CR-3. Passive Survivability

Over 2.7 million Californians were left in the dark when Pacific Gas and Electric Company and other utilities instituted extended blackouts to reduce wildfire risks in October 2019 (Botts 2019). Although entire cities lost power, the most impacted were low-income communities, people living with disabilities, and the elderly (Chabria and Luna 2019). Residents with money and resources are better able to escape to hotels, replace spoiled food, access generators, and maintain communications. For vulnerable communities, losing an entire refrigerator of food or being forced to upgrade cell phone plans to better access data can cause economic disaster. For those who rely on medical equipment, power outages can be life threatening. When the power outages caused schools to shut down, children who rely on school meals were left behind.

As underserved communities lack access to essential resources, face challenges in evacuating, and are often the last to receive emergency assistance, they must be prioritized for climate resilience efforts. One key solution, passive survivability, can help underserved communities stay safe and resilient at home. Under this architectural concept, buildings are designed to maintain livable conditions in the event of extreme weather or when cut off from utilities. As opposed to active approaches (e.g., onsite generators), passive survivability uses design and building materials to maintain livable conditions *passively,* without additional inputs. This can be particularly critical during extreme heat and heat waves to help residents stay cool without reliance on air-conditioning. On an everyday basis, passive survivability facilitates highly efficient climate control that translates into savings on energy bills.

Importantly, passive survivability principles can be applied to all types of buildings, including multifamily apartment buildings and high rises. Because a core component of passive survivability is increasing building efficiency, it is also complementary to zero net energy (Measure E-16) and renewable surplus (Measure E-17) buildings.

The following design elements are core components of passive survivability.

High-Performance Building Envelope

A highly efficient, well-insulated building envelope is key to passive survivability to minimize temperature gain (or loss) when cooling or heating systems become inoperable. Proponents are encouraged to design buildings to maintain occupant comfort based on reasonably expected historical and projected minimum and maximum temperatures, with particular focus on extremes. Set building design parameters, such as U-factors for window glazings and R-values for insulation, based on predictive climate data when designing the building envelope (DC Department of Energy and Environment 2017).

High-performance windows with low-e coatings, low-conductivity gas fill, and either double or triple glazing with an interior film can optimize the U-factor—a measurement of how well a window insulates—leading to greater energy efficiency (Wilson 2006). Radiant barriers for buildings with high-pitched attic spaces can help reduce radiant heat transfer. Other approaches include installing a cool roof, green roof, or vegetative façade.

To help control air and moisture, consider implementing a continuous air barrier in the building envelope to enhance efficiency and building durability. An air barrier is a system of materials that separates the indoor, conditioned air from outdoor, unconditioned air.

Finally, set an energy use intensity target in alignment with passive survivability principles. Energy use intensity is the building's annual energy consumption per square foot.

Cooling Load Avoidance

Cooling load avoidance strategies utilize geometry and architecture to reduce heat gain in buildings – critical to protecting people from extreme heat if air-conditioning equipment cannot operate. Design strategies to reduce heat gain include using a building orientation (typically north-south) that limits afternoon sun exposure; minimizing east- and west-facing glass; using low solar heat-gain coefficient glass for south, east, and west windows and skylights; shading south, east, and west windows; installing a cool or green roof, radiant barriers, or radiant barrier roof sheathing in unheated attics; or installing louvered shades on windows and vegetative shading (Wilson 2006).

Ventilation

Mechanical ventilation coupled with natural ventilation ensures efficient ventilation throughout the building. Natural ventilation creates pathways for exhaust air to escape without the use of electric fans. To achieve natural ventilation, consider optimal window placement, building geometry, cupola use, and other methods to allow exhaust air to escape near the peak of the roof (Wilson 2006).

During power outages, mechanical ventilation systems that rely on electricity may become inoperable. Manual controls such as operable windows, pull-down shades, and operable vents should be considered to ensure occupants maintain the ability to control indoor climate conditions (DC Department of Energy and Environment 2017).

Passive Solar Heating

Depending on the project site's climate, passive heating might be desirable during winter months. Passive solar heating strategies include optimizing the siting and orientation of the house and ensuring that there is adequate glazing and high-solar heat-gain coefficient glass for south-facing windows. High-mass materials within the envelope can bolster insulation. Passive ventilation can circulate sun-warmed air throughout the building (Wilson 2006).

Natural Daylighting

A building can be designed to predominantly rely on daylight as opposed to electric lighting. Solar apertures can effectively bring natural light deep into the building interior. Other strategies include light shelves—structures that have reflective upper surfaces that transmit natural light inside a building—and light-colored ceiling and wall finishes. Fiber-optic daylighting systems or tubular skylights can deliver light to locations within a building that do not have full access to windows (DC Department of Energy and Environment 2017).

Water Storage and Heating

In cases of emergency, rainwater catchment systems can provide occupants a critical source of water. Such systems can be used for outdoor irrigation, toilet flushing, washing, and after-filtration drinking and cooking water. Passive solar or PV-powered water heating systems can provide warm water during outages.

Solar Photovoltaic Power and Storage

Solar PV systems coupled with battery storage can provide power during outages, including at night and during times of lower solar availability.

Applicability

Residential projects located in rural, suburban, or urban communities

Scale and Timing

- Scale: Project/Site
- Timing: Planning, construction, operations

Communities or Issues Addressed

As the threat from extreme climate events becomes increasingly prevalent and severe, measures to boost buildings' climate resilience are imperative to structural resilience as well as occupant health and safety. In the United States, low-income people are more likely to live in housing and areas that are vulnerable to climate impacts and face greater challenges in accessing life-saving relief. In the 1995 Chicago heat wave, 739 people died—most of whom were low-income individuals (SAMHSA 2017). Additionally, following disasters, low-income communities face many barriers in receiving aid, leading to disproportionate emotional, economic, and health impacts.

Thus, this measure should be prioritized for low-income communities and those without access to safe and reliable infrastructure services. With an increase in the frequency and severity of extreme heat, precipitation, wildfires, and other climate disasters, power outages and rolling blackouts have become more common. Power outages can be particularly dangerous or even life threatening for people who depend upon medical equipment or electric mobility equipment. For the elderly, children, and other vulnerable people, extended outages also increase the risk of heat illnesses.

Even without power outages, passive survivability can help low-income and underserved communities respond to heat waves and other extreme weather events and help to reduce their utility costs. Communities who may be unwilling to use air-conditioning due to financial challenges or cultural preferences benefit from passive survivability to maintain cooler, livable temperatures.

Dimensions of Equity

Maintaining survivable temperature thresholds can be a significant barrier for underserved and low-income communities. When outages and extreme weather events occur, many cannot afford to turn up the air conditioner (or heater) or relocate to a hotel. Designing buildings to maintain passive survivability enhances *economic resilience, social resilience, climate resilience,* and *public health* for occupants.

Implementation Considerations

When designing passive survivability components, it is essential to account for the project location's climate trends and potential future need. While passive cooling may be more critical in the majority of California, passive solar heating may be needed in some locations. Cal-Adapt, developed by the State of California, can provide localized climate projections for extreme heat, precipitation, wildfire risk, and sea level rise, while local climate vulnerability assessments can provide another detailed analysis. Chapter 4 provides additional guidance and strategies for addressing sea level rise, flooding, temperature and extreme heat, extreme precipitation, wildfire, drought, decrease in snowpack, and air quality degradation and their cascading effects.

Software tools allow proponents to test a design's efficiency and effectiveness. It is important to simulate 5-day outage worst-case scenarios when examining a building's ability to achieve passive survivability (White 2018). Moreover, depending on the building type, other approaches might be necessary. New construction and retrofits will have different requirements and needs. Maintenance capacity is another factor that can determine the effectiveness of passive survivability strategies, such as solar PV power, vegetative roofs, and vegetative shading. Proponents should consider the project site's design and how it interacts with existing neighborhood features and community needs – for example, the proximity to evacuation routes out of town.

Examples

Multifamily Retrofit, McKeesport Downtown Housing, Pennsylvania

McKeesport Downtown Housing in Pennsylvania is an 84-unit housing complex designed for unhoused people and people at risk of homelessness. Formerly a YMCA, the building added new lighting, air-conditioning, make-up air ventilation systems, an elevator, and cooking facilities as part of its renovations. By using passive house design strategies, the building uses 66 percent less energy than the original even after these additions. The site also serves the community by offering a cold-weather shelter, 60-day emergency housing, bridge housing, and section 8 apartment rentals (Passive House Accelerator 2021).

Multifamily Retrofit, Harry and Jeanette Weinberg Commons, DC

Completed in 2015, the Harry and Jeanette Weinberg Commons is the first multifamily retrofit in the United States to receive a PHIUS+ passive building certification. The project offers 36 two-bedroom units for 60 percent of area median income residents and is a permanent supportive housing complex. The building elements consists of a wall with R-value of R-39, continuous roof insulation, triple-pane windows, energy recovery ventilators, shading, and rooftop solar panels (Fine 2017). The use of passive house principles for this multifamily complex helped increase the affordability for residents by effectively eliminating utility bills and reducing the project's long-term operating costs—allowing more resources for resident support services.

Resources

- Architecture 2030's 2030 Palette offers a database of strategies, tools, and resources for designing zero-carbon, adaptable, and resilient built environments.
- Passive Survivability: How LEED Helps When the Power Goes Out
- Washington, DC Department of Energy and Environment's Climate Ready DC: Resilient Design Guidelines
- Passivhaus Institute's Passipedia, the Passive House Resource: What is a Passive House?
- Passive House Institute United States' PHIUS+ 2018: Getting to Zero
- Passive Survivability: Designing for Tomorrow's Disasters
- Passive House Accelerator

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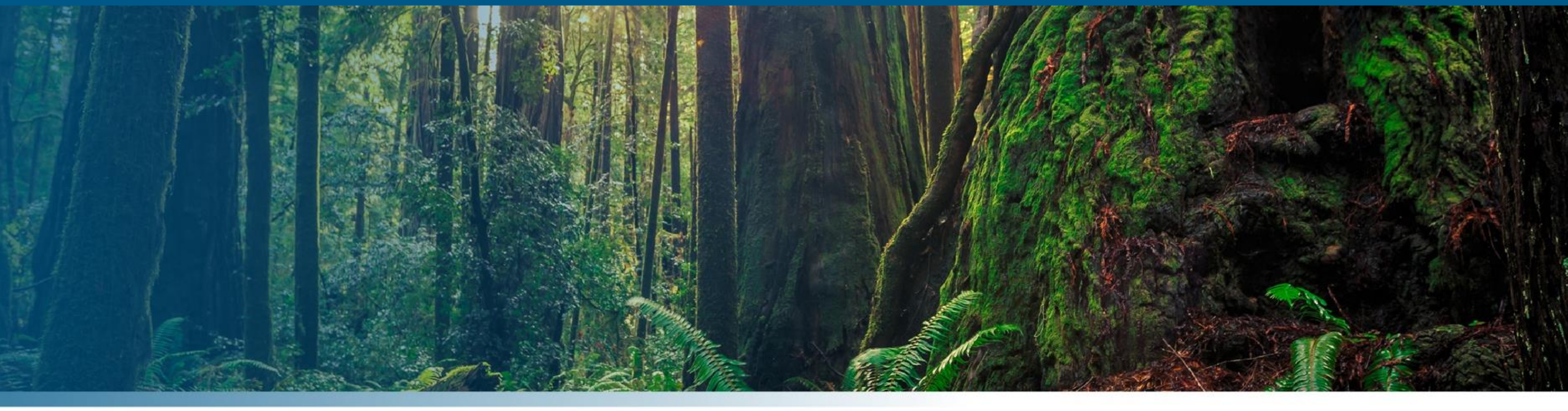
Resources to Support Resilient and Equitable Emission Reduction Planning

CHAPTER 6



Introduction

This Handbook provides techniques and strategies that can be implemented over the coming months and years to support and encourage sustainable, resilient, and equitable land use planning. While the measures, methods, and guidance presented in this Handbook represent the best available information at the time of publication, the number of resources relating to climate resilience, GHG reduction, and equity is continually growing. Models and tools also change regularly as they incorporate new science and data. Handbook users are encouraged to use the guidance presented in this Handbook, and where appropriate, supplement with data and ideas from a diverse array of additional resources.

Table 6-1 describes additional resources to expand on the principles outlined in this Handbook. Resources are presented in alphabetical order and grouped as either California specific or nationally applicable. Each resource is characterized by one or more function—community program; policy guidance; informational repository; local, regional, or state plan; model or data visualization software; measures/strategies; or reports, projections, or data. Table 6-1 also identifies the central topic(s)—climate resilience, GHG emission reductions, and health/equity—addressed by the resource, as indicated by the following graphics.

Climate Resilience | GHG Reduction | Health/Equity

Table 6-1. Additional Resources and Guidance to Support Sustainable, Resilient, and Equitable Land Use Planning

Name	Resource Type	Description	Topic(s)
California-Specific			
APEN: Mapping Resilience	Informational repository	Mapping Resilience: A Blueprint for Thriving in the Face of Climate Disasters, from the Asian Pacific Environmental Network, reports on the distribution of climate resilience efforts in California and how to get resilience projects to historically underserved communities that will face disproportionate negative impacts from climate change.	
ARCCA	Policy guide, community program; informational repository	The Alliance of Regional Collaboratives for Climate Adaptation (ARCCA) is a network of regional collaboratives and allies that work to advance statewide adaptation and community resilience efforts. Its website tracks the latest policy updates, describes ongoing resilience and equity initiatives, and provides additional resources, such as toolkits and roadmaps.	
CalAdapt	Model or data visualization software	CalAdapt collects and visualizes simplified versions of climate change projections and climate impact research from California's scientific community. CalAdapt has a variety of visualizations to choose from, including: ▪ Sea Level Rise ▪ Wildfires ▪ Local Climate Change Snapshot ▪ Extended Drought Models ▪ Extreme Heat Days and Warm Nights	
CalEEMod	Model or data visualization software	CalEEMod quantifies ozone precursors, criteria pollutants, and GHG emissions from construction and operation of new land use development and linear projects in California. The model also integrates data from CalEnviroScreen®, Cal-Adapt®, and HPI® to identify potential climate risks and environmental burdens within the project vicinity. Measures to reduce emissions, climate risks, and environmental burdens are available for user selection and analysis.[1]	
CalEnviroScreen	Model or data visualization software	CalEnviroScreen is a mapping tool that identifies communities that are the most affected by or vulnerable to different types of pollution. The data for CalEnviroScreen comes from environmental, health, and	

[1] This version of CalEEMod is still in development and will be released in 2022. The current version of CalEEMod (2020.4.0) quantifies ozone precursors, criteria pollutants, and GHG emissions from construction and operation of new land use development projects.

Name	Resource Type	Description	Topic(s)
		socioeconomic information at the state and federal level, and produces parceled data for every census tract in California.	
California Adaptation Clearinghouse	Informational repository	The State's Adaptation Clearinghouse is a searchable database of many resources that are useful for local, regional, and state adaptation planning efforts. Resources include tools, case studies, guidelines, scientific reports, and more. It also contains a clearinghouse for equity and environmental justice.	
California Climate Adaptation Planning Guide	Policy guidance; local, regional, or state plan	The California Adaptation Planning Guide (APG) is a tool that local governments and organizations can use to integrate best practices into their adaptation planning efforts. First published in 2012, the guide has since been updated in 2020, and includes processes communities can use to plan for climate change. The updated APG reflects the latest best practices, especially considering the many updates to California's plans, programs, science, regulations, and policies. An interactive version of the guidance is also available online.	
California Fourth Climate Change Assessment: Climate Justice and Tribal and Indigenous Communities Reports	Reports, projections, and data	California's Climate Change Assessments are a series of regional and state reports, tools, and models that contribute to the scientific foundation for understanding local scale climate-related vulnerability. The assessments identify how climate change may disproportionately affect underserved populations and tribal and indigenous communities. The Climate Justice report offers tools for mapping, discusses critical factors related to climate vulnerability and adaptive capacity, lists potential climate adaptation strategies, and discusses knowledge gaps in the field. The Tribal and Indigenous Communities report discusses how climate impacts uniquely affect tribal communities and offers related case studies and recommended actions.	
California Healthy Mobility Options Tool	Model or data visualization software	The California Healthy Mobility Options Tool (also known as the California Integrated Transport and Health Impacts Model / ITHIM CA) is a planning tool that compares the health impacts associated with different travel scenarios based on a mix of active and motorized transport modes. The tool calculates the associated change in deaths and years of life shortening and disability; health costs due to travel-related changes in air pollution, physical activity, and traffic injuries; and GHG emissions.	
California Healthy Places Index	Model or data visualization software	The California Healthy Places Index (HPI), developed by the Public Health Alliance of Southern California, is a tool that enables the user to explore local factors that affect life expectancy and compare community conditions across California, using a scoring system based on housing, transportation, education, and other key factors that influence health. There are many free features available,	

Name	Resource Type	Description	Topic(s)
		and users can also choose to pay for a premium account which unlocks additional features.	
California Heat Assessment Tool	Model or data visualization software	The California Heat Assessment Tool (CHAT) allows users to explore and understand how extreme heat will impact specific communities across the state. The tool allows users to explore how "heat health events" are projected to change in their communities over time. A heat health event is any heat event that generates public health impacts, regardless of the absolute temperature.	
Funding Wizard	Funding database	The Funding Wizard is a searchable funding database that helps to identify grants, rebates, and incentives for sustainability projects that are available in California. It includes various filters to help narrow down searches, and provides descriptions of funding opportunities and links for more information.	
CCHES	Policy guidance; measures/ strategies; informational repository; reports, projections, and data	The CDPH's Climate Change and Health Equity Section (CCHES) works across sectors to embed health and equity into California climate change programs and policies. CCHES administers the California Building Resilience Against Climate Effects (CalBRACE) project, which provides a comprehensive suite of tools for better understanding the effects of climate change on public health, including the Climate Change and Health Vulnerability Indicators for California, County-Level Climate and Health Profile Reports, an Adaptation Planning Toolkit for public health, and best practices for local health department partnerships.	
ICARP	Policy guidance; measures/ strategies	The Integrated Climate Adaptation and Resiliency Program (ICARP) provides a cohesive and coordinated programmatic response to climate change impacts in California. The program delivers holistic strategies to coordinate efforts at all governmental levels. The program website outlines current initiatives and provides multiple planning resources.	
Our Coast, Our Future	Model or data visualization software	Our Coast, Our Future uses data from the Coastal Storm Modeling System (CoSMoS) to provide a web visualization tool that assesses exposure to sea level rise and coastal flooding hazards. The tool assists coastal resource managers and land use planners in visualizing and anticipating vulnerabilities to sea level rise and storms.	
Resilience Before Disaster: The Need to Build Equitable, Community-Driven Social Infrastructure	Measures/ strategies; reports, projections, or data	The Resilience Before Disaster report offers recommendations for building resilient communities in California through investment in social infrastructure and climate resilience. It urges state policymakers to take urgent action to address climate change and social inequity to safeguard all Californians.	
SB 1000 Implementation Toolkit	Community program; policy guidance;	The California Environmental Justice Alliance's SB 1000 Implementation Toolkit is a guidance document intended for local governments, planners, community-based organizations, and other stakeholders who will be working to develop an environmental justice element or a set of	

Name	Resource Type	Description	Topic(s)
	measures/ strategies	environmental justice policies for their general plans to meet the requirements of SB 1000.	
Safeguarding California Plan	Measures/ strategies	The Safeguarding California Plan outlines California's Climate Adaptation Strategy by discussing current and necessary actions the state should take to strengthen California's climate resilience, lower GHG emissions, and address environmental justice. In addition to the 2018 update of the plan, the California Natural Resources Agency publishes case studies of ongoing climate action, resources for coordinating local action, and reports on recent research.	
Sea the Future	Model or data visualization software	Sea the Future aggregates and compares the wide variety of sea level rise and flooding visualization tools that exist for modeling in California and helps users understand the underlying assumptions and methodologies of each tool to make sure that they choose the most appropriate tool for their task.	
Sustainable Communities and Climate Protection Program	Policy guide; local, regional, or state plan; informational repository	The Sustainable Communities and Climate Protection Program supports California's goals to reduce GHG emissions through coordinated transportation, housing, and land use planning. The program uses a variety of resources and a comprehensive library of policy briefs to make it easier for a government to implement climate programs.	
Tracking California	Model or data visualization software	Tracking California, a program of the Public Health Institute, mobilizes data on pollution and disease to understand their cause, effect, and trends. This program tracks and analyzes data on public health and the environment to protect communities in California and give policymakers and community groups the tools they need to be informed about environmental justice and health equity.	
National Tools			
Coastal Resilience	Policy guidance; model or data visualization software; reports, projections, or data	Coastal Resilience is a program led by The Nature Conservancy that looks at nature-based solutions for reducing coastal flood risk. This program includes a methodology, web mapping tool, and network of global practitioners.	
Community-Driven Climate Resilience Planning: A Framework	Policy guidance	Developed by the Movement Strategy Center, the Community-Driven Climate Resilience Planning: A Framework identifies characteristics of community-driven climate resilience planning and emerging opportunities for planners to draw from.	

Name	Resource Type	Description	Topic(s)
Community Resilience Economic Decision Guide and Online Tool (EDG)	Policy guidance; model or data visualization software; reports, projections, or data	This Community Resilience Economic Decision Guide and Online Tool, from the National Institute of Standards and Technology, provides economic methodology for evaluating investment decisions related to adapting to, withstanding, and recovering from disrupting events for communities.	
Guide to Equitable, Community-Driven Climate Preparedness Planning	Policy guide; measures/ strategies	The Guide to Equitable, Community-Driven Climate Preparedness Planning was prepared by the Urban Sustainability Directors Network (USDN) and discusses social inequities, such as structural and institutional racism, and their place in climate preparedness planning. It offers a framework on community-driven planning for climate change, as well as equitable adaptation solutions. The guide also helps developers identify effective ways to engage with communities in resilience planning.	
Opportunities for Equitable Adaptation in Cities	Policy guidance; informational repository; measures/ strategies	Developed by the Georgetown Climate Center, this workshop summary report gives a framework that governments and community changemakers can use to determine the disproportionate impact of climate change on vulnerable communities and how best to alleviate those impacts while increasing overall resilience.	
Our Communities, Our Power: Advancing Resistance and Resilience in Climate Change Adaptation	Community program; policy guidance; informational repository	The NAACP's Our Communities, Our Power toolkit examines the power of communities in reducing GHG emissions and becoming climate resilient, while highlighting the opportunity that communities have to address equity and environmental justice while focusing on community programs.	
Social Cohesion: The Secret Weapon in the Fight for Equitable Climate Resilience	Community program; policy guidance	Social Cohesion: The Secret Weapon in the Fight for Equitable Climate Resilience by the Center for American Progress discusses how to integrate community resilience into climate resilience and how social cohesion builds up these goals.	
U.S. Adaptation Clearinghouse	Informational repository	The Georgetown Climate Center's Adaptation Clearinghouse allows users to search between tools related to climate adaptation and resilience and GHG reduction easily and provides summaries and comparisons of different tools and resources at a glance. Users can search by region, topic, or sector, and save their searches and favorites in a free account.	
U.S. Climate Resilience Toolkit	Model or data visualization software; reports,	The U.S. Climate Resilience Toolkit amasses research across U.S. federal agencies as well as scientists and researchers to provide an in-depth look at climate resilience by region of the U.S., topic, type of stressor, and steps to resilience. The toolkit specializes in examining not just the existing issues and their projected	

Name	Resource Type	Description	Topic(s)
	projections, or data	intensities, but how to improve the preparation for and response to climate impacts through policy, infrastructure, and behavior change.	

Sources: APEN 2019; ARCCA 2021; CalEJA 2016; CARB 2021a, 2021b; CARB et al. 2020; CDC 2019; CDPH 2020, 2021a, 2021b, 2021c; CEC 2021; CEMA and CNRA 2020; CNRA n.d., 2019; Georgetown Climate Center 2011, 2017, 2021; Gonzalez 2017; Lou et al. 2020; NAACP 2019; NIST 2020; NOAA 2021; OEHHA 2021; OPR 2021a, 2021b, 2021c; OPR, CEC, and CNRA 2018; SCC 2021; PHASC 2021; TNC n.d.; Tracking California 2021; USGS n.d.; USDN 2017.

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Key Terms and Definitions

APPENDIX A

Below is a glossary of key terms and definitions for the Handbook.

Adaptation (Climate Change): Adjusting to a changing environment. Adaptation involves working to reduce or eliminate the impacts of climate change on a community. Adaptation can minimize harm and costs and take advantage of potential opportunities associated with the impacts of climate change. Adaptation includes addressing current and future natural hazards (i.e., wildfire, drought, cyclones, heat waves), as well as gradual changes (i.e., sea level rise, increasing temperatures) that could impact economic sectors, natural resources, and community well-being.

Adaptation Measure: An action that addresses a climate impact. A measure will reduce risk and/or vulnerability for a specific resource, asset, project component, or community.

Adaptive Capacity: A project's existing capacity to cope with the effects of climate change (an element of vulnerability.) Adaptive capacity includes the policies, programs, plans, and practices that are already in place or can be easily implemented, which prepare a project for climate change, as well as the financial resources to implement such actions.

Albedo: The fraction of solar radiation reflected by a surface or object. Snow covered surfaces have a high albedo, while vegetation-covered surfaces and oceans have a low albedo. The Earth's albedo varies, because of the dynamic nature of clouds, snow, ice, leaf area, and land cover changes. The normal albedo of snow, for example, is around 1.0, whereas the albedo of vegetation can be as low as 0.1. Human-made surfaces designed to have high albedos (i.e., near 1.0) reflect solar radiation and can help reduce the urban heat island effect. Other human-made surfaces, such as asphalt or conventional shingle roofs, have low albedo and increase the urban heat island effect.

Anti-Displacement: Policies, programs, and actions that help people to remain in their communities, buffering the effects of rising costs (especially housing), lowered incomes, loss or conversion of housing units, or other factors.

Below Market Rate Housing: Housing provided at rates lower than the market rate. Below market rate housing is designed to assist lower-income families. When below market rate housing is provided near job centers or transit, it provides lower-income families with desirable job/housing match or greater opportunities for commuting to work through public transit.

Biogenic Emissions: Carbon dioxide (CO_2) emissions that result from materials that are derived from living cells, as opposed to CO_2 emissions derived from fossil fuels, limestone, and other materials that have been transformed by geological processes. Biogenic CO_2 contains carbon that is present in organic materials, including wood, paper, vegetable oils, animal fat, and waste from food, animals, and vegetation (such as yard or forest waste).

Building Climate Zones: Geographic areas of similar climatic characteristics, including temperature, weather, and other factors that affect building energy use. The California Energy Commission identified 16 Building Climate Zones for the Title 24 Standards. Building climate zones are different from Energy Demand Forecast Zones (EDFZs), which were developed by the California Energy Commission and used in the Residential Appliance Saturation Survey (RASS) and the 2018–2030 Uncalibrated Commercial Sector Forecast (Commercial Forecast).

Carbon Dioxide Equivalent (CO_2e): A measure for comparing CO_2 with other greenhouse gases (GHG). CO_2e is calculated by multiplying the metric tons of a GHG by its associated global warming potential (GWP).

California Environmental Quality Act (CEQA): A statute passed in 1970 that requires state and local agencies to identify the significant environmental impacts of their actions, to avoid or mitigate those impacts, and for projects with significant impacts to consider alternatives. The statute also requires public participation in the review of environmental documents.

Carbon Monoxide (CO): CO is a colorless, odorless, gas produced by incomplete combustion of carbon substances, such as gasoline or diesel fuel. While there are no ecological or environmental effects from CO, human exposure to CO at high concentrations can cause fatigue, headaches, confusion, dizziness, and chest pain.

Carbon Sink: Any process or mechanism that removes carbon dioxide from the atmosphere. A forest is an example of a carbon sink because it sequesters carbon dioxide from the atmosphere.

Climate Action Plan (CAP): A plan or series of plans that outline a strategy for an entity, such as a City, County, company, public agency, etc. to reduce their GHG emissions and/or to make the jurisdiction or agency more resilient to climate change. Some CAPs only cover GHG emissions and some also cover climate adaptation. The foundation of a CAP is usually a GHG inventory, forecast of the trajectory of emissions in the absence of any action, and a GHG reduction target by a set year. The CAP must include GHG reduction measures, such as those presented in this Handbook, for the entity to meet their stated GHG goals.

Co-Benefits: Additional benefits that accompany the emissions reductions associated with GHG reduction measures, such as improvement in air quality, employment, climate resiliency, or community quality of life.

Combined Heat and Power (CHP): CHP is the generation of both heat and electricity from the same process, such as combustion of fuel, with the purpose of utilizing or selling both simultaneously. In combined heat and power systems, the thermal energy byproducts of a process are captured and used, whereas, in a separate heat and power system, the byproducts would be wasted. Examples of combined heat and power systems include gas turbines, reciprocating engines, and fuel cells. CHP is also known as *cogeneration*.

Community Benefits Agreement: A contract signed by community groups and a project proponent that requires the proponent to provide specific amenities and/or mitigations to the local community or neighborhood. In exchange, the community groups agree to publicly support the project, or at least not oppose it. These amenities and/or mitigations are then included in the record of decision as conditions of approval, mitigation measures, or developer agreement, as appropriate.

Community Engagement: Process of involving and working collaboratively with individuals and groups for the benefit of a community. Effective community engagement ensures that community members from diverse backgrounds have ample opportunity to communicate their priorities and concerns and participate in planning and decision-making activities.

Commute Shed: The area from which a business can expect employees to be drawn, typically a 45-minute drive, but often in metropolitan areas include areas farther away.

Cordon Pricing: Tolls charged for entering a particular area (a *cordon*), such as a downtown core. For example, New York City evaluated an $8 daily fee for passenger vehicles and a $21 daily fee for trucks entering Manhattan below 86th Street from 6 am to 6 pm on weekdays.

Criteria Pollutants: Criteria pollutants are a group of six common air pollutants for which the federal and state governments have set national ambient air quality standards (NAAQS) and California ambient air quality standards (CAAQS), respectively. The standards are set to protect public health and welfare and the environment. The federal criteria pollutants are ozone (O_3), CO, lead (Pb), nitrogen dioxide (NO_2), sulfur dioxide (SO_2), and particulate matter (PM), which consists of particulates 10 microns in diameter or less (PM10) and 2.5 microns in diameter or less (PM2.5). Definitions of these pollutants are provided in this appendix (see *Carbon Monoxide*, *Lead*, *Nitrogen Dioxide*, *Ozone*, *Particulate Matter*, and

Sulfur Dioxide). California has set CAAQS for these six pollutants, in addition to standards for visibility reducing particles, hydrogen sulfide, and vinyl chloride.

Cultural Competency: As defined by the Child Welfare League of America, "the ability of individuals and systems to respond respectfully and effectively to people of all cultures, classes, races, ethnic backgrounds, sexual orientations, and faiths or religions in a manner that recognizes, affirms, and values the worth of individuals, families, tribes, and communities, and protects and preserves the dignity of each" (National Technical Assistance and Evaluation Center for Systems of Care 2009).

Destination Accessibility: A measure of the number of jobs or other attractions reachable within a given travel time. Destination accessibility tends to be highest at central locations and lowest at peripheral ones.

Disadvantaged Community: A disadvantaged community is defined by the State of California as a census tract that is in the top 25 percentile of CalEnviroScreen; census tracts without scores but having the highest 5 percent of cumulative pollution burden scores in CalEnviroScreen; disadvantaged census tracts from the 2017 designation of disadvantaged communities; and land under control of federally recognized Tribes. CalEnviroScreen is an environmental justice screening tool developed by the Office of Environmental Health Hazard Assessment to evaluate communities for their environmental pollution burden as well as vulnerability due to socioeconomic conditions. Disadvantaged community designation is often used by the State of California in funding and other programs (California Environmental Protection Agency n.d.).

Disadvantaged community may be alternatively defined based on other metrics or indicators, such as those included in the California Healthy Places Index, or even defined by local communities themselves. See also *Vulnerable Places* and *Vulnerable Population*, which are alternative terms used by the CDPH.

Elasticity: The percentage change of one variable in response to a percentage change in another variable. For example, if the elasticity of vehicle miles traveled (VMT) with respect to density is -0.12, this means a 100 percent increase in density leads to a 12 percent decrease in VMT. Elasticity is represented by the following formula [percent change in variable A] / [percent change in variable B], where the change in B leads to the change in A.

Emission Factor: A relative value that relates the quantity of a pollutant to an activity associated with the release of that pollutant. Emission factors are typically expressed in terms of pollutant weight divided by an activity rate. For example, metric tons of CO_2 emitted per VMT (annotated as MT CO_2/VMT).

ENERGY STAR: A joint program of the U.S. Environmental Protection Agency and the U.S. Department of Energy which sets national standards for energy-efficient consumer products. ENERGY STAR-certified products are guaranteed to meet the efficiency standards specified by the program.

Environmental Justice: The right of all communities to live, work, and play in a healthy, climate-resilient, and sustainable environment. Environmental justice also includes the right of communities for meaningful involvement and self-determination in land use planning and environmental decision-making (California Environmental Justice Alliance 2021).

Equity: Equity is the "just and fair inclusion into a society in which all can participate, prosper, and reach their full potential" (Policy Link 2021). Equity means creating the conditions, practices and environment that would enable all communities and individuals to lead healthy, thriving lives, recognizing that communities and individuals have historically faced and continue to face today discrimination and oppression because of their race, gender, sexuality, ability, citizenship status, or other characteristics. Thus, distributional equity includes increasing access to power, redistributing and providing additional resources, and eliminating barriers to opportunity.

Equality: Equality is treating every community and individual in the same way but may not recognize that communities and individuals are coming from different places and histories and have different needs and abilities.

Evapotranspiration: The loss of water from the soil both by evaporation and by transpiration from plants growing in the soil.

Exposure (to climate hazards): The effects of climate change that a project will face. Exposure includes change in the severity and location of a climate hazard (i.e., flood intensity associated with a flood zone). Projects can be exposed to both primary effects of climate change (i.e., sea level rise, reduced precipitation) and associated secondary effects (i.e., extreme high tides, reduced snowpack).

Exposure (to air pollution): The effects of air pollution that a project will face. People are exposed to air pollution in multiple ways, including breathing polluted air, eating foods that have accumulated pollutants, drinking contaminated water, ingesting contaminated soils, and touching contaminated surfaces. The primary human health and ecological impacts from exposure to criteria pollutants are defined in this appendix (see *Carbon Monoxide*, *Lead*, *Nitrogen Dioxide*, *Ozone*, *Particulate Matter*, and *Sulfur Dioxide*). Certain exposure reduction measures, such as MERV 13 filters in ventilation systems, may reduce exposure to air pollution.

General Plan: A set of long-term goals and policies that guide local land use decisions. The General Plan Guidelines developed by the California Office of Planning and Research provide advice on how to write a general plan that articulates a community's long-term vision, fulfills statutory requirements, and contributes to creating a prosperous community.

Global Warming Potential (GWP): The ratio of radiative forcing that would result from the emission of one unit of a GHG (e.g., methane, nitrous oxide) to that from the emission of one unit of CO_2 over a fixed period (e.g., 20 years, 100 years). For example, methane has a 100-year GWP of 25, which means 1 metric ton of methane has the same global warming impact as 25 metric tons of CO_2.

Gray Water: Water from sinks, showers, tubs, and washing machines that has not contacted biological pathogens. It is non-drinkable water that can be collected and reused on site for irrigation, flushing toilets, and other purposes.

Greenhouse Gas (GHG): This report focuses on the following five gases: CO_2, nitrous oxide (N_2O), methane (CH_4), hydrofluorocarbons (HFCs), and sulfur hexafluoride (SF_6), but there are several others.

Hazard (Climate Hazard): A danger to a project or a community caused or exacerbated by climate change, including extreme weather events or gradual changes in climate (i.e., flooding, wildfires, drought, increasing temperatures, reduced snowpack).

Headway: The amount of time, typically measured in minutes, that elapses between two public transit vehicles servicing a given route. Headways for buses and rail are generally shorter during peak periods and longer during off-peak periods. Headway is the inverse of frequency (i.e., headway = 1/frequency), where frequency is the number of arrivals over a given time, such as the number of buses per hour.

Health Equity: Health equity is achieved when all people have full and equal access to opportunities that enable them to lead healthy, thriving lives (California Health and Safety Code Section 131019.5).

Impact (on climate change): The way a project experiences an effect of climate change. A climate hazard's impact is determined by the project's vulnerability to a hazard and its adaptive capacity. Impacts can be direct (sea level rise, changes in precipitation) or secondary, meaning they are related to a specific sector (i.e., public health, water management, natural resources).

Infill Development: A project that is located within or contiguous with the central city. Examples of infill projects are construction on redevelopment areas, abandoned sites, or underutilized older buildings/sites.

Kilowatt Hour (kWh): The kilowatt hour is a measure of electrical energy that is equal to 3,600 kilojoules. It is commonly used by utilities to measure and bill consumers for their electricity use. The kWh is basis for most energy-related greenhouse gas emissions calculations. Alternatively, megawatt hours (MWh) are also used. There are 1,000 kWh hours in 1 MWh.

Lead (Pb): Pb is a soft metal that was previously added to gasoline, which when combusted, generated small Pb particles that could be inhaled and deposited in the environment (soil and water). Once absorbed into the body, Pb accumulates in bones and adversely affects multiple organ systems. Children are particularly at risk of lead poisoning. The primary health impacts of Pb exposure are anemia, behavioral disorders, low IQ, reading and learning disabilities, and nerve damage. Ecological effects of Pb include losses in biodiversity, changes in community composition, and decreased growth and reproductive rates in plants and animals. Leaded fuel in the U.S. was banned in all on-road vehicles in 1996. The primary sources of Pb emissions today are metal refineries, smelters, battery manufacturers, iron and steel producers, and racing and aircraft industries.

LGBTQIA+: Lesbian, gay, bisexual, transgender, queer and questioning, intersex, asexual, and other gender identities.

Lifecycle Emissions: Emissions that are produced from the energy and resources used throughout the lifecycle of a product or material. Lifecycle emissions include the extraction of raw resources, physical distribution, use of the product or material, and disposal at the end of a product's life.

Locational Context: Used to identify emission reduction measures within the transportation sector that are appropriate in certain types of neighborhoods differentiated by transportation characteristics and level of development (e.g., urban, rural, suburban). See *Suburban*, *Urban*, and *Rural*.

Lumen: A unit measure of the brilliance of a source of visible light, or the power of light perceived by the human eye. The more lumens, the brighter the light. For example, a 100-watt incandescent bulb produces about 1,600 lumens. A 40-watt energy savings bulb produces about 450 lumens.

Measure Scales: The measures in this report are applicable to different scales and geographies (Project/Site scale and Program/Community scale). *Project/Site* refers to measures that reduce emissions at the scale of a parcel, employer, or development project. *Program/Community* refers to measures that reduce emissions at the scale of a neighborhood (e.g., specific plan), corridor, or entire municipality (e.g., city- or county-level).

Mixed-Use: A development project that incorporates more than one type of land use. For example, a mixed-use development may be a building with ground-floor retail and housing on the floors above. A larger mixed-use development may incorporate a variety of land uses within a short proximity of each other. This may include integrating office space, shopping, parks, schools, and residential development. Given the close proximities, mixed-use developments can encourage walking and other non-auto modes of transport from residential to office/commercial/institutional locations (and vice versa).

Multiplier Effect: The multiplier effect refers to the increase in final income arising from any new injection of spending. Some forms of new spending in a community can increase the total income of that community beyond the initial spending depending on how they interact with the local economy. Different types of economic activity will have different multiplier effects.

Nitrogen Dioxide (NO_2): NO_2 can be directly emitted from combustion sources, such as boilers, gas turbines, and mobile and stationary engines. NO_2 is also naturally formed through photochemical reactions among nitric oxide (NO) and other air pollutants. Human exposure to NO_2 at high concentrations can aggravate lung and heart problems, intensify responses to allergens in asthmatics, decrease lung-function in children, and potentially lead to premature death. NO_2 is a precursor to O_3 formation and acid rain and can contribute to global warming and reduce water quality. High ambient NO_2 concentrations over prolonged periods may also injure crops.

Ordinance: A local law usually found in municipal code. Examples of ordinances include those related to noise control, snow removal, pet restrictions, and zoning.

Ozone (O_3): Ground-level O_3, or smog, is not directly emitted into the atmosphere. Rather, it is naturally formed through photochemical reactions between reactive organic gases (ROG) and nitrogen oxides (NO_X) (both by-products of combustion). Concentrations of ground-level O_3 are typically greatest on sunny days in urban environments, but because O_3 can be transported long distances in the air, rural communities also experience O_3 pollution. Exposure to ground-level O_3 at certain concentrations can make breathing more difficult, cause shortness of breath and coughing, inflame and damage the airways, aggravate lung diseases, increase the frequency of asthma attacks, and cause chronic obstructive pulmonary disease. Within the environment, ground-level O_3 can cause crop damage, typically in the form of stunted growth, leaf discoloration, cell damage, and premature death.

Particulate Matter: PM pollution consists of very small liquid and solid particles floating in the air, which can include smoke, soot, dust, salts, acids, and metals. NAAQS and CAAQS have been set for two sizes of PM—PM10 (10 microns in diameter or less) and PM2.5 (2.5 microns in diameter or less). PM10 typically deposits on the surfaces of the larger airways of the upper region of the lung and can induce tissue damage and lung inflammation and is linked with asthma and chronic obstructive pulmonary disease. PM2.5 travels into and deposits on the surface of the deeper parts of the lung and can induce tissue damage and lung inflammation and is also linked with hospitalizations from heart and lung causes. Depending on its composition, PM10 and PM2.5 can also affect water quality and acidity, deplete soil nutrients, damage sensitive forests and crops, affect ecosystem diversity, and contribute to acid rain.

Photovoltaic (PV): A system that converts sunlight directly into electricity using cells made of silicon or other conductive materials. When sunlight hits the cells, a chemical reaction occurs, resulting in the generation of electricity. There are often many PV cells in a single solar panel.

Program/Community: See Measure Scales.

Project/Site: See Measure Scales.

Quimby Requirements: The Quimby Act, within the Subdivision Map Act, authorizes the legislative body of a city or county to require the dedication of land or to impose fees for park or recreational purposes as a condition of the approval of a tentative or parcel subdivision map, if specified requirements are met. This is the primary source of funding and land for park development at the local level.

Racial Equity: Racial equity is both an outcome and a process. As an outcome, racial equity is achieved when race is no longer a predictor for life and socio-economic outcomes, and when everyone can lead healthy, thriving lives, regardless of their race.

"As a process, we apply racial equity when those most impacted by structural racial inequity are meaningfully involved in the creation and implementation of the institutional policies and practices that impact their lives" (Race Forward 2021). We achieve racial equity by eliminating the policies, structures, practices, mindsets, and cultural messages that perpetuate racist outcomes and processes. (Race Forward 2021; Nelson et al. 2015; Racial Equity Tools 2020)

Recycled Water: Non-drinkable water that can be reused for irrigation, flushing toilets, and other purposes. It has been processed through a wastewater treatment plant, unlike greywater, and typically needs to be redistributed from the treatment plant to the site where it will be used.

Renewable Energy: Energy sources that are sustainable, and include non-carbon technologies, such as solar energy, hydropower, and wind, as well as carbon-neutral technologies such as biomass.

Resilience (to climate change): The ability of an individual, project, community, or natural system to prepare, cope, and recover from disruptions, shocks, and stresses caused by climate impacts.

Ridesharing: A form of carpooling or vanpooling where multiple people travel in the same vehicle instead of separately driving in individual vehicles. Ridesharing can be casual and formed independently or as part of an employer program.

Rural: An area characterized by little development. Compared to urban and suburban areas, rural areas have a lower density of residences, higher numbers of single-family residences, and higher numbers of vehicle dependent land use patterns. Where applicable, the Handbook provides three land use distinctions within the *rural* locational context category—R^a, R^b, and R^c. R^a refers rural areas within a master-planned community. These rural areas often include a broad offering of amenities and services, which may be accessed by walking or other alternative forms of transportation. R^b refers to rural areas adjacent to a commuter rail station with convenient rail service to a major employment center. As the name implies, these rural areas have greater access to commuter rail as an alternative mode of transportation. R^c refers to rural areas with transit service and that are near jobs/services.

Sector: Categories used to organize the sources that generate GHG emissions. Sectors are the standard method of categorizing emissions, such as transportation or energy.

Self-Selection: A type of bias where individuals select themselves into a group, potentially creating a non-representative sample.

Sensitivity (to climate change): The project's susceptibility to the effects of climate change. The degree to which different components of a project will be exposed to climate change and their capabilities hindered. Points of sensitivity include the project's functions, structures, and individuals who interact with the project. Sensitivity is an element of *Vulnerability*.

Separate Heat and Power: A typical system for acquiring heat and, separately, acquiring power. Thermal energy and electricity are generated and used separately. For example, heat is generated from a boiler while electricity is acquired from the local utility. Separate heat and power systems can be replaced by more efficient combined heat and power systems.

Sequestration/Sequester: The process of increasing the carbon content of a carbon reservoir other than the atmosphere. Biological approaches to sequestration include direct removal of carbon dioxide from the atmosphere through afforestation, reforestation, and practices that enhance soil carbon in agriculture. Physical approaches include separation and disposal of carbon dioxide from flue gases or from processing fossil fuels to produce hydrogen- and carbon dioxide-rich fractions and long-term storage in underground depleted oil and gas reservoirs, coal seams, and saline aquifers.

Spillover (Parking): A term used to describe the effects of implementing a parking management strategy in one area that has the unintended consequence of impacting surrounding areas. For example, if parking meters are installed on all streets in a commercial/retail block with no other parking strategies implemented, customers may no longer park in the metered spots and will instead "spillover" to the surrounding residential neighborhoods where parking is unrestricted.

Suburban: An area characterized by dispersed, low-density, single-use, automobile dependent land use patterns, usually outside of the central city. Also known as a suburb.

Sulfur Dioxide (SO_2): SO_2 is generated by burning fossil fuels, industrial processes, and natural sources, such as volcanoes. Exposure to SO_2 at certain concentrations can increase incidence of pulmonary symptoms and disease, decrease pulmonary function, and lead to increased risk of mortality, especially among the elderly and people with cardiovascular disease or chronic lung disease. SO_2 deposition in the environment contributes to soil and surface water acidification and acid rain.

Title 24: Title 24, Part 6 regulates building energy efficiency standards in California. Regulated energy uses include space heating and cooling, ventilation, domestic hot water heating, and some hard-wired lighting. Title 24 determines compliance by comparing the modeled energy use of a "proposed home" to that of a minimally Title 24 compliant "standard home" of equal dimensions. Title 24 focuses on building energy efficiency per square foot; it places no limits upon the size of the house, or the actual energy used per dwelling unit. The current Title 24 standards were published in 2019.

Transit Ridership: The number of passengers who use a public transportation system, such as buses and subways.

Transportation Demand Management (TDM): A transportation strategy designed to increase the transportation system efficiency and reduce demand on the system. Common TDM strategies include discouraging single-occupancy vehicle travel; encouraging more efficient travel patterns and alternative modes of transportation (e.g., walking, bicycling, public transit, and ridesharing); and shifting travel patterns from peak to off-peak hours and to closer destinations.

Transit-Oriented Development (TOD): TOD refers to projects built in compact, walkable areas that have easy access to public transit, ideally in a location with a mix of uses, including housing, retail offices, and community facilities. TODs are generally described as places within a 10-minute walk (0.5 mile) of a high-frequency rail transit station (either rail, or bus with headways less than 15 minutes).

Underserved (or Under-Represented), Under-Resourced, and/or Marginalized Communities: Communities that have been historically neglected by governments at all levels, whether because of policy (e.g., redlining), systemic racism, or a combination of factors. These communities are likely to not only experience greater levels of day-to-day pollution burdens, but also have greater vulnerability to climate disasters, economic disruptions, and other challenges. In addition, community members have often been excluded from decision-making and lack the resources and capacity to participate meaningfully in land use planning and other civic and political processes.

Urban: An area located within the central city with higher density land uses than in the suburbs. Often characterized by multi-family housing, tall office buildings and dense retail.

Urban Heat Island Effect: A term used to describe when a developed area is warmer than the surrounding rural areas, caused by urban land surfaces that retain heat (e.g., concrete, asphalt, metal, and other materials found in buildings and pavements). These urban surfaces can be darker than natural vegetation found in more rural areas. Darker surfaces absorb more sunlight that lighter surfaces, resulting in more heat (see *Albedo*). Urban environments also tend to have fewer plants and trees compared to rural locations. Plants and trees release water vapor to the air through transpiration, cooling the ambient temperature. Urban tree planting and measures requiring lighting building surfaces can help reduce the urban heat island effect.

Vehicle Miles Traveled (VMT): The number of miles driven by vehicles, an important traffic parameter, and the basis for most traffic-related greenhouse gas emissions calculations.

Vehicle Occupancy: The number of persons in a vehicle during a trip, including the driver and passengers.

Vulnerable Places: Places or communities with inequities in the social, economic, educational, or physical environment or environmental health and that have insufficient resources or capacity to protect and promote the health and well-being of their residents (Health and Safety Code Section 131019.5).

Vulnerable Population (to climate change): A group of individuals or a community that faces greater risks and has higher sensitivity to the impacts of climate change. Additionally, these groups may have a lower ability and/or fewer or insufficient resources to manage or recover from climate impacts. Populations may be vulnerable because of their physical environment, socio-economic demographics, political status, or other drivers. Example factors that can contribute to a population's vulnerable status include race, class, sexual orientation, sexual identification, and income-status.

Vulnerability (to climate change): The extent to which a project is susceptible to climate change. Vulnerability is the combination of a project's sensitivity, exposure, and adaptive capacity to climate hazards. Vulnerability includes susceptibility to direct climate impacts as well as secondary climate impacts. Vulnerability encompasses not only physical threats to a project's structure or facilities, but also impacts to a project's functions, operations, and users.

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Federal and State Planning Framework

APPENDIX B

Federal and State Planning Efforts

This appendix describes important federal and state regulations, policies, orders, guidance, and legislation related to greenhouse gas (GHG) emissions reductions, climate change vulnerability and adaptation, and public health and equity. These various directives directly influence and inform planning efforts across California. This appendix organizes federal regulations and requirements by climate change and GHG emissions and by public health and equity. State regulations and requirements are organized by GHG emissions reductions, adaptation, and public health and equity. Both sections present the regulations and requirements within each subsection chronologically. It is important to note that while rules and regulations are grouped into subcategories, many are cross-cutting across the topic areas.

The regulatory landscape is constantly shifting as amendments, revocations, and new requirements are adopted. The text in this section was drafted in 2021 and reflects the regulatory landscape as of this date. The appendix likewise is not exhaustive. Readers may need to conduct additional research to ensure they have the latest information. Links to websites and external resources that are frequently updated are presented at the conclusion of the appendix.

Federal Regulations and Requirements

Although currently there is no comprehensive federal law specifically related to climate change, climate adaptation, or the reduction of GHG emissions, in 2021, the U.S. rejoined the Paris Agreement to reduce national GHG emissions, and the federal government submitted to the United Nations Framework Convention on Climate Change the U.S. Nationally Determined Contribution (NDC), which aims to reduce national GHG emissions 50 to 52 percent by 2030 from 2005 levels. The NDC, executive orders, and other goals and efforts of the Biden administration make up a new whole-of-government approach to reduce GHG emissions, increase resilience, improve equity, and boost economic growth (White House 2021a).

Additionally, the U.S. Environmental Protection Agency (U.S. EPA) is charged with implementing the federal Clean Air Act (CAA) and related regulations, and U.S. EPA and the National Highway Traffic and Safety Administration (NHTSA) implement fuel efficiency standards that have a direct effect on GHG emissions and public health and safety. The Civil Rights Act and several executive orders aim to improve equity and address environmental injustice. These regulations and rules are summarized below.

Climate Change and GHG Emissions

Clean Air Act and National Ambient Air Quality Standards (1963)

The CAA was enacted in 1963 and has been amended numerous times since (1965, 1967, 1970, 1977, and 1990). The CAA established federal national ambient air quality standards for six criteria air pollutants—lead, sulfur dioxide, particulate matter, ozone, carbon monoxide, and nitrogen dioxide—and specifies future dates for achieving compliance. These standards were set to improve air quality and public health outcomes. The CAA also mandates that states submit and implement a state implementation plan (SIP) for local areas not meeting those standards. The SIPs must include pollution control measures that demonstrate how the standards will be met (U.S. EPA 2021).

National Environmental Policy Act (1970)

Signed in 1970, the National Environmental Policy Act (NEPA) requires federal agencies to incorporate environmental considerations into planning and decision-making processes by using a systematic interdisciplinary approach. The purpose of NEPA is "to foster and promote the general welfare, to create and maintain conditions under which man and nature can exist in productive harmony, and fulfill the social, economic, and other requirements of present and future generations of Americans," (42 United States Code [U.S.C.] 4331(a)). Each federal agency has adopted its own NEPA procedures, but all must assess the potential environmental effects, and related social and economic effects, of proposed actions and alternative actions (U.S. EPA 2020a). The assessments must be reported in an environmental assessment (EA) that includes the following.

- The environmental impacts of the proposed action.
- Any adverse effects that cannot be avoided.
- Alternatives to the proposed action.
- The relationship between local short-term uses of the environment and the long-term productivity.
- Any irreversible and irretrievable commitments of resources that would be involved in the proposed action 42 U.S.C. 4332(2)(C).

If the EA determines the environmental impacts of the proposed action will be significant, the agency must prepare an environmental impact statement, which involves much stricter requirements, greater public participation, and a more detailed analysis.

CAFE Standards (1975)

The Corporate Average Fuel Economy (CAFE) standards were first enacted in 1975 to reduce energy consumption by improving the fuel economy of vehicles. The standards set fleet-wide averages that each automaker must meet. By improving the fuel efficiency of vehicles, the standards improve national energy security, save consumers money, and reduce GHG emissions.

Mandatory Greenhouse Gas Reporting Rule (2009)

In 2009, U.S. EPA released its final Greenhouse Gas Reporting Rule (Reporting Rule). The Reporting Rule is a response to the 2008 Consolidated Appropriations Act, which required U.S. EPA to develop mandatory reporting of greenhouse gases above appropriate thresholds. The Reporting Rule applies to most entities that emit 25,000 metric tons (MT) of carbon dioxide equivalent (CO_2e) or more per year. Starting in 2010, facility owners were required to submit an annual GHG emissions report with detailed calculations of facility GHG emissions. The Reporting Rule also mandates recordkeeping and administrative requirements to help U.S. EPA to verify annual GHG emissions reports (U.S. EPA 2016).

Endangerment and Cause or Contribute Findings (2009)

In 2009, U.S. EPA signed the Endangerment and Cause or Contribute Findings for Greenhouse Gases under Section 202(a) of the CAA. Under the Endangerment Finding, U.S. EPA found that the current and projected concentrations of the six key GHGs—carbon dioxide (CO_2), methane (CH_4), nitrous oxide, perfluorinated carbons, sulfur hexafluoride, and hydrofluorocarbons—in the atmosphere threaten the public health and welfare of current and future generations. U.S. EPA also found that the combined emissions of these GHGs from motor vehicle engines contribute to the GHG pollution that threatens public health and welfare (U.S. EPA 2020b).

Executive Order 13547—Stewardship of the Ocean, Our Coasts, and the Great Lakes (2010)

In 2010, Executive Order 13547, also known as the National Ocean Policy, was signed by the president to protect, maintain, and restore the quality of ocean and coastal ecosystems. This order aims to protect aquatic resources, improve sustainable ocean and coastal businesses, and help adapt to and manage climate change and ocean acidification. The order also established a National Ocean Council to guide policy and action (White House 2010).

GHG Emissions Standards and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles (2011, 2016)

In 2011, the U.S. EPA and NHTSA issued a final rule for GHG emissions standards and fuel efficiency standards for medium- and heavy-duty engines and vehicles. This rule includes three regulatory categories of heavy-duty vehicles—combination tractors, heavy-duty pickup trucks and vans, and vocational vehicles—and applies to model years 2014–2018. U.S. EPA and NHTSA estimate that these standards will reduce CO_2 emissions by about 270 million metric tons and save about 530 million barrels of oil over the life of vehicles built for these model years, generating $49 billion in net program benefits.

The U.S. EPA and NHTSA established Phase 2 of these standards in 2016, which apply to model years 2019–2027 medium- and heavy-duty vehicles. The agencies expect the standards to reduce CO_2 emissions by approximately 1.1 billion metric tons, save $170 billion in fuel costs, and reduce oil consumption by up to 2 billion barrels over the lifetime of the vehicles built for these model years (U.S. EPA 2020c).

CAFE Standards (2012)

The 2012 CAFE standards (for model years 2017 to 2025) update incorporated stricter fuel economy requirements promulgated by U.S. EPA and NHTSA. The 2012 standards established GHG emissions regulations that required new passenger cars and light trucks to reach 54.5 miles per gallon in 2025. The program also included incentives to encourage adoption of new technologies to improve vehicle performance, such as electric vehicles (U.S DOT 2014).

SAFE Rule (2020)

In 2018, the Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule was proposed, which would amend prior CAFE and GHG emissions standards and create new standards for model year 2021 to 2026 vehicles and reduce fuel economy requirements. In September 2019, NHTSA and U.S. EPA established "The Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule Part One: One National Program," which withdrew California's ability to create its own fuel economy standards under the CAA, which was finalized in 2020 (NHTSA 2020). The One National Program Rule enables U.S. EPA/NHTSA to provide nationwide uniform fuel economy and GHG vehicle standards, specifically by 1) clarifying that federal law preempts state and local tailpipe GHG standards, 2) affirming NHTSA's statutory authority to set nationally applicable fuel economy standards, and 3) withdrawing California's CAA preemption waiver to set state-specific standards.

U.S. EPA and NHTSA published their decisions to withdraw California's waiver and finalize regulatory text related to the preemption on September 27, 2019 (Part One of the SAFE Vehicles Rule) (84 Fed. Reg. 51310). U.S. EPA and NTHSA published final rules to amend and establish national CO_2 and fuel economy standards on April 30, 2020 (Part Two of the SAFE Vehicles Rule) (85 Fed. Reg. 24174). The revised rule changes the national fuel economy standards for light duty vehicles from 46.7 mpg to 40.4 mpg in future years. California, 22 other states, the District of Columbia filed a petition for review of the final rule on May 27, 2020.

On January 20, 2021, President Joseph Biden issued an executive order directing U.S. EPA and NHTSA to review the SAFE Vehicles Rule and propose a new rule suspending, revising, or rescinding it. On April 22, 2021, NTHSA issued a notice of proposed rulemaking to repeal the SAFE Vehicles Rule (49 Code of Federal Regulations Parts 531 and 533), and the rule was officially repealed in January 2022.

Public Health and Equity

Title VI of the Civil Rights Act (1964)

Passed in 1964, the Civil Rights Act is a law that protects civil rights and outlaws discrimination based on race, color, religion, sex, and national origin. Title VI specifically prohibits discrimination based on race, color, or national origin by any program or activity that receives federal funds, and any recipient of federal funds found to be violating Title VI may lose federal funding. Title VI requires each federal department and agency to execute the provisions of the act.

Executive Order 12898 (1994)

Executive Order 12898 was signed in 1994 and orders all federal agencies to make achieving environmental justice part of their mission. Agencies are directed to identify and address disproportionately high and adverse human health or environmental effects of agency programs, policies, and activities on minority and low-income populations. The order also established an Interagency Working Group on Environmental Justice that comprises the heads of numerous federal departments, agencies, and other bodies. The Working Group provides guidance to federal agencies on setting criteria to identify disproportionate effects, and to provide coordination and cooperation among agencies to develop projects and strategies that improve environmental justice outcomes (*Federal Register* 1994).

Environmental Justice Guidance Under the National Environmental Policy Act (1997)

In response to Executive Order 12898, the White House Council on Environmental Quality developed guidance for agencies to carry out the order, documented in a report titled *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*. The guidance includes six principles for environmental justice analyses and provides guidance for how to assess human health or environmental effects on low-income, minority, and tribal communities and how to create opportunities for such communities and the public to participate in related planning processes (CEQ 1997). Following this guidance, federal agencies have developed (and since updated) plans, guidance, or strategies to address environmental justice through agency actions.

Executive Order 13985—Advancing Racial Equity and Support for Underserved Communities Through the Federal Government (2021)

Executive Order 13985 aims to advance racial equity by addressing issues that have historically created inequity, and to advance civil rights, social justice, and equal opportunity. The directive declares that the government will address historic failures to invest sufficiently, justly, and equally in underserved communities, and will increase investment in underserved communities by promoting equitable delivery of government benefits and opportunities. To do so, it directs agencies to conduct equity assessments and allocate resources to advance fairness and opportunity. The order defines equity as "the consistent and systematic fair, just, and impartial treatment of all individuals, including individuals who belong to underserved communities that have been denied such treatment," including minorities, LGBTQ+, disabled, rural, poor, and other disadvantaged groups (White House 2021a).

Executive Order 13990—Protecting Public Health and the Environment and Restoring Science to Tackle the Climate Crisis (2021)

Executive Order 13990 declares a recommitment to follow scientific evidence in decision-making processes to advance public health and environment outcomes. More specifically, it states the administration's intent to ensure clean air and water, reduce GHG emissions, limit pollution and hold polluters responsible, reduce exposure to toxic chemicals, enhance environmental justice, bolster climate change resilience, and create well-paying union jobs. To do so, the order directs all executive departments and agencies to review all federal regulations and other actions made in the prior administration, and address those that conflict with the new national objectives. Specifically, it requires agency heads to propose suspending, revising, or rescinding the following rules.

- Oil and Natural Gas Sector: Emission Standards for New, Reconstructed, and Modified Sources Reconsideration.
- The SAFE Vehicles Rule Part One: One National Program.
- Energy Conservation Program for Appliance Standards: Procedures for Use in New or Revised Energy Conservation Standards and Test Procedures for Consumer Products and Commercial/Industrial Equipment.
- National Emission Standards for Hazardous Air Pollutants: Coal- and Oil-Fired Electric Utility Steam Generating Units—Reconsideration of Supplemental Finding and Residual Risk and Technology Review.

In carrying out these reviews, agencies must seek input from environmental justice organizations and other stakeholders. Additional mandates include revoking the permit for the Keystone XL pipeline and barring oil drilling in the Arctic National Wildlife Refuge, reviewing the possibility of restoring national monuments, and mandating the development of a social cost of carbon and social cost of CH_4 to be used by agencies in accounting procedures (White House 2021b).

State Regulations and Rules

California has adopted numerous statewide laws, regulations, and policies to address GHG emissions reductions, climate adaptation, and public health and equity. In many instances, California has been a trailblazer and standard setter for climate-related regulations and program. For example, California passed the Pavley 1 rule in 2002, which set the nation's first GHG standards for automobiles, and the State's GHG cap-and-trade program was the first multi-sector cap-and-trade program in North America.

GHG Emission Reductions

California Environmental Quality Act (1970)

The California Environmental Quality Act (CEQA) guidelines explain how to determine if an activity is subject to environmental review, what steps are involved in the environmental review process, and what environmental documents are required. Specifically, they require agencies to describe, calculate, or estimate the amount of GHG emissions that are expected to result from a project. They also require a determination of whether the project would directly exacerbate climate change effects (for example by increasing wildfire potential in areas where wildfire is more likely due to climate change). CEQA Guidelines apply to public agencies. CEQA Guidelines confirm agencies have discretion to determine appropriate significance thresholds, but require the preparation of an environmental impact report if "there is substantial evidence that the possible effects of a particular project are still cumulatively considerable notwithstanding compliance with adopted regulations or requirements" (AEP 2010). The guidelines were updated in 2010 and 2018 to include revisions to transportation impact analysis and GHG emissions analysis (OPR 2021a).

Assembly Bill 1493—Pavley Rules (2002, Amendments 2009)

Known as "Pavley I," AB 1493 set the nation's first GHG standards for automobiles. AB 1493 requires the California Air Resources Board (CARB) to adopt vehicle standards that will lower GHG emissions from new light-duty autos to the maximum extent feasible beginning in 2009 (CARB 2021a). In 2012, CARB strengthened the Pavley standards through the Advanced Clean Cars regulations, which limit GHG emissions from passenger vehicles for model years 2017–2025 (CARB 2021b).

Senate Bill 1078 (2002), Senate Bill 107 (2006), Senate Bill 2 (2011), Senate Bill 350 (2015), Senate Bill 100 (2018)—Renewables Portfolio Standard

SB 1078 and SB 107, California's Renewables Portfolio Standard, obligates investor-owned utilities, energy service providers, and Community Choice Aggregations to procure an additional 1 percent of retail sales per year from eligible renewable sources until 20 percent is reached, by no later than 2010. The California Public Utilities Commission and California Energy Commission are jointly responsible for implementing the program. Senate Bill (SB) X 1-2, passed in 2011, expanded the target to 33 percent of retail sales by 2020. Next, SB 350 (passed in 2015) established an ambitious long-term target to source 50 percent of electricity retail sales from renewable resources by 2030 (CARB 2021c). In 2018, SB 100 raised the 2030 target to 60 percent, and mandates that California source 100 percent of its electricity from carbon-free resources by 2045 (California Legislative Information 2018a).

Executive Order S-3-05 (2005)

Executive Order S-3-05 states that California is vulnerable to the effects of climate change and to help mitigate it, established the following GHG emissions reduction targets for state agencies.

- By 2010, reduce GHG emissions to 2000 levels.
- By 2020, reduce GHG emissions to 1990 levels.
- By 2050, reduce GHG emissions to 80 percent below 1990 levels.

The Executive Order also requires the secretary of the California Environmental Protection Agency (CalEPA) to report to the governor and state legislature biannually the impacts of global warming on California, mitigation and adaptation plans, and progress made toward reducing GHG emissions and meeting the targets established in this Executive Order (Office of Governor 2005).

Assembly Bill 32—California Global Warming Solutions Act (2006)

In 2006, AB 32—the California Global Warming Solutions Act of 2006—was adopted by the State legislature. AB 32 established a cap on statewide GHG emissions and created a regulatory framework to reduce emissions. Under AB 32, CARB is required to take the following actions:

- Adopt early action measures to reduce GHGs,
- Establish a statewide GHG emissions cap for 2020 based on 1990 emissions,
- Adopt mandatory reporting rules for significant GHG sources,
- Adopt a scoping plan indicating how emission reductions would be achieved through regulations, market mechanisms, and other actions, and
- Adopt regulations needed to achieve the maximum technologically feasible and cost-effective reductions in GHGs (CARB 2018a).

Executive Order S-01-07—Low Carbon Fuel Standard (2007)

Executive Order S-01-07 establishes a statewide goal to reduce the carbon intensity of California's transportation fuels by at least 10 percent by 2020. The executive order initiated a research and regulatory process at CARB, which led to regulation that became effective in 2010 (CARB 2021c). In 2018, CARB passed amendments to the LCFS that set a target to reduce fuel carbon intensity by 20 percent by 2030, compared to a 2010 baseline (CARB 2018b).

California Air Resources Board Greenhouse Gas Mandatory Reporting Rule Title 17 (2007)

In 2007, CARB approved a rule requiring mandatory reporting of GHG emissions from certain sources, pursuant to AB 32. Facilities subject to the rule started to report their emissions from the calendar year 2009 and were required to have those emissions verified by a third party in 2010. The rule applies to facilities emitting more than 25,000 MT CO_2e in any given calendar year, or electricity generating facilities with a generating capacity greater than 1 megawatt and/or emitting more than 25,000 MT CO_2e per year. Additional requirements also apply to cement plants and entities that buy and sell electricity in-state. The most recent amendments to the regulation were made in 2018, and became effective in April of 2019, for 2019 data (CARB 2021d). These amendments more clearly define current requirements for calculation and reporting, ensure that electricity import emissions are fully accounted for, and support the State's GHG cap-and-trade program.

Senate Bill 375—Sustainable Communities Strategy (2008)

SB 375 provides a planning process that coordinates land use planning, regional transportation plans, and funding priorities to help California meet the GHG reduction goals established in AB 32. SB 375 requires regional transportation plans developed by metropolitan planning organizations to incorporate a sustainable communities strategy in their regional transportation plans. The goal of the SCS is to reduce regional vehicle miles traveled (VMT) through land use planning and transportation planning. SB 375 also includes provisions for streamlined CEQA review for some infill projects such as transit-oriented development (Institute for Local Government 2015).

Greenhouse Gas Cap-and-Trade Program (2011)

In 2011, CARB adopted a cap-and-trade program for California. The program is a key mechanism to reduce statewide GHG emissions and achieve California's GHG reduction goals. The cap-and-trade program created a market-based system that set an overall emissions limit (a "cap") for specific sectors, which is reduced annually. The program currently regulates more than 85 percent of California's emissions, including emissions from electricity generation, large industrial sources, fuel combustion, and transportation. Revenues from the program are deposited into a GHG Reduction Fund, which then distributes appropriations to state agencies to implement programs that reduce GHG emissions (35 percent of funds are required to be directed toward environmentally disadvantaged and low-income communities). More than $5 billion in revenue has been generated since the program began. In 2014, the program linked with Quebec, Canada's cap-and-trade program through the Western Climate Initiative (C2ES n.d.).

Assembly Bill 341 (2011)

AB 341 was passed in 2011 and sets requirements for the statewide mandatory commercial recycling program. The purpose of the law is to reduce GHG emissions by diverting commercial solid waste to recycling facilities and to expand recycling services.

AB 341 requires businesses and public entities that generate four cubic yards or more of commercial solid waste and multifamily residential buildings of five units or more to arrange for recycling services. It also requires local jurisdictions to implement a commercial solid waste recycling program, including education, outreach, and monitoring to help divert waste, and to report progress annually. CalRecycle must review each jurisdiction's program periodically (CalRecycle 2020a).

Senate Bill 743 (2013)

SB 743, passed in 2013, required revisions to the CEQA Guidelines (which occurred in 2018 and became effective in 2020) to establish new impact analysis criteria for the assessment of a project's transportation impacts. The intent behind SB 743 and the CEQA Guidelines revision was to integrate and better balance the needs of congestion management, infill development, active transportation, and GHG emissions reduction (Caltrans 2021). Starting on July 1, 2020, agencies are required to look at VMT instead of levels of service when analyzing the transportation impacts of new projects. The change was made because VMT is a better measure of the transportation system's impact on the climate, environment, and human health, and also indicates access to economic and social opportunity (OPR 2021b).

Assembly Bill 1826 (2014)

AB 1826 was passed in 2014 and requires businesses and public entities that generate four cubic yards or more of commercial solid waste and multifamily residential buildings of five units or more to arrange for organic waste (e.g., food and lawncare waste) recycling services and for local jurisdictions to implement organic waste recycling programs. A 2014 report found that approximately one-third of overall waste was organic waste and seven percent was compostable paper. AB 1826 targeted this waste stream to reduce GHGs and to use the waste for more beneficial purposes such as compost, mulch, and biofuel production. The law phased in requirements over time and exempted rural counties. In 2020, CalRecycle reduced the threshold to 2 cubic yards of solid waste (CalRecycle 2020b).

Senate Bill 605 (2014) and Senate Bill 1383 (2016)—Short-Lived Climate Pollutants Reduction Strategy

SB 605 (passed in 2014) directed CARB, in coordination with other state agencies and local air districts, to develop a comprehensive Short-Lived Climate Pollutants (SLCP) Reduction Strategy. SB 1383 (passed in 2016) directed CARB to approve and implement the SLCP Reduction Strategy to achieve the following reductions in SLCPs.

- 40 percent reduction in CH_4 below 2013 levels by 2030.
- 40 percent reduction in hydrofluorocarbon gases below 2013 levels by 2030.
- 50 percent reduction in anthropogenic black carbon below 2013 levels by 2030.

The bill also establishes the following targets for reducing organic waste in landfills and CH_4 emissions from dairy and livestock operations.

- 50 percent reduction in organic waste disposal from the 2014 level by 2020.
- 75 percent reduction in organic waste disposal from the 2014 level by 2025.
- 40 percent reduction in CH_4 emissions from livestock manure management operations and dairy manure management operations below the dairy and livestock sector's 2013 levels by 2030 (BAAQMD 2020).

Final regulations to achieve the GHG reduction goals expressed in SB 1383 were codified under the California Code of Regulations (Title 14, Division 7, Chapters 3 and Title 27, Division 2, Chapters 2, 3, and 4) in November 2020. The regulation goes into effect on January 1, 2022.

Executive Order B-30-15 (2015)

Signed in 2015, Executive Order B-30-15 establishes the connection between reducing GHG emissions to limit future climate change and adapting to current and future climate change impacts. It established a statewide interim GHG reduction target to reduce GHG emissions by 40 percent below 1990 levels by 2030 to ensure the state reduces emissions 80 percent below 1990 levels by 2050, and mandated state agencies to implement measures to achieve these targets. It also requires that the California Natural Resources Agency (CNRA) update the State's climate adaptation strategy—Safeguarding California—every 3 years. The strategy must:

- Identify vulnerabilities to climate change by sector and regions;
- Outline the primary risks to residents, property, communities, and natural systems and identify priority actions to reduce those risks; and
- Identify a lead agency or group of agencies to lead adaptation efforts in each sector.

The order also requires state agencies to take into account current and future climate impacts in all planning and investment decisions (Office of Governor 2015).

Senate Bill 32—California Global Warming Solutions Act (2016)

In 2016, the California legislature passed SB 32, which mandates a 40 percent reduction in GHG emissions from 1990 levels by 2030 and directs CARB to use the most advanced technology feasible to achieve cost-efficient reductions in GHG emissions. SB 32 also includes an environmental justice component that requires GHG reduction targets to be met in a way that benefits the most disadvantaged communities, which are often most affected by climate change (California Legislative Information 2016b).

Assembly Bill 197—State Air Resources Board: Greenhouse Gases – Regulations (2016)

In 2016, the California Assembly passed AB 197, which provides guidance to CARB on enacting GHG emission reduction measures and making air emissions data more accessible to the public. Specifically, AB 197 requires the following.

- Presenting GHG benchmarks and toxic air contaminant data to the public.

- Considering social costs of GHG emissions.
- Prioritizing reductions from large stationary sources and mobile sources when passing emission reduction rules and regulations that protect disadvantaged communities.
- Identifying the following for each GHG emissions reduction measure.
  - Potential range of GHG emission reductions.
  - Potential range of air pollution reductions.
  - Cost-effectiveness of the measure (including social costs) (California Legislative Information 2016a).

2017 Climate Change Scoping Plan (2017)

CARB adopted the *2017 Climate Change Scoping Plan* in November 2017 to meet the GHG reduction requirement set forth in SB 32. The plan outlines how the State can reach the 2030 climate target to reduce GHG emissions by 40 percent from 1990 levels and provides a path for state regulators and policymakers to follow. Specifically, it describes how California can build on past policies and increase electric vehicle adoption, generate cleaner electricity, design denser and more walkable communities, improve energy efficiency, and reduce agricultural pollution (CARB 2021e).

Executive Order B-55-18 (2018)

Executive Order B-55-18 established a new state goal to achieve carbon neutrality as soon as possible, and no later than 2045, and to achieve and maintain net negative emissions thereafter. To track progress toward this goal, it orders CARB to work with state agencies to develop an implementation and accounting framework. It also states that all policies and programs undertaken to achieve the goal should support climate adaptation, resource conservation, biodiversity, and improve public health in urban and rural communities, particularly low-income and disadvantaged communities (Office of Governor 2018).

Innovative Clean Transit Regulation (2019)

Adopted in 2019, the Innovative Clean Transit (ICT) regulation requires all public transit agencies to transition to a 100 percent zero-emission bus fleet by 2040 and requires large transit agencies to begin to purchase zero-emission buses (ZEBs) as early as 2023. Large and small transit agencies must submit their ZEB rollout plans by July 1, 2020, and July 1, 2023, respectively. The agencies are required to phase in the proportion of ZEBs purchased over time. State funding to transit agencies is contingent upon the agencies purchasing the required level of ZEBs.

The ICT also encourages agencies to provide innovative first- and last-mile connectivity for riders. The ICT will significantly reduce NO_x and GHG emissions, especially in transit-dependent and disadvantaged communities, and is expected to provide other benefits including reduced dependency on fossil fuels, expanding the zero-emissions vehicle industry, creating high quality green jobs, and improving mobility and connectivity (CARB 2021g).

California Green Building Standards Code (2019)

The California Green Building Standards Code (Part 11, Title 24), known as CALGreen, was adopted in 2007 as part of the California Building Standards Code. It established voluntary standards that became mandatory under the 2010 edition of the code. These involved sustainable site development, energy efficiency (above California Energy Code requirements), water conservation (e.g., low-flow fixtures), material conservation, and reducing internal air contaminants. The energy efficiency standards are updated every three years (California Building Standards Commission n.d.).

California 2030 Natural and Working Lands Climate Change Implementation Plan (2019)

In 2019, CARB, CNRA, CalEPA, and other state agencies released the 2030 Natural and Working Lands Climate Change Implementation Plan that describes how effectively utilizing natural and working lands can help reduce GHG emissions and improve resilience. The plan outlines specific conservation, restoration, and management activities that will improve resilience, maintain a natural carbon sink, and improve environmental quality. The plan sets a goal to at minimum double the pace and scale of State-supported land activities by 2030 and beyond. Additionally, by 2030, the plan strives to do the following.

- Double the rate of State-funded forest management or restoration efforts.
- Triple the rate of State-funded oak woodland and riparian restoration.
- Quintuple the number of acres of cultivated lands and rangelands under State-funded soil conservation practices.
- Double the rate of State-funded wetland and seagrass restoration.

The plan estimates that these activities will decrease emissions by 12.4 to 35.9 million MT CO_2e by 2030 and reduce emissions by 83.1 to 84.2 million MT CO_2e by 2045. (CARB 2019).

Advanced Clean Truck Regulation (2020)

CARB adopted the Advanced Clean Truck (ACT) Regulation in June 2020 to accelerate a large-scale transition to zero-emission medium- and heavy-duty vehicles. The purpose of the regulation is to reduce NO_x and GHG emissions to improve air quality and public health. The regulation requires the sale of zero-emission medium- and heavy-duty vehicles as an increasing percentage of total annual California sales from 2024 to 2035. By 2035, zero-emission truck/chassis sales would need to be 55 percent of Class 2b–3 truck sales, 75 percent of Class 4–8 straight truck sales, and 40 percent of truck tractor sales. By 2045, every new medium- and heavy-duty truck sold in California will be zero-emission. The regulation requires fleet owners with 50 or more trucks to report on their existing fleet operations. The regulation is the first in the world to require manufacturers to sell increasing percentages of zero-emissions trucks (ICCT 2020).

2022 Climate Change Scoping Plan (2022)

CARB adopted the 2022 Climate Change Scoping Plan in December 2022 to meet the GHG reduction requirements set forth in SB 32. The plan outlines how the State can achieve carbon neutrality by 2045 or earlier through technologically feasible, cost-effective, and equity-focused pathways. The plan charts a path to reduce anthropogenic emissions to 85 percent below 1990 levels by 2045, and it describes how California can expand actions to capture and store carbon using a variety of mechanical approaches and through the state's natural and working lands (CARB 2022).

Assembly Bill 1279—The California Climate Crisis Act (2022)

In 2022, the California Assembly passed AB 1279, which declares the policy of the state to achieve net zero greenhouse gas emissions as soon as possible, but no later than 2045, and achieve and maintain net negative greenhouse gas emissions thereafter. The state must ensure that by 2045, statewide anthropogenic greenhouse gas emissions are reduced to at least 85% below the 1990 levels. The bill also requires the state board to submit an annual report detailing progress.

Climate Adaptation

Executive Order S-13-08 (2008)

Signed in 2008, Executive Order S-13-08 requires the CNRA to develop a state Climate Adaptation Strategy (described below) in partnership with local, regional, state, and federal entities. It also requires the development of a California Sea Level Rise Assessment Report that is reviewed every two years. Among other directives, it directs state agencies planning construction projects to assess their vulnerability to sea level rise and other climate change impacts (Adaptation Clearinghouse 2008).

California Climate Adaptation Strategy (2009) and Update (2018)

In 2009, California adopted a statewide Climate Adaptation Strategy (CAS) that summarized climate change impacts and recommended adaptation strategies for seven sectors—public health, biodiversity and habitat, oceans and coastal resources, water, agriculture, forestry, and transportation and energy. In 2018, the CNRA updated the CAS to lay out ongoing climate actions, cost-effective and achievable next steps to respond to climate change in 11 sectors, and overarching strategies to make California more resilient to climate change (CNRA 2018).

Senate Bill 246—Integrated Climate Adaptation and Resiliency Program (2015)

Signed in 2015, SB 246 establishes a statewide plan for integrated climate adaptation and resiliency that coordinates regional and local efforts with state strategies to effectively adapt to climate change. The program emphasizes climate equity considerations throughout all sectors and regions to help develop holistic strategies for climate adaptation. The bill requires numerous state agencies and other government bodies to coordinate with local and regional efforts to do the following.

- Develop tools and guidance.
- Promote and coordinate state agency support for local and regional efforts.
- Inform state-led programs to better facilitate local and regional goals and efforts to improve adaptation and resilience (California Legislative Information 2015).

As a result of SB 246, in 2020, a new version of the California Climate Adaptation Planning Guide was developed by the California Governor's Office of Emergency Services and OPR to include new requirements for local adaptation planning.

Senate Bill 379 (2015)

SB 379 was adopted in 2015 to ensure that climate adaptation is integrated into local jurisdictions' general plan processes. Jurisdictions must review and update the safety elements of their general plans to include climate adaptation and resilience strategies. The bill requires jurisdictions to do the following in their safety element review and update.

1. Conduct a vulnerability assessment that identifies climate change risks.
2. Set adaptation and resilience goals, policies, and objectives based on the vulnerability assessment.
3. Set feasible implementation measures to achieve the goals and objectives.

Jurisdictions with a local hazard mitigation plan (LHMP) or a climate adaptation plan that meet these requirements can comply with SB 379 by incorporating these documents by summary in the safety element. For jurisdictions that have already adopted a local hazard mitigation plan, these requirements were to be satisfied upon the next of the LHMP starting January 1, 2017; those without an LHMP must update the safety element of the general plan by January 1, 2022 (OPR 2017).

Sea-Level Rise Policy Guidance (2015) and Science Update (2018)

The California Coastal Commission adopted the Sea-Level Rise Policy Guidance in 2015. The guidance provides an overview of the sea level rise science and a methodology for addressing sea level rise in the Coastal Commission planning and regulatory actions. The Coastal Commission describes the guidance as "a menu of options" that local planners can select from as appropriate, rather than a checklist of requirements. The guidance is broadly applicable and is used by the Coastal Commission, local governments, project applicants, and other stakeholders.

In 2018, the Coastal Commission adopted a "Science Update" to the guidance that integrates the best available scientific data. The update provides broad recommendations for how to plan for and address sea level rise impacts, and includes new projections that can inform planning, permitting, investment, and other decisions (CCC 2019).

California Water Action Plan (2016)

The California Water Action Plan sets forth a collection of actions developed by the CNRA, California Department of Food and Agriculture, and CalEPA with the goals to improve reliable water supply, restore the state's ecosystems, and build a resilient and sustainable water resource system. The plan provides specific actions to improve water conservation, protect and restore ecosystems, improve drought planning, expand water storage, recycle water, and identify sustainable and integrated financing opportunities. The Water Action Plan also emphasizes diversified regional supply portfolios to increase resilience to droughts, floods, population growth, and climate change (CNRA 2016).

State Water Board Resolution 2017-0012—Comprehensive Response to Climate Change (2017)

The State Water Resources Control Board (State Water Board) has taken a variety of actions to respond to climate change, including the adoption of Resolution 2017-0012 in 2017, known as the Comprehensive Response to Climate Change. The resolution requires that proactive measures to respond to climate change must be integrated into all State Water Board actions. The resolution outlines specific measures to reduce GHG emissions, improve ecosystem resilience, and respond to climate change impacts. Some measures include capturing CH_4 to support the SLCP Reduction strategy, improve water efficiency and conservation, recycle water, improve storm water capture infiltration, and improve energy efficiency and use renewable energy to power water systems (State Water Board 2017).

Senate Bill 901—Wildfire Preparedness and Response (2018)

The Wildfire Preparedness and Response bill, signed in 2018, supports the State's climate adaptation and resilience efforts in response to increasingly frequent and extreme wildfires. The bill allocates $200 million annually from 2019 through 2024 to fund grants to fire departments, cities, counties, and nonprofit organizations to help reduce forest fuel loads with thinning and prescribed burns in high-risk areas. The California Department of Forestry and Fire Protection (CAL FIRE) distributes the funding and will create a Wildfire Resilience Program to provide technical assistance to non-industrial timberland owners. It also requires CARB to develop a standardized approach to quantifying the carbon emissions from fuel reduction activities and the emissions attributed to wildfires. Furthermore, SB 901 creates a s process for electrical utilities to seek approval to recoup costs from wildfires, but also requires them to create and implement wildfire mitigation plans (Adaptation Clearinghouse 2018).

Senate Bill 1035 (2018)

Local California jurisdictions are required to adopt a comprehensive, long-term general plan that includes, among other things, a housing element and safety element to protect against geologic and climatic hazards. SB 1035 requires local planning agencies to review, and if necessary, revise the safety element during each revision of the housing element or a local hazard mitigation plan, and not less than once every eight years. The review must identify any new information related to flood and fire hazards and adaptation and resiliency strategies that are applicable to the jurisdiction (California Legislative Information 2018b).

Executive Order N-82-20 (2020)

Signed in 2020, Executive Order N-82-20 requires the CNRA to establish the California Biodiversity Collaborative (Collaborative) to bring together governmental and tribal partners, experts, business and community leaders, and other stakeholders to protect and restore the state's biodiversity. State agencies will consult the Collaborative on efforts to advance multi-benefit, voluntary and cooperative approaches that protect and restore biodiversity while stewarding natural and working lands, building climate resilience, and supporting economic sustainability.

Public Health and Equity

Senate Bill 535 (2012, 2022) and Assembly Bill 1550 (2016)—Disadvantaged and Low-Income Communities

SB 535 requires California to invest a portion of the proceeds from cap-and-trade auctions—the Greenhouse Gas Reduction Fund (GGRF)—in disadvantaged communities. At least 25 percent of funds must benefit disadvantaged communities, and at least 10 percent must be invested directly in disadvantaged communities. In 2016, AB 1550 updated the GGRF funding targets to 25 percent for projects located within and directly benefiting disadvantaged communities, and 10 percent for low-income households or communities.

SB 535 requires CalEPA to identify disadvantaged communities in California based on environmental pollution burden, exposure, socioeconomic characteristics, and other criteria. In 2022, CalEPA released updated criteria for designating disadvantaged communities, after receiving public input. To identify communities, CalEPA relied upon the California Communities Environmental Health Screening Tool (CalEnviroScreen), which scores all census tracts in California for their exposure and vulnerability to pollution burden. CalEPA defined disadvantaged communities as census tracts scoring in the top 25th percentile of CalEnviroScreen scores; census tracts without scores but having the highest 5 percent of cumulative pollution burden scores in CalEnviroScreen; disadvantaged census tracts from the 2017 designation of disadvantaged communities; and land under control of federally recognized Tribes. Low-income households and census tracts are defined as those at or below 80 percent of the statewide median income, or at or below the low-income threshold for each county set by the California Department of Housing and Community Development.

Senate Bill 1000—Land Use: General Plans: Safety and Environmental Justice (2016)

SB 1000 requires cities and counties with disadvantaged communities to include an environmental justice element in their General Plans to ensure that local governments address environmental justice when planning long-term goals and policies related to land use and growth. To do so, local governments must identify any disadvantaged communities and develop measures to mitigate and reduce health risks that can be attributed to the environment. Additionally, the bill requires cities and counties to create policies to include members of disadvantaged communities in decision-making processes and to prioritize projects and improvements in those communities (Strategic Growth Council 2021). OPR has developed updated and expanded guidance on environmental justice and SB 1000 (OPR 2021).

Assembly Bill 2722—Transformative Climate Communities Program (2016)

AB 2722 was signed in 2016 to help create more sustainable cities, address climate justice, and help California meet its GHG emissions reduction goals. To achieve this, the California Strategic Growth Council created the Transformative Climate Communities program, which issues competitive grants to eligible entities to help develop "transformative" climate community plans. Entities must use the funds to implement community plans that improve air and water quality, reduce GHG emissions, and that show the potential to provide climate, economic, employment, health, and environmental benefits to disadvantaged communities. Up to $250 million in funding will be provided for the program (California Legislative Information 2016c).

Assembly Bill 617 (2017)

Passed in 2017, AB 617 requires the State to develop a statewide annual reporting system for emissions of criteria air pollutants and toxic air contaminants for certain stationary sources. It also requires the State to prepare a monitoring plan for emissions and to prepare a statewide strategy to reduce emissions of toxic air contaminants and criteria pollutants in communities that experience a high cumulative exposure burden. Environmental justice groups and other stakeholders must be consulted in developing the monitoring plan, and the reduction strategy must be updated every five years. Furthermore, the law requires the provision of grants to community organizations for technical assistance and requires air districts to adopt community emissions reduction programs (California Legislative Information 2017).

In response, CARB established the Community Air Protection Program (CAPP), which focuses on reducing pollution exposure to communities that are most affected by air pollution. CAPP includes community air monitoring and emissions reductions programs, which are funded to deploy clean technologies in communities. Additional funding is used to retrofit pollution controls on industrial sources. The CAPP also increases penalty fees for polluters and improves transparency and greater access to air quality and emissions data (CARB 2021f).

Additional Resources

For additional information, interested readers can reference the following resources. Please also refer to Chapter 6, *Resources to Support Resilient and Equitable Emission Reduction Planning*.

- CNRA's (2018) *Safeguarding California Plan: 2018 Update*. The plan provides a timeline highlighting climate adaptation policies in California.

- **Georgetown Climate Center (n.d.).** The Georgetown Climate Center offers an overview of and links to all state and agency laws and policies, as well as local and regional plans that guide California's approach to planning for climate change.
- **CARB (2021h) Local Actions for Climate Change.** CARB's website provides background information and resources to help local government take part in helping California achieve its climate goals.
- **Berkeley Law (2021) California Climate Policy Dashboard.** The dashboard collects all major state laws and programs in a concise format to provide background and direct links to resources related to climate policies.
- **OPR's (2021c) Resilient California Adaptation Clearinghouse**: The State's Adaptation Clearinghouse is a searchable database of the many resources that are useful for local, regional, and state adaptation planning efforts. Resources include tools, case studies, guidelines, scientific reports, and more. It also contains a clearinghouse for equity and environmental justice.
- **ARCCA (2021) Website**: The Alliance of Regional Collaborative for Climate Adaptation (ARCCA) is a network of regional collaboratives and allies that work to advance statewide adaptation and community resilience efforts. Their website tracks the latest policy updates, describes ongoing resilience and equity initiatives, and provides additional resources such as toolkits and roadmaps.

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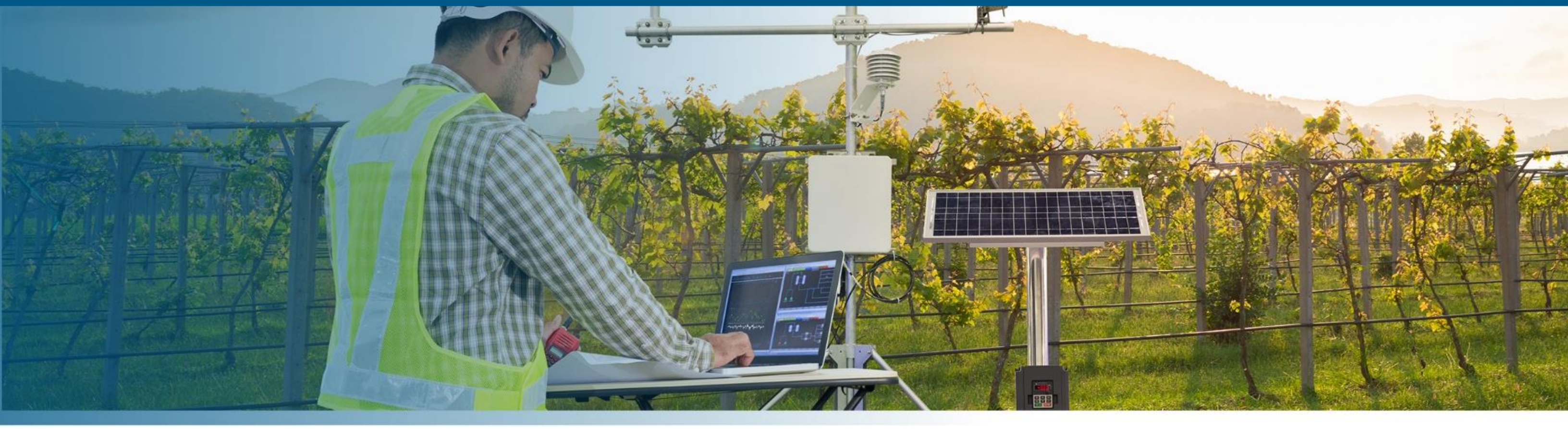
Emission Factors and Data Tables

APPENDIX C



Tables

Table T-3.1. Average Transit and Vehicle Mode Share of All Trips by California Core-Based Statistical Area

Core-Based Statistical Area	Mode Share	
	Transit	Vehicle
Los Angeles-Long Beach-Anaheim	4.23%	94.19%
Riverside-San Bernardino-Ontario	1.37%	96.88%
Sacramento-Roseville-Arden-Arcade	2.90%	95.04%
San Diego-Carlsbad	2.40%	94.85%
San Francisco-Oakland-Hayward	11.38%	86.96%
San Jose-Sunnyvale-Santa Clara	6.69%	91.32%

Source: Federal Highway Administration. 2017. National Household Travel Survey – 2017 Table Designer. Travel Day PMT by TRPTRANS by HH_CBSA. Available: https://nhts.ornl.gov/. Accessed: January 2021.

Table T-8.1. Reduction in Employee Commute Vehicle Miles Traveled by Place Type

Place Type	Reduction in Employee Commute VMT
Urban	-8%
Suburban	-4%
Rural	—

Source: San Diego Association of Governments (SANDAG). 2019. Mobility Management VMT Reduction Calculator Tool – Design Document. June. Available: https://www.icommutesd.com/docs/default-source/planning/tool-design-document_final_7-17-19.pdf?sfvrsn=ec39eb3b_2. Accessed: January 2021

— = measure not applicable in this place type; VMT = vehicle miles traveled.

Table T-9.1. Average Transit Mode Share of Work Trips by California Core-Based Statistical Area

Core-Based Statistical Area	Transit Mode Share of Work Trips
Los Angeles-Long Beach-Anaheim	5.39%
Riverside-San Bernardino-Ontario	1.12%
Sacramento-Roseville-Arden-Arcade	5.44%
San Diego-Carlsbad	4.74%
San Francisco-Oakland-Hayward	25.60%
San Jose-Sunnyvale-Santa Clara	6.11%

Source: Federal Highway Administration. 2017. National Household Travel Survey – 2017 Table Designer. WRKTRANS by HH_CBSA. Available: https://nhts.ornl.gov/. Accessed: January 2021.

Table T-10.1. Average One-Way Bicycle and Vehicle Trip Length of All Trips by California Core-Based Statistical Area

Core-Based Statistical Area	Trip Length (miles)	
	Bicycle	Vehicle
Los Angeles-Long Beach-Anaheim	1.7	9.7
Riverside-San Bernardino-Ontario	2.2	11.7
Sacramento-Roseville-Arden-Arcade	2.9	10.9
San Diego-Carlsbad	2.0	19.1
San Francisco-Oakland-Hayward	2.1	12.4
San Jose-Sunnyvale-Santa Clara	2.8	11.5

Source: Federal Highway Administration. 2017. National Household Travel Survey – 2017 Table Designer. Travel Day PT by TRPTRANS by HH_CBSA. Available: https://nhts.ornl.gov/. Accessed: January 2021.

Table T-10.2. Average Bicycle and Vehicle Mode Share of Work Trips by California Core-Based Statistical Area

Core-Based Statistical Area	Mode Share	
	Bicycle	Vehicle
Los Angeles-Long Beach-Anaheim	1.0%	90.7%
Riverside-San Bernardino-Ontario	0.4%	95.3%
Sacramento-Roseville-Arden-Arcade	2.2%	89.5%
San Diego-Carlsbad	1.3%	91.8%
San Francisco-Oakland-Hayward	2.8%	67.1%
San Jose-Sunnyvale-Santa Clara	4.1%	86.6%

Source: Federal Highway Administration. 2017. National Household Travel Survey – 2017 Table Designer. Workers by WRKTRANS by HH_CBSA. Available: https://nhts.ornl.gov/. Accessed: January 2021.

Table T-11.1. Average One-Way Vehicle Commute Trip[1] Length by California Core-Based Statistical Area

Core-Based Statistical Area	Vehicle Trip Length (miles)
Los Angeles-Long Beach-Anaheim	14.07
Riverside-San Bernardino-Ontario	18.62
Sacramento-Roseville-Arden-Arcade	14.23
San Diego-Carlsbad	14.52
San Francisco-Oakland-Hayward	15.63
San Jose-Sunnyvale-Santa Clara	12.44

Source: Federal Highway Administration. 2017. National Household Travel Survey – 2017 Table Designer. Travel Day VT by HH_CBSA by TRPTRANS by TRIPPURP. Available: https://nhts.ornl.gov/. Accessed: January 2021.

[1]Trips included in this dataset were for work-related trips (HBW).

Table T-16.1. Typical Monthly Parking Prices by Facility Type

Facility Type	Monthly Cost per Space
Suburban, Surface	$36
Urban, Surface	$65
Urban, Structure	$133
Urban, Underground	$191

Source: Litman. 2020b. Parking Requirement Impacts on Housing Affordability. June. Available: https://www.vtpi.org/park-hou.pdf. Accessed: January 2021.

Table T-19.1. Active Transportation Adjustment Factors

Average Daily Traffic (vehicle trips per day)	One-way Facility Length[1]	Adjustment Factor for a Population > 250,000 or a Non-university Town with Population < 250,000	Adjustment Factor for a University Town with Population <250,000
1 to 12,000	≤1	0.0019	0.0104
	1.02 to 2	0.0029	0.0155
	>2	0.0038	0.0207
12,001 to 24,000	≤1	0.0014	0.0073
	1.02 to 2	0.0020	0.0109
	>2	0.0027	0.0145
24,001 to 30,000	≤1	0.0010	0.0052
	1.02 to 2	0.0014	0.0078
	>2	0.0019	0.0104

Source: California Air Resources Board. 2020. Quantification Methodology for the Strategic Growth Council's Affordable Housing and Sustainable Communities Program. September. Available: https://ww2.arb.ca.gov/sites/default/files/classic/cc/capandtrade/auctionproceeds/draft_sgc_ahsc_qm_091620.pdf. Accessed: January 2021.

< = less than; > = greater than; ≤ = less than or equal to

[1]Measurements of bike facilities should not include the length of crosswalks.

Table T-19.2. Key Destination Credits[1,2]

Number of Key Destinations[3]	Credit within ½ Mile of Facility	Credit Within ¼ Mile of Facility
0 to 2	0.0000	0.000
3	0.0005	0.001
4 to 6	0.0010	0.002
≥ 7	0.0015	0.003

Source: California Air Resources Board. 2020. *Quantification Methodology for the California Natural Resource Agency's Urban Greening Grant Program*. March. Available: https://ww2.arb.ca.gov/sites/default/files/classic/cc/capandtrade/auctionproceeds/cnra_ug_finalqm.pdf. Accessed: January 2021.

≥ = greater than or equal to

[1] The largest value from either credit column that matches the project activities should be used. For example, if there are 3 activity centers within ¼ mile of the facility and 7 activity centers within ½ mile of the facility, the correct value to use is 0.0015.

[2] These metrics should be evaluated for the project location site and surrounding area which can extend a distance not to exceed a ½ mile. If a shopping center has multiple activity centers, each of those activity centers would count

individually. For example, if a bank, grocery store, and post office are all located in a shopping center, they would be input as three activity centers for the purposes of this quantification methodology.

[3] Key destination examples: banks, post offices, grocery stores, medical centers, pharmacies, office parks, places of worship, public libraries, schools, universities, colleges, and light rail stations (park & ride).

Table T-19.3. Growth Factor Adjustment

Facility Type	Growth Factor Adjustment
New Class I bike path[1] or Class IV bikeway[2]	1.54
New Class II bike lane[3]	1.0
Conversion from Class II to IV	0.54

Source: California Air Resources Board. 2020. *Quantification Methodology for the Strategic Growth Council's Affordable Housing and Sustainable Communities Program.* September. Available: https://ww2.arb.ca.gov/sites/default/files/classic/cc/capandtrade/auctionproceeds/sgc_ahsc_qm_022521.pdf. Accessed: March 2021.

[1] Class I bike paths are physically separated from motor vehicle traffic.

[2] Class IV bikeways are protected on-street bikeways, also called cycle tracks.

[3] Class II bike lanes are striped bicycle lanes that provide exclusive use to bicycles on a roadway.

Table T-19.4. Bike Facility Default Days of Use per Year by County

County	Days	County	Days	County	Days	County	Days
Alameda	302	Kern	333	Placer	291	San Joaquin	314
Alpine	291	Kings	328	Plumas	292	San Luis Obispo	321
Amador	302	Lake	298	Riverside	337	San Mateo	295
Butte	294	Los Angeles	332	Sacramento	307	Solano	309
Calaveras	304	Lassen	309	San Benito	315	Stanislaus	319
Contra Costa	307	Madera	314	San Bernardino	333	Sutter	304
Colusa	309	Marin	296	Santa Barbara	328	Tehama	297
Del Norte	252	Mariposa	307	Santa Clara	307	Trinity	277
El Dorado	295	Mendocino	279	Santa Cruz	304	Tulare	314
Fresno	320	Merced	316	San Diego	323	Tuolumne	299
Glenn	304	Modoc	287	San Francisco	301	Ventura	334

Table T-19.4. Bike Facility Default Days of Use per Year by County (cont.)

County	Days	County	Days	County	Days	County	Days
Humboldt	262	Mono	311	Shasta	283	Yolo	311
Imperial	353	Monterey	310	Sierra	301	Yuba	293
Inyo	331	Orange	335	Siskiyou	280	Statewide	311

Source: National Oceanic and Atmospheric Administration (NOAA). 2021. *Global Historical Climatology Network – Daily (GHCN-Daily), Version 3.* 2015-2019 average of days per year with precipitation >0.1 inches. Available: https://www.ncei.noaa.gov/access/search/data-search/daily-summaries?bbox=38.922,-120.071,38.338,-119.547&place=County:1276&dataTypes=PRCP&startDate=2015-01-01T00:00:00&endDate=2019-01-01T23:59:59. Accessed: May 2021.

Table T-20.1. Bicycle Mode Share of All Trips by California Core-Based Statistical Area

Core-Based Statistical Area	Bicycle Mode Share
Los Angeles-Long Beach-Anaheim	0.18%
Riverside-San Bernardino-Ontario	0.06%
Sacramento-Roseville-Arden-Arcade	0.56%
San Diego-Carlsbad	0.23%
San Francisco-Oakland-Hayward	0.47%
San Jose-Sunnyvale-Santa Clara	0.79%

Source: Federal Highway Administration. 2017. National Household Travel Survey – 2017 Table Designer. Travel Day PT by TRPTRANS by HH_CBSA. Available: https://nhts.ornl.gov/. Accessed: January 2021.

Table T-26.1. Transit Bus Fuel Economy by Fuel Type

Fuel Type	Fuel Economy	Unit
Gasoline	0.21261	gal/mile
Diesel	0.15691	gal/mile
Natural gas[1]	0.24890	gal/mile
Electric[2]	2.39132	kWh/mile

Sources: California Air Resources Board. 2020. EMFAC2017 v1.0.3. August. Available: https://arb.ca.gov/emfac/emissions-inventory. Accessed: January 2021.

U.S. Department of Energy (U.S. DOE). 2021. Fuel Economy Datasets for All Model Years (1984-2021). January. Available: https://www.fueleconomy.gov. Accessed: January 2021.

gal = gallon; kwh = kilowatt hour

[1] Natural gas fuel economy is based on a conversion of natural gas fuel consumption to gallons of diesel equivalent.

[2] Scaled from diesel equivalent based on energy efficiency ratio (EER) of 2.5 and assumption of 38.1 kWh electricity per gallon of diesel.

Table T-30.1. Battery Electric Vehicle Efficiency by Vehicle Type

Vehicle Type[1]	BEV Efficiency (kWh/mile)
Light-duty automobile (LDA)	0.33
Light-duty truck (LDT)	0.38
Light-heavy duty truck 1 (LHDT1)	1.47
Light-heavy duty truck 2 (LHDT2)	1.67
Medium-heavy duty truck (MHDT)	1.56
Heavy-heavy duty truck (HHDT)	2.33

Sources: California Air Resources Board. 2020b. EMFAC2017 v1.0.3. August. Available: https://arb.ca.gov/emfac/emissions-inventory. Accessed: January 2021.

California Air Resources Board. 2020c. Unofficial electronic version of the Low Carbon Fuel Standard Regulation. Available: https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf. Accessed: January 2021.

U.S. Department of Energy (U.S. DOE). 2021. Fuel Economy Datasets for All Model Years (1984-2021). January. Available: https://www.fueleconomy.gov. Accessed: January 2021.

kWh = kilowatt-hours; BEV = battery electric vehicle

[1] Vehicles listed reflect a subset of the EMFAC vehicle categories.

Table T-30.2. Vehicle Fuel Efficiency, Energy Density, and Well-to-Wheels Carbon Intensity and Emission Factor by Vehicle Category and Fuel Type

		Fuel Efficiency			Energy Density			Carbon Intensity			Emission Factor
Vehicle	Fuel	Value	Units	Ref	Value	Units	Ref	Value	Units	Ref	(g CO_2e/mile)[11]
LDA	Gasoline	30.3	mpg	1	115.8	MJ/gal	7	93.2	g CO_2e/MJ	5	356.2
	Gasoline hybrid	45.5	mpg	2	115.8	MJ/gal	7	93.2	g CO_2e/MJ	5	237.2
	Flex fuel (E85)	22.7	mpg	3	86.7	MJ/gal	6	66.8	g CO_2e/MJ	9	255.1
	PHEV[10]	—	—	—	—	—	—	—	—	—	173.0
	BEV	0.327	kWh/mile	4	3.6	MJ/kWh	7	82.9	g CO_2e/MJ	7	97.6
LDT1	Gasoline	25.9	mpg	1	115.8	MJ/gal	5	93.2	g CO_2e/MJ	5	416.9
	Gasoline hybrid	38.9	mpg	2	115.8	MJ/gal	5	93.2	g CO_2e/MJ	5	277.4
	Flex fuel (E85)	19.4	mpg	3	86.7	MJ/gal	6	66.8	g CO_2e/MJ	9	298.5
	PHEV[10]	—	—	—	—	—	—	—	—	—	202.6
	BEV	0.383	kWh/mile	4	3.6	MJ/kWh	7	82.9	g CO_2e/MJ	7	114.3
LDT2	Gasoline	23.8	mpg	1	115.8	MJ/gal	5	93.2	g CO_2e/MJ	5	453.5
	Composite Diesel[1,2]	23.8	mpg	1, 3	130.5	MJ/gal	5, 8	45.4	g CO2e/MJ	5, 9	248.9
	Diesel	34.9	mpg	1	134.5	MJ/gal	5	94.2	g CO_2e/MJ	5	363.0
MDV	Gasoline	19.4	mpg	1	115.8	MJ/gal	5	93.2	g CO_2e/MJ	5	556.3
	Composite Diesel[1,2]	19.4	mpg	1, 3	130.5	MJ/gal	5, 8	45.4	g CO2e/MJ	5, 9	305.4
	Diesel	26.4	mpg	1	134.5	MJ/gal	5	94.2	g CO_2e/MJ	5	479.9
LHDT1	Gasoline	9.2	mpg	1	115.8	MJ/gal	5	93.2	g CO_2e/MJ	5	1,173.1
	Composite Diesel[1,2]	9.2	mpg	1, 3	130.5	MJ/gal	5, 8	45.4	g CO2e/MJ	5, 9	664.0
	Diesel	18.9	mpg	1	134.5	MJ/gal	5	94.2	g CO_2e/MJ	5	670.4
	BEV	1.47	kWh/mile	4	3.6	MJ/kWh	7	82.9	g CO_2e/MJ	7	438.7
LHDT2	Gasoline	8.1	mpg	1	115.8	MJ/gal	5	93.2	g CO_2e/MJ	5	1,332.4
	Composite Diesel[1,2]	8.1	mpg	1, 3	130.5	MJ/gal	5, 8	45.4	g CO2e/MJ	5, 9	731.4
	Diesel	17.1	mpg	1	134.5	MJ/gal	5	94.2	g CO_2e/MJ	5	740.9
	BEV	1.67	kWh/mile	4	3.6	MJ/kWh	7	82.9	g CO_2e/MJ	7	498.4

Table T-30.2. Vehicle Fuel Efficiency, Energy Density, and Well-to-Wheels Carbon Intensity and Emission Factor by Vehicle Category and Fuel Type (cont.)

		Fuel Efficiency			Energy Density			Carbon Intensity			Emission Factor
Vehicle	Fuel	Value	Units	Ref	Value	Units	Ref	Value	Units	Ref	(g CO_2e/mile)[11]
MHDT	Gasoline	4.9	mpg	1	115.8	MJ/gal	5	93.2	g CO_2e/MJ	5	2,202.6
	Composite Diesel[1,2]	9.4	mpg	1, 3	130.5	MJ/gal	5, 8	45.4	g CO2e/MJ	5, 9	630.3
	Diesel	9.4	mpg	1	134.5	MJ/gal	5	94.2	g CO_2e/MJ	5	1347.9
	BEV	1.56	kWh/mile	4	3.6	MJ/kWh	7	93.8	g CO_2e/MJ	7	526.8
HHDT	Composite Diesel[1,2]	6.3	mpg	1, 3	130.5	MJ/gal	5, 8	45.4	gCO2e/MJ	4, 9	940.4
	Diesel	6.3	mpg	1	134.5	MJ/gal	5	94.2	g CO_2e/MJ	5	2011.1
	Natural gas	5.9	mpgde	3	134.5	MJ/gal	5	32.7	g CO_2e/MJ	9	745.4
	BEV	2.33	kWh/mile	4	3.6	MJ/kWh	7	93.8	g CO_2e/MJ	7	786.8

Sources: See footnotes.

LDA = light-duty automobile; light-duty truck 1 (LDT1); light-duty truck 2 (LDT2); MDV = medium-duty vehicle; light-heavy duty truck 1 (LHDT1); light-heavy duty truck 2 (LHDT2); MHDT = medium-heavy duty truck; HHDV = heavy-heavy duty vehicle; MJ = megajoules; mpg = miles per gallon; mpgde = miles per gallon of diesel equivalent; gal = gallon; kWh = kilowatt-hours; CO_2e = carbon dioxide equivalent; g = grams; ref = reference

[1] California Air Resources Board. 2020a. EMFAC2017 v1.0.3. August. Available: https://arb.ca.gov/emfac/emissions-inventory. Accessed: January 2021.

Statewide analysis for the year 2021.

[2] U.S. Department of Energy (U.S. DOE). 2021. Fuel Economy Datasets for All Model Years (1984-2021). January. Available: https://www.fueleconomy.gov. Accessed: January 2021.

Assumes 50% improvement vs. gasoline, based on comparison of gasoline and hybrid Toyota Camry and Corolla.

[3] Scaled from gasoline equivalent based on energy density values.

[4] U.S. DOE 2021. Scaled from gasoline or diesel equivalent based on energy efficiency ratio (EER) of 2.5 and assumption of 33.7 kWh electricity per gallon gasoline or 38.1 kWh electricity per gallon diesel.

[5] Gasoline value reflects California Reformulated Gasoline (RFG), which consists of a blend of California Reformulated Gasoline Blendstock for Oxygenate Blending (CARBOB) and 10% ethanol. California Air Resources Board. 2020b. Unofficial electronic version of the Low Carbon Fuel Standard Regulation. Available: https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf. Accessed: January 2021.

[6] Assumes 85% denatured ethanol and 15% California reformulated gasoline (CaRFG).

[7] California Air Resources Board. 2020c. California Climate Investments Quantification Methodology Emission Factor Database and Documentation. August. Available: https://ww2.arb.ca.gov/resources/documents/cci-quantification-benefits-and-reporting-materials. Accessed: January 2021.

[8] Assumes 80% diesel and 20% FAME Biodiesel

[9] California Air Resources Board. 2019. LCFS Pathway Certified Carbon Intensities. Available: https://ww2.arb.ca.gov/resources/documents/lcfs-pathway-certified-carbon-intensities. Accessed: January 2021.

[10] CARB 2020a. Can be calculated as 46% BEV and 54% gasoline hybrid, based on eVMT fraction. See Equation A2 for further instruction.

[11] Where fuel efficiency is measured in miles per gallon, the emission factor is calculated as (fuel efficiency * energy density * carbon intensity). Where fuel efficiency is measured in kilowatt-hours per mile, the emission factor is calculated as ((1/fuel efficiency) * energy density * carbon intensity).

[12] Composite diesel is a blend of conventional fossil diesel (6%), biodiesel (16%), and renewable diesel (78%). The percentages are based on the percent of total volume blended into diesel sold in California (CARB 2020c).

Table T-40.1. Average Student Occupancy of School Buses

Location	Average Student Occupancy of School Buses (students per bus)
San Francisco Bay Area	10.1
Los Angeles, Orange County, and Long Beach	17.3
San Diego	14.9
California Average	9.3

Source: Wang, Y., R. Mingo, J. Lutin, W. Zhu, and M. Zhu. 2019. *Developing a Statistically Valid and Practical Method to Compute Bus and Truck Occupancy Data*. Federal Highway Administration. Available: https://www.academia.edu/64325343/Developing_a_Statistically_Valid_and_Practical_Method_to_Compute_Bus_and_Truck_Occupancy_Data. Accessed: December 2023.

Table T-40.2. California School Bus Emission Factors by Fuel Type

Fuel Type	Fuel Efficiency		Energy Density		Carbon Intensity		Emission Factor [5] (g CO_2e/mile)
	Value	Units	Value	Units	Value	Units	
Gasoline	9.42[1]	miles/gallon (mpg)	115.8[2]	Mega Joule (MJ)/gallon	93.2[2]	grams CO_2e/Mega Joule (g CO_2e/MJ)	1145.7
Diesel	7.92[1]	mpg	134.5[2]	MJ/gallon	94.2[2]	g CO_2e/MJ	1599.7
Electricity	1.1[1]	kWh/mile	3.6[3]	MJ/kWh	93.8[3]	g CO_2e/MJ	371.4
Natural Gas	4.48[1]	mpg-diesel equivalent	134.5[2]	MJ/gallon	32.7[4]	g CO_2e/MJ	981.7

Sources: See footnotes.

[1] California Air Resources Board. 2021. EMFAC2021. Available: https://arb.ca.gov/emfac/emissions-inventory/5fe430c4465c4fa60d41f578fbaefa5c758b58ef. Accessed: December 2023.

[2] Gasoline value reflects California Reformulated Gasoline (RFG), which consists of a blend of California Reformulated Gasoline Blendstock for Oxygenate Blending (CARBOB) and 10 percent ethanol. Source: California Air Resources Board. 2020b. *Unofficial electronic version of the Low Carbon Fuel Standard Regulation*. Available: https://ww2.arb.ca.gov/sites/default/files/2020-07/2020_lcfs_fro_oal-approved_unofficial_06302020.pdf. Accessed: December 2023.

[3] California Air Resources Board. 2020c. *California Climate Investments Quantification Methodology Emission Factor Database and Documentation*. August. Available: https://ww2.arb.ca.gov/resources/documents/cci-quantification-benefits-and-reporting-materials. Accessed: December 2023.

[4] California Air Resources Board. 2019. *LCFS Pathway Certified Carbon Intensities*. Available: https://ww2.arb.ca.gov/resources/documents/lcfs-pathway-certified-carbon-intensities. Accessed: December 2023.

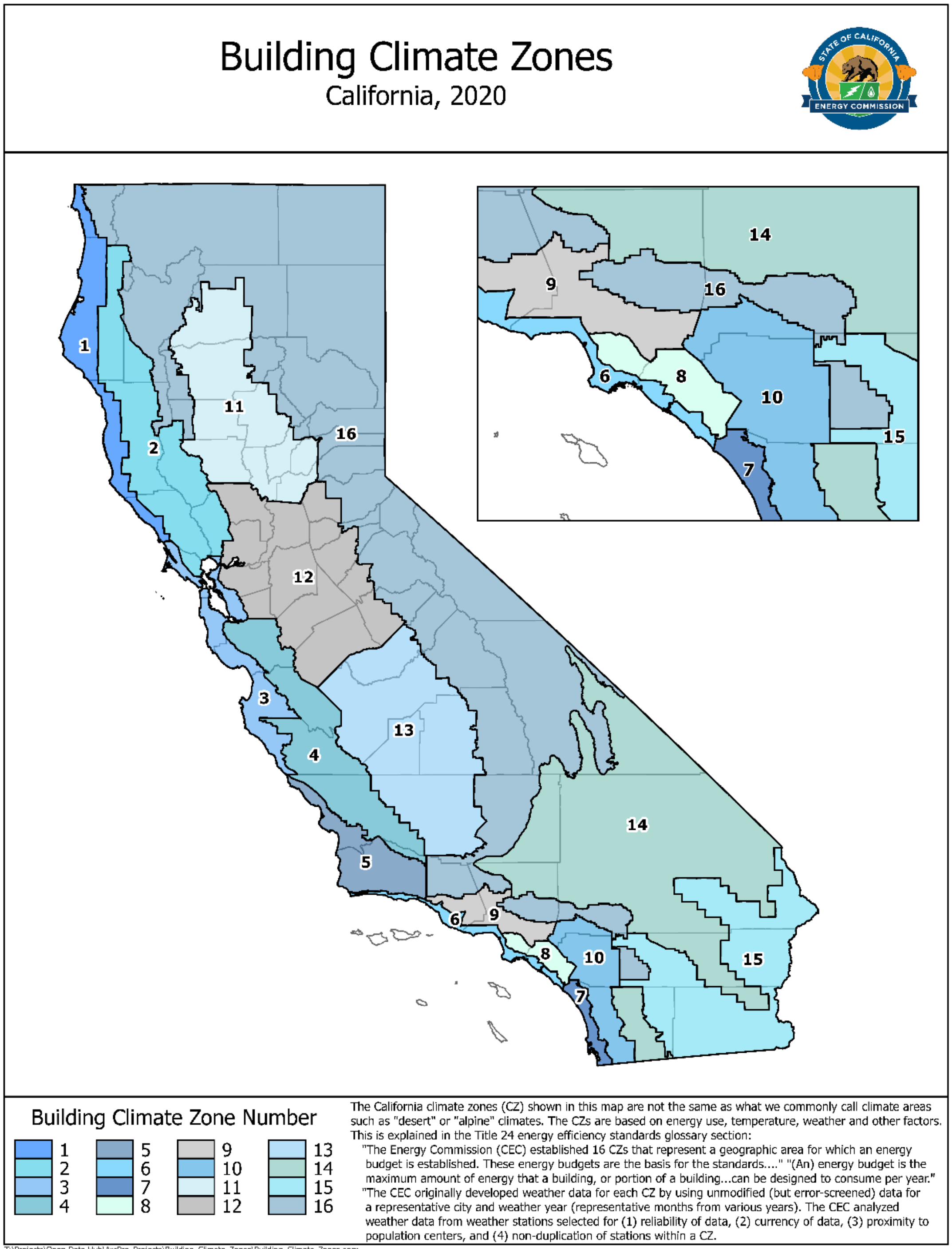
[5] Where fuel efficiency is measured in miles per gallon, the emission factor is calculated as (fuel efficiency * energy density * carbon intensity). Where fuel efficiency is measured in kilowatt-hours per mile, the emission factor is calculated as ([1/fuel efficiency] * energy density * carbon intensity).

Figure E-1.1. California Energy Commission Electricity Demand Forecast Zones

Note: This figure is intended to provide a general depiction of the forecast zones as not all details can be clearly depicted at this scale. Those interested in additional detail should refer directly to the interactive version of this map, available on CEC's website at the following URL: https://cecgis-caenergy.opendata.arcgis.com/datasets/86fef50f6f344fabbe545e58aec83edd_0/data?geometry=-165.327%2C31.004%2C-72.427%2C43.220.

Source: California Energy Commission (CEC). 2017. *California Electricity Demand Forecast Zones.* Available: https://cecgis-caenergy.opendata.arcgis.com/datasets/86fef50f6f344fabbe545e58aec83edd_0/data?geometry=-165.327%2C31.004%2C-72.427%2C43.220. Accessed: June 2021.

Figure E-4.1. CEC Building Climate Zones



T:\Projects\Open Data Hub\ArcPro Projects\Building Climate Zones\Building Climate Zones.aprx

Note: The CEC has an online climate zone search tool available at the following URL: https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/climate-zone-tool-maps-and.

Source: California Energy Commission (CEC). 2020. Building Climate Zones. August. Available: https://caenergy.maps.arcgis.com/home/item.html?id=eaf3158767674e6cb14f4407186d3607. Accessed: January 2021.

Table E-1.1. Proxy Zones to Use for Electric Demand Forecast Zones

EDFZ Name	EDFZ	Residential (RASS) Proxy Zone	Commercial Proxy Zones
Other-A	0-A	4	4
Other-B	0-B	2	2
Other-C	0-C	3	3
Other-D	0-D	3	3
Other-E	0-E	10	10
Other-F	0-F	3	3
Other-G	0-G	3	3
Other-H	0-H	4	4
Greater Bay Area	1	—	—
North Coast	2	—	—
North Valley	3	—	—
Central Valley	4	—	—
Southern Valley	5	—	—
Central Coast	6	—	—
LA Metro	7	—	—
Big Creek West	8	—	—
Big Creek East	9	—	—
Northeast	10	—	—
Eastern	11	—	—
SDG&E	12	—	—
SMUD Service Territory	13	—	—
Turlock Irrigation District	14	4	—
Rest of BANC Control Area	15	3	—
LADWP Coastal	16	—	—
LADWP Inland	17	—	—
Burbank/Glendale	18	17	—
Imperial Irrigation District	19	11	—
Valley Electric	20	10	10

Source: California Energy Commission (CEC). 2017. *California Electricity Demand Forecast Zones*. Available: https://cecgis-caenergy.opendata.arcgis.com/datasets/86fef50f6f344fabbe545e58aec83edd_0/data?geometry=-165.327%2C31.004%2C-72.427%2C43.220. Accessed: June 2021.

- = N/A. EDFZ is already included in the RASS or commercial end use forecast. Numbers only listed for missing zones.

EDFZ = Electricity Demand Forecast Zone; RASS = Residential Appliance Saturation Study; LA = Los Angeles; LADWP = Los Angeles Department of Water and Power; BANC = Balancing Authority of California; SDG&E = San Diego Gas & Electric; SMUD = Sacramento Municipal Utility District

Table E-1.2. Non-Residential Electricity Reduction for 1 Percent Improvement over 2019 Title 24 Requirements

Non-Residential Building Type[1]	Electricity Reduction by EDFZ[2]																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	State
Arena	0.44%	0.43%	0.50%	0.43%	0.50%	0.41%	0.85%	0.86%	0.83%	0.85%	0.86%	0.83%	0.44%	0.54%	0.53%	0.68%	0.70%	0.42%	0.68%	0.61%
Automobile Care Center	0.44%	0.43%	0.50%	0.43%	0.50%	0.41%	0.85%	0.86%	0.83%	0.85%	0.86%	0.83%	0.44%	0.54%	0.53%	0.68%	0.70%	0.42%	0.68%	0.61%
Bank (with Drive-Through)	0.44%	0.43%	0.50%	0.43%	0.50%	0.41%	0.85%	0.86%	0.83%	0.85%	0.86%	0.83%	0.44%	0.54%	0.53%	0.68%	0.70%	0.42%	0.68%	0.61%
Convenience Market (24 hour)	0.37%	0.39%	0.46%	0.39%	0.46%	0.39%	0.35%	0.35%	0.38%	0.35%	0.35%	0.35%	0.39%	0.49%	0.47%	0.36%	0.36%	0.34%	0.24%	0.39%
Convenience Market with Gas Pumps	0.37%	0.39%	0.46%	0.39%	0.46%	0.39%	0.35%	0.35%	0.38%	0.35%	0.35%	0.35%	0.39%	0.49%	0.47%	0.36%	0.36%	0.34%	0.24%	0.39%
Day-Care Center	0.80%	0.80%	0.81%	0.80%	0.81%	0.80%	0.86%	0.86%	0.87%	0.86%	0.86%	0.84%	0.87%	0.79%	0.79%	0.76%	0.78%	0.85%	0.95%	0.85%
Discount Club	0.71%	0.71%	0.77%	0.73%	0.77%	0.71%	0.79%	0.79%	0.80%	0.79%	0.79%	0.81%	0.76%	0.79%	0.78%	0.65%	0.66%	0.72%	0.77%	0.75%
Electronic Superstore	0.71%	0.71%	0.77%	0.73%	0.77%	0.71%	0.79%	0.79%	0.80%	0.79%	0.79%	0.81%	0.76%	0.79%	0.78%	0.65%	0.66%	0.72%	0.77%	0.75%
Elementary School	0.80%	0.80%	0.81%	0.80%	0.81%	0.80%	0.86%	0.86%	0.87%	0.86%	0.86%	0.84%	0.87%	0.79%	0.79%	0.76%	0.78%	0.85%	0.95%	0.85%
Fast Food Restaurant w/o Drive Thru	0.34%	0.36%	0.41%	0.36%	0.41%	0.36%	0.53%	0.54%	0.52%	0.50%	0.51%	0.51%	0.39%	0.43%	0.42%	0.48%	0.50%	0.47%	0.44%	0.44%
Fast Food Restaurant with Drive Thru	0.34%	0.36%	0.41%	0.36%	0.41%	0.36%	0.53%	0.54%	0.52%	0.50%	0.51%	0.51%	0.39%	0.43%	0.42%	0.48%	0.50%	0.47%	0.44%	0.44%
Free-Standing Discount store	0.71%	0.71%	0.77%	0.73%	0.77%	0.71%	0.79%	0.79%	0.80%	0.79%	0.79%	0.81%	0.76%	0.79%	0.78%	0.65%	0.66%	0.72%	0.77%	0.75%
Free-Standing Discount Superstore	0.71%	0.71%	0.77%	0.73%	0.77%	0.71%	0.79%	0.79%	0.80%	0.79%	0.79%	0.81%	0.76%	0.79%	0.78%	0.65%	0.66%	0.72%	0.77%	0.75%
Gasoline/Service Station	0.44%	0.43%	0.50%	0.43%	0.50%	0.41%	0.85%	0.86%	0.83%	0.85%	0.86%	0.83%	0.44%	0.54%	0.53%	0.68%	0.70%	0.42%	0.68%	0.61%
General Heavy Industry	0.44%	0.43%	0.50%	0.43%	0.50%	0.41%	0.85%	0.86%	0.83%	0.85%	0.86%	0.83%	0.44%	0.54%	0.53%	0.68%	0.70%	0.42%	0.68%	0.61%
General Light Industry	0.44%	0.43%	0.50%	0.43%	0.50%	0.41%	0.85%	0.86%	0.83%	0.85%	0.86%	0.83%	0.44%	0.54%	0.53%	0.68%	0.70%	0.42%	0.68%	0.61%
General Office Building	0.65%	0.65%	0.69%	0.66%	0.69%	0.65%	0.81%	0.81%	0.81%	0.81%	0.81%	0.78%	0.67%	0.69%	0.68%	0.73%	0.73%	0.65%	0.62%	0.71%
Government (Civic Center)	0.65%	0.65%	0.69%	0.66%	0.69%	0.65%	0.81%	0.81%	0.81%	0.81%	0.81%	0.78%	0.67%	0.69%	0.68%	0.73%	0.73%	0.65%	0.62%	0.71%
Government Office Building	0.65%	0.65%	0.69%	0.66%	0.69%	0.65%	0.81%	0.81%	0.81%	0.81%	0.81%	0.78%	0.67%	0.69%	0.68%	0.73%	0.73%	0.65%	0.62%	0.71%
Hardware/Paint Store	0.71%	0.71%	0.77%	0.73%	0.77%	0.71%	0.79%	0.79%	0.80%	0.79%	0.79%	0.81%	0.76%	0.79%	0.78%	0.65%	0.66%	0.72%	0.77%	0.75%
Health Club	0.44%	0.43%	0.50%	0.43%	0.50%	0.41%	0.85%	0.86%	0.83%	0.85%	0.86%	0.83%	0.44%	0.54%	0.53%	0.68%	0.70%	0.42%	0.68%	0.61%
High School	0.80%	0.80%	0.81%	0.80%	0.81%	0.80%	0.86%	0.86%	0.87%	0.86%	0.86%	0.84%	0.87%	0.79%	0.79%	0.76%	0.78%	0.85%	0.95%	0.85%
High Turnover (Sit Down Restaurant)	0.34%	0.36%	0.41%	0.36%	0.41%	0.36%	0.53%	0.54%	0.52%	0.50%	0.51%	0.51%	0.39%	0.43%	0.42%	0.48%	0.50%	0.47%	0.44%	0.44%
Home Improvement Superstore	0.71%	0.71%	0.77%	0.73%	0.77%	0.71%	0.79%	0.79%	0.80%	0.79%	0.79%	0.81%	0.76%	0.79%	0.78%	0.65%	0.66%	0.72%	0.77%	0.75%
Hospital	0.45%	0.46%	0.51%	0.47%	0.51%	0.47%	0.66%	0.65%	0.66%	0.66%	0.66%	0.69%	0.55%	0.55%	0.55%	0.46%	0.50%	0.47%	0.85%	0.55%
Hotel	0.49%	0.49%	0.49%	0.47%	0.49%	0.48%	0.76%	0.76%	0.78%	0.79%	0.79%	0.69%	0.54%	0.53%	0.53%	0.72%	0.72%	0.59%	0.83%	0.67%
Industrial Park	0.65%	0.65%	0.69%	0.66%	0.69%	0.65%	0.81%	0.81%	0.81%	0.81%	0.81%	0.78%	0.67%	0.69%	0.68%	0.73%	0.73%	0.65%	0.62%	0.71%
Junior College (2yr)	0.83%	0.83%	0.84%	0.83%	0.84%	0.82%	0.79%	0.78%	0.80%	0.79%	0.79%	0.78%	0.83%	0.84%	0.84%	0.64%	0.67%	0.65%	0.87%	0.78%

Table E-1.2. Non-Residential Electricity Reduction for 1 Percent Improvement over 2019 Title 24 Requirements (cont.)

Non-Residential Building Type[1]	Electricity Reduction by EDFZ[2]																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	State
Junior High School	0.80%	0.80%	0.81%	0.80%	0.81%	0.80%	0.86%	0.86%	0.87%	0.86%	0.86%	0.84%	0.87%	0.79%	0.79%	0.76%	0.78%	0.85%	0.95%	0.85%
Library	0.44%	0.43%	0.50%	0.43%	0.50%	0.41%	0.85%	0.86%	0.83%	0.85%	0.86%	0.83%	0.44%	0.54%	0.53%	0.68%	0.70%	0.42%	0.68%	0.61%
Manufacturing	0.44%	0.43%	0.50%	0.43%	0.50%	0.41%	0.85%	0.86%	0.83%	0.85%	0.86%	0.83%	0.44%	0.54%	0.53%	0.68%	0.70%	0.42%	0.68%	0.61%
Medical Office Building	0.65%	0.65%	0.69%	0.66%	0.69%	0.65%	0.81%	0.81%	0.81%	0.81%	0.81%	0.78%	0.67%	0.69%	0.68%	0.73%	0.73%	0.65%	0.62%	0.71%
Motel	0.49%	0.49%	0.49%	0.47%	0.49%	0.48%	0.76%	0.76%	0.78%	0.79%	0.79%	0.69%	0.54%	0.53%	0.53%	0.72%	0.72%	0.59%	0.83%	0.67%
Movie Theater (No Matinee)	0.44%	0.43%	0.50%	0.43%	0.50%	0.41%	0.85%	0.86%	0.83%	0.85%	0.86%	0.83%	0.44%	0.54%	0.53%	0.68%	0.70%	0.42%	0.68%	0.61%
Office Park	0.65%	0.65%	0.69%	0.66%	0.69%	0.65%	0.81%	0.81%	0.81%	0.81%	0.81%	0.78%	0.67%	0.69%	0.68%	0.73%	0.73%	0.65%	0.62%	0.71%
Pharmacy/Drugstore w/o Drive Thru	0.71%	0.71%	0.77%	0.73%	0.77%	0.71%	0.79%	0.79%	0.80%	0.79%	0.79%	0.81%	0.76%	0.79%	0.78%	0.65%	0.66%	0.72%	0.77%	0.75%
Pharmacy/Drugstore with Drive Thru	0.71%	0.71%	0.77%	0.73%	0.77%	0.71%	0.79%	0.79%	0.80%	0.79%	0.79%	0.81%	0.76%	0.79%	0.78%	0.65%	0.66%	0.72%	0.77%	0.75%
Place of Worship	0.44%	0.43%	0.50%	0.43%	0.50%	0.41%	0.85%	0.86%	0.83%	0.85%	0.86%	0.83%	0.44%	0.54%	0.53%	0.68%	0.70%	0.42%	0.68%	0.61%
Quality Restaurant	0.34%	0.36%	0.41%	0.36%	0.41%	0.36%	0.53%	0.54%	0.52%	0.50%	0.51%	0.51%	0.39%	0.43%	0.42%	0.48%	0.50%	0.47%	0.44%	0.44%
Racquet Club	0.44%	0.43%	0.50%	0.43%	0.50%	0.41%	0.85%	0.86%	0.83%	0.85%	0.86%	0.83%	0.44%	0.54%	0.53%	0.68%	0.70%	0.42%	0.68%	0.61%
Refrigerated Warehouse-No Rail	0.08%	0.08%	0.09%	0.08%	0.09%	0.08%	0.10%	0.11%	0.09%	0.08%	0.08%	0.09%	0.08%	0.10%	0.10%	0.09%	0.10%	0.18%	0.09%	0.09%
Refrigerated Warehouse-Rail	0.08%	0.08%	0.09%	0.08%	0.09%	0.08%	0.10%	0.11%	0.09%	0.08%	0.08%	0.09%	0.08%	0.10%	0.10%	0.09%	0.10%	0.18%	0.09%	0.09%
Regional Shopping Center	0.71%	0.71%	0.77%	0.73%	0.77%	0.71%	0.79%	0.79%	0.80%	0.79%	0.79%	0.81%	0.76%	0.79%	0.78%	0.65%	0.66%	0.72%	0.77%	0.75%
Research & Development	0.65%	0.65%	0.69%	0.66%	0.69%	0.65%	0.81%	0.81%	0.81%	0.81%	0.81%	0.78%	0.67%	0.69%	0.68%	0.73%	0.73%	0.65%	0.62%	0.71%
Strip Mall	0.71%	0.71%	0.77%	0.73%	0.77%	0.71%	0.79%	0.79%	0.80%	0.79%	0.79%	0.81%	0.76%	0.79%	0.78%	0.65%	0.66%	0.72%	0.77%	0.75%
Supermarket	0.37%	0.39%	0.46%	0.39%	0.46%	0.39%	0.35%	0.35%	0.38%	0.35%	0.35%	0.35%	0.39%	0.49%	0.47%	0.36%	0.36%	0.34%	0.24%	0.39%
University/College (4yr)	0.83%	0.83%	0.84%	0.83%	0.84%	0.82%	0.79%	0.78%	0.80%	0.79%	0.79%	0.78%	0.83%	0.84%	0.84%	0.64%	0.67%	0.65%	0.87%	0.78%
Unrefrigerated Warehouse-No Rail	0.35%	0.37%	0.37%	0.35%	0.37%	0.36%	0.67%	0.67%	0.62%	0.65%	0.65%	0.67%	0.47%	0.47%	0.46%	0.54%	0.54%	0.58%	0.33%	0.46%
Unrefrigerated Warehouse-Rail	0.35%	0.37%	0.37%	0.35%	0.37%	0.36%	0.67%	0.67%	0.62%	0.65%	0.65%	0.67%	0.47%	0.47%	0.46%	0.54%	0.54%	0.58%	0.33%	0.46%

Source: ICF calculations; California Energy Commission (CEC). 2021. Excel database with the 2018-2030 Uncalibrated Commercial Sector Forecast, provided to ICF. January 21, 2021.

EDFZ = Electricity Demand Forecast Zone; yr = year

[1] The 12 building types used by the commercial end use forecast have been cross walked to the 49 non-residential land use types in CalEEMod, as shown in Table E-1.6.

[2] Data for some EDFZ were not available in the commercial end use forecast, and a representative EDFZ was assumed (refer to Table E-1.1).

Table E-1.3. Non-Residential Natural Gas Reduction for 1 Percent Improvement over 2019 Title 24 Requirements

Non-Residential Building Type[1]	Natural Gas Reduction by EDFZ[2]																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	State
Arena	0.42%	0.42%	0.40%	0.41%	0.40%	0.42%	0.38%	0.37%	0.42%	0.39%	0.39%	0.51%	0.42%	0.39%	0.38%	0.38%	0.38%	0.38%	0.21%	0.40%
Automobile Care Center	0.42%	0.42%	0.40%	0.41%	0.40%	0.42%	0.38%	0.37%	0.42%	0.39%	0.39%	0.51%	0.42%	0.39%	0.38%	0.38%	0.38%	0.38%	0.21%	0.40%
Bank (with Drive-Through)	0.42%	0.42%	0.40%	0.41%	0.40%	0.42%	0.38%	0.37%	0.42%	0.39%	0.39%	0.51%	0.42%	0.39%	0.38%	0.38%	0.38%	0.38%	0.21%	0.40%
Convenience Market (24 hour)	0.76%	0.78%	0.69%	0.72%	0.68%	0.75%	0.18%	0.17%	0.27%	0.20%	0.19%	0.34%	0.49%	0.67%	0.67%	0.17%	0.18%	0.36%	0.17%	0.51%
Convenience Market with Gas Pumps	0.76%	0.78%	0.69%	0.72%	0.68%	0.75%	0.18%	0.17%	0.27%	0.20%	0.19%	0.34%	0.49%	0.67%	0.67%	0.17%	0.18%	0.36%	0.17%	0.51%
Day-Care Center	0.99%	0.99%	0.99%	0.99%	0.99%	0.99%	0.51%	0.52%	0.65%	0.58%	0.58%	0.55%	0.98%	0.99%	0.99%	0.50%	0.50%	0.70%	0.35%	0.83%
Discount Club	0.98%	0.98%	0.99%	0.99%	0.99%	0.98%	0.24%	0.23%	0.31%	0.24%	0.23%	0.29%	0.99%	0.99%	0.99%	0.24%	0.23%	0.41%	0.44%	0.68%
Electronic Superstore	0.98%	0.98%	0.99%	0.99%	0.99%	0.98%	0.24%	0.23%	0.31%	0.24%	0.23%	0.29%	0.99%	0.99%	0.99%	0.24%	0.23%	0.41%	0.44%	0.68%
Elementary School	0.99%	0.99%	0.99%	0.99%	0.99%	0.99%	0.51%	0.52%	0.65%	0.58%	0.58%	0.55%	0.98%	0.99%	0.99%	0.50%	0.50%	0.70%	0.35%	0.83%
Fast Food Restaurant w/o Drive Thru	0.17%	0.21%	0.22%	0.22%	0.22%	0.19%	0.18%	0.18%	0.20%	0.19%	0.19%	0.16%	0.23%	0.22%	0.22%	0.18%	0.18%	0.16%	0.13%	0.19%
Fast Food Restaurant with Drive Thru	0.17%	0.21%	0.22%	0.22%	0.22%	0.19%	0.18%	0.18%	0.20%	0.19%	0.19%	0.16%	0.23%	0.22%	0.22%	0.18%	0.18%	0.16%	0.13%	0.19%
Free-Standing Discount store	0.98%	0.98%	0.99%	0.99%	0.99%	0.98%	0.24%	0.23%	0.31%	0.24%	0.23%	0.29%	0.99%	0.99%	0.99%	0.24%	0.23%	0.41%	0.44%	0.68%
Free-Standing Discount Superstore	0.98%	0.98%	0.99%	0.99%	0.99%	0.98%	0.24%	0.23%	0.31%	0.24%	0.23%	0.29%	0.99%	0.99%	0.99%	0.24%	0.23%	0.41%	0.44%	0.68%
Gasoline/Service Station	0.42%	0.42%	0.40%	0.41%	0.40%	0.42%	0.38%	0.37%	0.42%	0.39%	0.39%	0.51%	0.42%	0.39%	0.38%	0.38%	0.38%	0.38%	0.21%	0.40%
General Heavy Industry	0.42%	0.42%	0.40%	0.41%	0.40%	0.42%	0.38%	0.37%	0.42%	0.39%	0.39%	0.51%	0.42%	0.39%	0.38%	0.38%	0.38%	0.38%	0.21%	0.40%
General Light Industry	0.42%	0.42%	0.40%	0.41%	0.40%	0.42%	0.38%	0.37%	0.42%	0.39%	0.39%	0.51%	0.42%	0.39%	0.38%	0.38%	0.38%	0.38%	0.21%	0.40%
General Office Building	0.79%	0.79%	0.87%	0.83%	0.88%	0.78%	0.79%	0.80%	0.85%	0.81%	0.81%	0.88%	0.86%	0.87%	0.86%	0.78%	0.78%	0.49%	0.51%	0.82%
Government (Civic Center)	0.79%	0.79%	0.87%	0.83%	0.88%	0.78%	0.79%	0.80%	0.85%	0.81%	0.81%	0.88%	0.86%	0.87%	0.86%	0.78%	0.78%	0.49%	0.51%	0.82%
Government Office Building	0.79%	0.79%	0.87%	0.83%	0.88%	0.78%	0.79%	0.80%	0.85%	0.81%	0.81%	0.88%	0.86%	0.87%	0.86%	0.78%	0.78%	0.49%	0.51%	0.82%
Hardware/Paint Store	0.98%	0.98%	0.99%	0.99%	0.99%	0.98%	0.24%	0.23%	0.31%	0.24%	0.23%	0.29%	0.99%	0.99%	0.99%	0.24%	0.23%	0.41%	0.44%	0.68%
Health Club	0.42%	0.42%	0.40%	0.41%	0.40%	0.42%	0.38%	0.37%	0.42%	0.39%	0.39%	0.51%	0.42%	0.39%	0.38%	0.38%	0.38%	0.38%	0.21%	0.40%
High School	0.99%	0.99%	0.99%	0.99%	0.99%	0.99%	0.51%	0.52%	0.65%	0.58%	0.58%	0.55%	0.98%	0.99%	0.99%	0.50%	0.50%	0.70%	0.35%	0.83%
High Turnover (Sit Down Restaurant)	0.17%	0.21%	0.22%	0.22%	0.22%	0.19%	0.18%	0.18%	0.20%	0.19%	0.19%	0.16%	0.23%	0.22%	0.22%	0.18%	0.18%	0.16%	0.13%	0.19%
Home Improvement Superstore	0.98%	0.98%	0.99%	0.99%	0.99%	0.98%	0.24%	0.23%	0.31%	0.24%	0.23%	0.29%	0.99%	0.99%	0.99%	0.24%	0.23%	0.41%	0.44%	0.68%
Hospital	0.75%	0.76%	0.71%	0.73%	0.70%	0.74%	0.65%	0.66%	0.69%	0.69%	0.69%	0.80%	0.69%	0.70%	0.70%	0.63%	0.61%	0.70%	0.69%	0.70%
Hotel	0.89%	0.89%	0.92%	0.92%	0.92%	0.88%	0.51%	0.51%	0.60%	0.53%	0.53%	0.78%	0.96%	0.91%	0.92%	0.52%	0.49%	0.76%	0.63%	0.76%
Industrial Park	0.79%	0.79%	0.87%	0.83%	0.88%	0.78%	0.79%	0.80%	0.85%	0.81%	0.81%	0.88%	0.86%	0.87%	0.86%	0.78%	0.78%	0.49%	0.51%	0.82%
Junior College (2yr)	0.96%	0.96%	0.88%	0.96%	0.86%	0.96%	0.85%	0.85%	0.87%	0.87%	0.87%	0.91%	0.96%	0.85%	0.92%	0.84%	0.85%	0.86%	0.71%	0.88%
Junior High School	0.99%	0.99%	0.99%	0.99%	0.99%	0.99%	0.51%	0.52%	0.65%	0.58%	0.58%	0.55%	0.98%	0.99%	0.99%	0.50%	0.50%	0.70%	0.35%	0.83%

Table E-1.3. Non-Residential Natural Gas Reduction for 1 Percent Improvement over 2019 Title 24 Requirements (cont.)

Non-Residential Building Type[1]	Natural Gas Reduction by EDFZ[2]																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	State
Library	0.42%	0.42%	0.40%	0.41%	0.40%	0.42%	0.38%	0.37%	0.42%	0.39%	0.39%	0.51%	0.42%	0.39%	0.38%	0.38%	0.38%	0.38%	0.21%	0.40%
Manufacturing	0.42%	0.42%	0.40%	0.41%	0.40%	0.42%	0.38%	0.37%	0.42%	0.39%	0.39%	0.51%	0.42%	0.39%	0.38%	0.38%	0.38%	0.38%	0.21%	0.40%
Medical Office Building	0.79%	0.79%	0.87%	0.83%	0.88%	0.78%	0.79%	0.80%	0.85%	0.81%	0.81%	0.88%	0.86%	0.87%	0.86%	0.78%	0.78%	0.49%	0.51%	0.82%
Motel	0.89%	0.89%	0.92%	0.92%	0.92%	0.88%	0.51%	0.51%	0.60%	0.53%	0.53%	0.78%	0.96%	0.91%	0.92%	0.52%	0.49%	0.76%	0.63%	0.76%
Movie Theater (No Matinee)	0.42%	0.42%	0.40%	0.41%	0.40%	0.42%	0.38%	0.37%	0.42%	0.39%	0.39%	0.51%	0.42%	0.39%	0.38%	0.38%	0.38%	0.38%	0.21%	0.40%
Office Park	0.79%	0.79%	0.87%	0.83%	0.88%	0.78%	0.79%	0.80%	0.85%	0.81%	0.81%	0.88%	0.86%	0.87%	0.86%	0.78%	0.78%	0.49%	0.51%	0.82%
Pharmacy/Drugstore w/o Drive Thru	0.98%	0.98%	0.99%	0.99%	0.99%	0.98%	0.24%	0.23%	0.31%	0.24%	0.23%	0.29%	0.99%	0.99%	0.99%	0.24%	0.23%	0.41%	0.44%	0.68%
Pharmacy/Drugstore with Drive Thru	0.98%	0.98%	0.99%	0.99%	0.99%	0.98%	0.24%	0.23%	0.31%	0.24%	0.23%	0.29%	0.99%	0.99%	0.99%	0.24%	0.23%	0.41%	0.44%	0.68%
Place of Worship	0.42%	0.42%	0.40%	0.41%	0.40%	0.42%	0.38%	0.37%	0.42%	0.39%	0.39%	0.51%	0.42%	0.39%	0.38%	0.38%	0.38%	0.38%	0.21%	0.40%
Quality Restaurant	0.17%	0.21%	0.22%	0.22%	0.22%	0.19%	0.18%	0.18%	0.20%	0.19%	0.19%	0.16%	0.23%	0.22%	0.22%	0.18%	0.18%	0.16%	0.13%	0.19%
Racquet Club	0.42%	0.42%	0.40%	0.41%	0.40%	0.42%	0.38%	0.37%	0.42%	0.39%	0.39%	0.51%	0.42%	0.39%	0.38%	0.38%	0.38%	0.38%	0.21%	0.40%
Refrigerated Warehouse-No Rail	0.24%	0.27%	0.58%	0.16%	0.57%	0.26%	0.02%	0.02%	0.03%	0.02%	0.02%	0.02%	0.05%	0.54%	0.39%	0.01%	0.01%	0.02%	0.03%	0.06%
Refrigerated Warehouse-Rail	0.24%	0.27%	0.58%	0.16%	0.57%	0.26%	0.02%	0.02%	0.03%	0.02%	0.02%	0.02%	0.05%	0.54%	0.39%	0.01%	0.01%	0.02%	0.03%	0.06%
Regional Shopping Center	0.98%	0.98%	0.99%	0.99%	0.99%	0.98%	0.24%	0.23%	0.31%	0.24%	0.23%	0.29%	0.99%	0.99%	0.99%	0.24%	0.23%	0.41%	0.44%	0.68%
Research & Development	0.79%	0.79%	0.87%	0.83%	0.88%	0.78%	0.79%	0.80%	0.85%	0.81%	0.81%	0.88%	0.86%	0.87%	0.86%	0.78%	0.78%	0.49%	0.51%	0.82%
Strip Mall	0.98%	0.98%	0.99%	0.99%	0.99%	0.98%	0.24%	0.23%	0.31%	0.24%	0.23%	0.29%	0.99%	0.99%	0.99%	0.24%	0.23%	0.41%	0.44%	0.68%
Supermarket	0.76%	0.78%	0.69%	0.72%	0.68%	0.75%	0.18%	0.17%	0.27%	0.20%	0.19%	0.34%	0.49%	0.67%	0.67%	0.17%	0.18%	0.36%	0.17%	0.51%
University/College (4yr)	0.96%	0.96%	0.88%	0.96%	0.86%	0.96%	0.85%	0.85%	0.87%	0.87%	0.87%	0.91%	0.96%	0.85%	0.92%	0.84%	0.85%	0.86%	0.71%	0.88%
Unrefrigerated Warehouse-No Rail	0.84%	0.87%	0.84%	0.85%	0.84%	0.86%	0.04%	0.04%	0.08%	0.04%	0.04%	0.04%	0.76%	0.83%	0.83%	0.04%	0.04%	0.06%	0.05%	0.21%
Unrefrigerated Warehouse-Rail	0.84%	0.87%	0.84%	0.85%	0.84%	0.86%	0.04%	0.04%	0.08%	0.04%	0.04%	0.04%	0.76%	0.83%	0.83%	0.04%	0.04%	0.06%	0.05%	0.21%

Source: ICF calculations; California Energy Commission (CEC). 2021. Excel database with the 2018-2030 Uncalibrated Commercial Sector Forecast, provided to ICF. January 21, 2021.

EDFZ = Electricity Demand Forecast Zone; yr = year

[1] The 12 building types used by the commercial end use forecast have been cross walked to the 49 non-residential land use types in CalEEMod, as shown in Table E-1.6.

[2] Data for some EDFZ were not available in the commercial end use forecast, and a representative EDFZ was assumed (refer to Table E-1.1).

Table E-1.4. Residential Electricity Reduction for 1 Percent Improvement over 2019 Title 24 Requirements

	Electricity Reduction by EDFZ[2]															
Housing Type[1]	1	2	3	4	5	6	7	8	9	10	11	12	13	16	17	State
Single Family Housing	0.14%	0.15%	0.33%	0.26%	0.34%	0.15%	0.22%	0.17%	0.31%	0.32%	0.34%	0.18%	0.24%	0.20%	0.26%	0.23%
Apartments Low Rise	0.11%	0.12%	0.28%	0.24%	0.31%	0.11%	0.16%	0.15%	0.24%	0.28%	0.41%	0.11%	0.27%	0.12%	0.20%	0.27%
Apartments Mid Rise	0.13%	0.14%	0.24%	0.27%	0.32%	0.13%	0.17%	0.15%	0.31%	0.27%	0.36%	0.15%	0.27%	0.13%	0.22%	0.29%
Apartments High Rise	0.13%	0.14%	0.24%	0.27%	0.32%	0.13%	0.17%	0.15%	0.31%	0.27%	0.36%	0.15%	0.27%	0.13%	0.22%	0.29%
Condo/Townhouse	0.10%	0.12%	0.22%	0.22%	0.27%	0.10%	0.16%	0.15%	0.26%	0.24%	0.40%	0.12%	0.29%	0.10%	0.24%	0.24%
Condo/Townhouse High Rise	0.13%	0.14%	0.24%	0.27%	0.32%	0.13%	0.17%	0.15%	0.31%	0.27%	0.36%	0.15%	0.27%	0.13%	0.22%	0.29%
Mobile Home Park	0.20%	0.19%	0.38%	0.28%	0.34%	0.16%	0.23%	0.11%	0.32%	0.31%	0.39%	0.21%	0.27%	0.19%	0.27%	0.35%
Retirement Community	0.11%	0.12%	0.28%	0.24%	0.31%	0.11%	0.16%	0.15%	0.24%	0.28%	0.41%	0.11%	0.27%	0.12%	0.20%	0.27%
Congregate Care	0.13%	0.14%	0.24%	0.27%	0.32%	0.13%	0.17%	0.15%	0.31%	0.27%	0.36%	0.15%	0.27%	0.13%	0.22%	0.29%

Source: ICF calculations; California Energy Commission. 2020. Excel database with the 2019 Residential Appliance Saturation Study (RASS), provided to ICF. November 13, 2020.
EDFZ = Electricity Demand Forecast Zone
[1] The five housing types used by the RASS have been cross walked to the nine residential land use types in CalEEMod, as shown in Table E-1.6.
[2] Data for some EDFZ were not available in the RASS, and a representative EDFZ was assumed (refer to Table E-1.1).

Table E-1.5. Residential Natural Gas Reduction for 1 Percent Improvement over 2019 Title 24 Requirements

	Natural Gas Reduction by EDFZ[2]															
Housing Type[1]	1	2	3	4	5	6	7	8	9	10	11	12	13	16	17	State
Single Family Housing	0.94%	0.95%	0.95%	0.95%	0.94%	0.94%	0.88%	0.89%	0.93%	0.89%	0.86%	0.91%	0.95%	0.88%	0.88%	0.92%
Apartments Low Rise	0.94%	0.94%	0.95%	0.93%	0.92%	0.91%	0.87%	0.88%	0.91%	0.89%	0.90%	0.90%	0.91%	0.89%	0.88%	0.91%
Apartments Mid Rise	0.93%	0.98%	0.95%	0.96%	0.95%	0.93%	0.87%	0.88%	0.96%	0.91%	0.90%	0.91%	0.96%	0.84%	0.81%	0.90%
Apartments High Rise	0.93%	0.98%	0.95%	0.96%	0.95%	0.93%	0.87%	0.88%	0.96%	0.91%	0.90%	0.91%	0.96%	0.84%	0.81%	0.90%
Condo/Townhouse	0.94%	0.97%	0.98%	0.94%	0.92%	0.93%	0.89%	0.90%	0.94%	0.89%	0.90%	0.92%	0.95%	0.89%	0.89%	0.92%
Condo/Townhouse High Rise	0.93%	0.98%	0.95%	0.96%	0.95%	0.93%	0.87%	0.88%	0.96%	0.91%	0.90%	0.91%	0.96%	0.84%	0.81%	0.90%
Mobile Home Park	0.92%	0.95%	0.92%	0.92%	0.92%	0.93%	0.92%	0.93%	0.93%	0.94%	0.91%	0.92%	0.94%	0.94%	0.88%	0.92%
Retirement Community	0.94%	0.94%	0.95%	0.93%	0.92%	0.91%	0.87%	0.88%	0.91%	0.89%	0.90%	0.90%	0.91%	0.89%	0.88%	0.91%
Congregate Care	0.93%	0.98%	0.95%	0.96%	0.95%	0.93%	0.87%	0.88%	0.96%	0.91%	0.90%	0.91%	0.96%	0.84%	0.81%	0.90%

Source: ICF calculations; California Energy Commission. 2020. Excel database with the 2019 Residential Appliance Saturation Study (RASS), provided to ICF. November 13, 2020.
EDFZ = Electricity Demand Forecast Zone
[1] The five housing types used by the RASS have been cross walked to the nine residential land use types in CalEEMod, as shown in Table E-1.6.
[2] Data for some EDFZ were not available in the RASS, and a representative EDFZ was assumed (refer to Table E-1.1).

Table E-1.6. Residential Appliance Saturation Study/Commercial End Use Forecast to CalEEMod Land Use Type Mapping

Land Use Type[1]	Mapped Land Use Type[2]
College	Junior college (2yr), University/college (4yr)
Grocery	Convenience market (24 hour), Convenience market with gas pumps, Supermarket
Hospital	Hospital
Hotel/motel	Hotel, Motel
Large office	General office building, Government (civic center), Government office building, Industrial park, Medical office building, Office park, Research & development
Miscellaneous	Arena, automobile care center, Bank (with drive-through), Gasoline/service station, General heavy industry, General light industry, Health club, Library, Manufacturing, Movie theater (no matinee), Place of worship, Racquet club
Refg. Warehouse	Refrigerated warehouse
Restaurant	Fast food restaurant w/o drive thru, Fast food restaurant with drive thru, High turnover (sit down restaurant), Quality restaurant
Retail	Discount club, Electronic superstore, Free-standing discount store, Free-standing discount superstore, Hardware/paint store, Home improvement superstore, Pharmacy/drugstore, Regional shopping center, Strip mall
Schools	Day-care center, Elementary school, High school, Junior high school
Small office	n/a
Warehouse	Unrefrigerated warehouse
Single family detached	Single family housing
Apartment or condo (2-4 units)	Apartments low rise, Retirement community
Apartment or condo (5+ units)	Apartments mid rise, Apartments high rise, Condo/townhome high rise, Congregate care
Townhome, duplex, or row house	Condo/townhouse
Mobile home	Mobile home park

RASS = Residential Appliance Saturation Study; Refg. = refrigerated; yr = year; n/a = no mapped land use type

[1] Excludes land use types with zero energy consumption in the commercial end use forecast and RASS.

[2] The commercial end use forecast and RASS land use types were mapped to those analyzed in the California Emissions Estimator Model (CalEEMod).

Table E-2.1. Electricity Reduction of ENERGY STAR Appliance compared to Conventional Appliance

Appliance Type	Electricity Reduction (%)
Commercial Refrigerator	-20%
Residential Refrigerator	-9%
Clothes Washer	-25%
Dishwasher	-12%
Ceiling Fan	-60%

Sources: ENERGY STAR. 2014. Refrigerators – Overview. September. Available: https://www.energystar.gov/products/appliances/refrigerators. Accessed: January 2021.

ENERGY STAR. 2016. Dishwashers – Overview. January. Available: https://www.energystar.gov/products/appliances/dishwashers. Accessed: January 2021.

ENERGY STAR. 2017. Commercial Refrigerators & Freezers – Overview. March. Available: https://www.energystar.gov/products/commercial_food_service_equipment/commercial_refrigerators_freezers. Accessed: January 2021

ENERGY STAR. 2018a. Clothes Washers – Overview. February. Available: https://www.energystar.gov/products/appliances/clothes_washers?qt-consumers_product_tab=2#qt-consumers_product_tab. Accessed: January 2021.

ENERGY STAR. 2018b. Ceiling Fans – Overview. June. Available: https://www.energystar.gov/products/lighting_fans/ceiling_fans. Accessed: January 2021.

Table E-2.2. Non-Residential Percent of Total Building Electricity for Commercial Refrigerators

Non-Residential Building Type[1]	Commercial Refrigerator Percent of Total Building Electricity by EDFZ[2]																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	State
Arena	1%	2%	1%	2%	1%	2%	<1%	<1%	<1%	<1%	<1%	<1%	2%	2%	2%	<1%	<1%	<1%	<1%	<1%
Automobile Care Center	1%	2%	1%	2%	1%	2%	<1%	<1%	<1%	<1%	<1%	<1%	2%	2%	2%	<1%	<1%	<1%	<1%	<1%
Bank (with Drive-Through)	1%	2%	1%	2%	1%	2%	<1%	<1%	<1%	<1%	<1%	<1%	2%	2%	2%	<1%	<1%	<1%	<1%	<1%
Convenience Market (24 hour)	23%	23%	21%	23%	20%	23%	57%	57%	52%	56%	57%	55%	27%	23%	24%	55%	55%	50%	45%	35%
Convenience Market with Gas Pumps	23%	23%	21%	23%	20%	23%	57%	57%	52%	56%	57%	55%	27%	23%	24%	55%	55%	50%	45%	35%
Day-Care Center	3%	3%	3%	3%	3%	3%	1%	1%	2%	2%	2%	1%	2%	3%	3%	1%	1%	<1%	1%	2%
Discount Club	2%	2%	1%	2%	1%	2%	2%	2%	2%	2%	2%	2%	2%	1%	1%	2%	2%	2%	2%	2%
Electronic Superstore	2%	2%	1%	2%	1%	2%	2%	2%	2%	2%	2%	2%	2%	1%	1%	2%	2%	2%	2%	2%
Elementary School	3%	3%	3%	3%	3%	3%	1%	1%	2%	2%	2%	1%	2%	3%	3%	1%	1%	<1%	1%	2%
Fast Food Restaurant w/o Drive Thru	13%	12%	12%	13%	12%	13%	24%	24%	23%	26%	26%	22%	15%	14%	14%	19%	20%	19%	16%	17%
Fast Food Restaurant with Drive Thru	13%	12%	12%	13%	12%	13%	24%	24%	23%	26%	26%	22%	15%	14%	14%	19%	20%	19%	16%	17%
Free-Standing Discount store	2%	2%	1%	2%	1%	2%	2%	2%	2%	2%	2%	2%	2%	1%	1%	2%	2%	2%	2%	2%
Free-Standing Discount Superstore	2%	2%	1%	2%	1%	2%	2%	2%	2%	2%	2%	2%	2%	1%	1%	2%	2%	2%	2%	2%
Gasoline/Service Station	1%	2%	1%	2%	1%	2%	<1%	<1%	<1%	<1%	<1%	<1%	2%	2%	2%	<1%	<1%	<1%	<1%	<1%
General Heavy Industry	1%	2%	1%	2%	1%	2%	<1%	<1%	<1%	<1%	<1%	<1%	2%	2%	2%	<1%	<1%	<1%	<1%	<1%
General Light Industry	1%	2%	1%	2%	1%	2%	<1%	<1%	<1%	<1%	<1%	<1%	2%	2%	2%	<1%	<1%	<1%	<1%	<1%
General Office Building	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%
Government (Civic Center)	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%
Government Office Building	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%
Hardware/Paint Store	2%	2%	1%	2%	1%	2%	2%	2%	2%	2%	2%	2%	2%	1%	1%	2%	2%	2%	2%	2%
Health Club	1%	2%	1%	2%	1%	2%	<1%	<1%	<1%	<1%	<1%	<1%	2%	2%	2%	<1%	<1%	<1%	<1%	<1%
High School	3%	3%	3%	3%	3%	3%	1%	1%	2%	2%	2%	1%	2%	3%	3%	1%	1%	<1%	1%	2%
High Turnover (Sit Down Restaurant)	13%	12%	12%	13%	12%	13%	24%	24%	23%	26%	26%	22%	15%	14%	14%	19%	20%	19%	16%	17%
Home Improvement Superstore	2%	2%	1%	2%	1%	2%	2%	2%	2%	2%	2%	2%	2%	1%	1%	2%	2%	2%	2%	2%
Hospital	<1%	<1%	<1%	<1%	<1%	<1%	1%	1%	<1%	1%	1%	2%	<1%	<1%	<1%	<1%	<1%	<1%	9%	1%
Hotel	4%	4%	4%	4%	4%	4%	8%	8%	7%	8%	8%	10%	5%	5%	5%	8%	8%	7%	3%	7%
Industrial Park	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%
Junior College (2yr)	<1%	<1%	<1%	<1%	<1%	<1%	4%	4%	3%	4%	4%	3%	<1%	<1%	<1%	3%	2%	3%	5%	3%

Table E-2.2. Non-Residential Percent of Total Building Electricity for Commercial Refrigerators (cont.)

Non-Residential Building Type[1]	Commercial Refrigerator Percent of Total Building Electricity by EDFZ[2]																			
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	State
Junior High School	3%	3%	3%	3%	3%	3%	1%	1%	2%	2%	2%	1%	2%	3%	3%	1%	1%	<1%	1%	2%
Library	1%	2%	1%	2%	1%	2%	<1%	<1%	<1%	<1%	<1%	<1%	2%	2%	2%	<1%	<1%	<1%	<1%	<1%
Manufacturing	1%	2%	1%	2%	1%	2%	<1%	<1%	<1%	<1%	<1%	<1%	2%	2%	2%	<1%	<1%	<1%	<1%	<1%
Medical Office Building	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%
Motel	4%	4%	4%	4%	4%	4%	8%	8%	7%	8%	8%	10%	5%	5%	5%	8%	8%	7%	3%	7%
Movie Theater (No Matinee)	1%	2%	1%	2%	1%	2%	<1%	<1%	<1%	<1%	<1%	<1%	2%	2%	2%	<1%	<1%	<1%	<1%	<1%
Office Park	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%
Pharmacy/Drugstore w/o Drive Thru	2%	2%	1%	2%	1%	2%	2%	2%	2%	2%	2%	2%	2%	1%	1%	2%	2%	2%	2%	2%
Pharmacy/Drugstore with Drive Thru	2%	2%	1%	2%	1%	2%	2%	2%	2%	2%	2%	2%	2%	1%	1%	2%	2%	2%	2%	2%
Place of Worship	1%	2%	1%	2%	1%	2%	<1%	<1%	<1%	<1%	<1%	<1%	2%	2%	2%	<1%	<1%	<1%	<1%	<1%
Quality Restaurant	13%	12%	12%	13%	12%	13%	24%	24%	23%	26%	26%	22%	15%	14%	14%	19%	20%	19%	16%	17%
Racquet Club	1%	2%	1%	2%	1%	2%	<1%	<1%	<1%	<1%	<1%	<1%	2%	2%	2%	<1%	<1%	<1%	<1%	<1%
Refrigerated Warehouse-No Rail	64%	64%	64%	64%	64%	64%	80%	79%	81%	83%	83%	82%	72%	71%	71%	78%	78%	52%	73%	72%
Refrigerated Warehouse-Rail	64%	64%	64%	64%	64%	64%	80%	79%	81%	83%	83%	82%	72%	71%	71%	78%	78%	52%	73%	72%
Regional Shopping Center	2%	2%	1%	2%	1%	2%	2%	2%	2%	2%	2%	2%	2%	1%	1%	2%	2%	2%	2%	2%
Research & Development	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%	<1%
Strip Mall	2%	2%	1%	2%	1%	2%	2%	2%	2%	2%	2%	2%	2%	1%	1%	2%	2%	2%	2%	2%
Supermarket	23%	23%	21%	23%	20%	23%	57%	57%	52%	56%	57%	55%	27%	23%	24%	55%	55%	50%	45%	35%
University/College (4yr)	<1%	<1%	<1%	<1%	<1%	<1%	4%	4%	3%	4%	4%	3%	<1%	<1%	<1%	3%	2%	3%	5%	3%
Unrefrigerated Warehouse-No Rail	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Unrefrigerated Warehouse-Rail	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

Source: ICF calculations; California Energy Commission (CEC). 2021. Excel database with the 2018-2030 Uncalibrated Commercial Sector Forecast, provided to ICF. January 21, 2021.

EDFZ = Electricity Demand Forecast Zone; yr = year

[1] The 12 building types used by the commercial end use forecast have been cross walked to the 49 non-residential land use types in CalEEMod, as shown in Table E-1.6.

[2] Data for some EDFZ were not available in the commercial end use forecast, and a representative EDFZ was assumed (refer to Table E-1.1).

Table E-2.3. Residential Percent of Total Building Electricity by Appliance

Housing Type[1]	Percent of Total Electricity by Appliance by EDFZ[2]														
	1	2	3	4	5	6	7	8	9	10	11	12	13	16	17	State
Refrigerator																
Single Family Housing	18%	18%	14%	15%	13%	18%	17%	17%	15%	15%	13%	18%	16%	18%	15%	16%
Apartments Low Rise	26%	29%	22%	25%	21%	27%	28%	26%	25%	23%	17%	27%	25%	27%	28%	26%
Apartments Mid Rise	28%	29%	25%	24%	22%	29%	28%	29%	22%	24%	21%	28%	24%	30%	27%	27%
Apartments High Rise	28%	29%	25%	24%	22%	29%	28%	29%	22%	24%	21%	28%	24%	30%	27%	27%
Condo/Townhouse	24%	24%	24%	22%	22%	26%	24%	24%	22%	24%	17%	26%	21%	27%	23%	24%
Condo/Townhouse High Rise	28%	29%	25%	24%	22%	29%	28%	29%	22%	24%	21%	28%	24%	30%	27%	27%
Mobile Home Park	23%	21%	15%	17%	16%	23%	22%	28%	17%	18%	17%	21%	21%	25%	20%	19%
Retirement Community	26%	29%	22%	25%	21%	27%	28%	26%	25%	23%	17%	27%	25%	27%	28%	26%
Congregate Care	28%	29%	25%	24%	22%	29%	28%	29%	22%	24%	21%	28%	24%	30%	27%	27%
Clothes Washer																
Single Family Housing	1.1%	0.8%	0.7%	0.8%	0.9%	1.0%	1.2%	1.1%	0.9%	1.0%	0.9%	1.1%	0.9%	1.1%	1.1%	1.0%
Apartments Low Rise	1.0%	1.0%	1.0%	0.6%	0.8%	0.9%	1.0%	1.0%	0.9%	1.0%	0.6%	1.0%	0.6%	1.0%	0.5%	0.9%
Apartments Mid Rise	0.6%	0.6%	0.7%	0.6%	0.6%	0.5%	0.5%	0.6%	0.7%	0.6%	0.5%	0.6%	0.7%	0.5%	0.6%	0.6%
Apartments High Rise	0.6%	0.6%	0.7%	0.6%	0.6%	0.5%	0.5%	0.6%	0.7%	0.6%	0.5%	0.6%	0.7%	0.5%	0.6%	0.6%
Condo/Townhouse	1.3%	1.1%	0.8%	1.1%	1.1%	1.4%	1.3%	1.2%	1.2%	1.3%	0.8%	1.2%	1.0%	1.3%	1.6%	1.2%
Condo/Townhouse High Rise	0.6%	0.6%	0.7%	0.6%	0.6%	0.5%	0.5%	0.6%	0.7%	0.6%	0.5%	0.6%	0.7%	0.5%	0.6%	0.6%
Mobile Home Park	1.5%	1.1%	0.9%	0.8%	0.8%	1.0%	1.1%	1.3%	0.9%	0.8%	0.8%	0.9%	0.9%	0.6%	1.3%	0.9%
Retirement Community	1.0%	1.0%	1.0%	0.6%	0.8%	0.9%	1.0%	1.0%	0.9%	1.0%	0.6%	1.0%	0.6%	1.0%	0.5%	0.9%
Congregate Care	0.6%	0.6%	0.7%	0.6%	0.6%	0.5%	0.5%	0.6%	0.7%	0.6%	0.5%	0.6%	0.7%	0.5%	0.6%	0.6%
Dishwasher																
Single Family Housing	1.1%	0.9%	0.6%	0.8%	0.7%	0.9%	0.9%	1.0%	0.7%	0.8%	0.8%	1.0%	0.9%	0.8%	0.8%	0.9%
Apartments Low Rise	1.0%	0.9%	1.0%	0.7%	0.8%	0.9%	0.8%	1.1%	0.8%	1.0%	0.7%	1.1%	0.8%	0.6%	0.6%	0.9%
Apartments Mid Rise	1.0%	0.7%	0.9%	0.7%	0.7%	0.8%	0.9%	0.7%	0.9%	0.9%	0.8%	1.0%	0.9%	0.8%	1.1%	0.9%
Apartments High Rise	1.0%	0.7%	0.9%	0.7%	0.7%	0.8%	0.9%	0.7%	0.9%	0.9%	0.8%	1.0%	0.9%	0.8%	1.1%	0.9%
Condo/Townhouse	1.2%	1.0%	0.6%	0.9%	0.8%	1.3%	1.1%	1.2%	0.8%	0.9%	0.7%	1.2%	0.8%	0.7%	1.1%	1.1%
Condo/Townhouse High Rise	1.0%	0.7%	0.9%	0.7%	0.7%	0.8%	0.9%	0.7%	0.9%	0.9%	0.8%	1.0%	0.9%	0.8%	1.1%	0.9%
Mobile Home Park	0.8%	0.6%	0.4%	0.6%	0.4%	0.8%	0.6%	0.6%	0.5%	0.4%	0.5%	0.8%	0.6%	0.3%	0.6%	0.6%
Retirement Community	1.0%	0.9%	1.0%	0.7%	0.8%	0.9%	0.8%	1.1%	0.8%	1.0%	0.7%	1.1%	0.8%	0.6%	0.6%	0.9%

Table E-2.3. Residential Percent of Total Building Electricity by Appliance (cont.)

	Percent of Total Electricity by Appliance by EDFZ[2]															
Housing Type[1]	1	2	3	4	5	6	7	8	9	10	11	12	13	16	17	State
Congregate Care	1.0%	0.7%	0.9%	0.7%	0.7%	0.8%	0.9%	0.7%	0.9%	0.9%	0.8%	1.0%	0.9%	0.8%	1.1%	0.9%
Ceiling Fan																
Single Family Housing	1.3%	1.2%	0.9%	1.0%	0.9%	1.3%	1.2%	1.3%	0.9%	1.1%	0.9%	1.3%	0.9%	1.2%	1.0%	1.1%
Apartments Low Rise	2.2%	2.4%	1.8%	1.9%	1.7%	2.6%	2.2%	2.1%	1.8%	1.8%	1.2%	2.4%	1.7%	2.3%	2.3%	2.1%
Apartments Mid Rise	2.4%	2.6%	1.7%	1.8%	1.7%	2.8%	2.3%	2.4%	1.6%	1.9%	1.5%	2.5%	1.7%	2.5%	2.1%	2.3%
Apartments High Rise	2.4%	2.6%	1.7%	1.8%	1.7%	2.8%	2.3%	2.4%	1.6%	1.9%	1.5%	2.5%	1.7%	2.5%	2.1%	2.3%
Condo/Townhouse	1.9%	2.0%	1.6%	1.6%	1.5%	2.3%	1.8%	1.9%	1.6%	1.7%	1.1%	2.0%	1.3%	2.1%	1.6%	1.8%
Condo/Townhouse High Rise	2.4%	2.6%	1.7%	1.8%	1.7%	2.8%	2.3%	2.4%	1.6%	1.9%	1.5%	2.5%	1.7%	2.5%	2.1%	2.3%
Mobile Home Park	2.0%	1.5%	1.1%	1.2%	1.2%	1.8%	1.7%	2.3%	1.2%	1.5%	1.2%	1.8%	1.5%	1.9%	1.7%	1.4%
Retirement Community	2.2%	2.4%	1.8%	1.9%	1.7%	2.6%	2.2%	2.1%	1.8%	1.8%	1.2%	2.4%	1.7%	2.3%	2.3%	2.1%
Congregate Care	2.4%	2.6%	1.7%	1.8%	1.7%	2.8%	2.3%	2.4%	1.6%	1.9%	1.5%	2.5%	1.7%	2.5%	2.1%	2.3%

Source: ICF calculations; California Energy Commission (CEC). 2020. Excel database with the 2019 Residential Appliance Saturation Study (RASS), provided to ICF. November 13, 2020.

EDFZ = Electricity Demand Forecast Zone

[1] The five housing types used by the RASS have been cross walked to the nine residential land use types in CalEEMod, as shown in Table E-1.6.

[2] Data for some EDFZ were not available in the RASS, and a representative EDFZ was assumed (refer to Table E-1.1).

Table E-3-A.1. Average Annual Fuel Use and Savings by Boiler Type for Residential Boilers

	Annual Fuel Use		
AFUE by Boiler Type[1, 2]	Total (MMBtu/yr)[3]	Savings (MMBtu/yr)	Change (%)
Gas-fired[4] Hot Water Boiler			
84% (Standard)	82.1	—	—
85%	81.1	1.0	-1.2%
90%	75.2	6.9	-8.4%
92%	73.6	8.5	-10.4%
96% (Max Tech)	70.6	11.5	-14.0%
Gas-fired Steam Boiler			
82% (Standard)	83.9	—	—
83% (Max Tech)	82.9	1.0	-1.2%
Oil-fired Hot Water Boiler			
86% (Standard)	84.3	—	—
91% (Max Tech)	80.1	4.2	-5.0%
Oil-fired Steam Boiler			
85% (Standard)	82.9	—	—
86% (Max Tech)	81.9	1.0	-1.2%

Source: U.S. Department of Energy (U.S. DOE). 2015. Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Residential Boilers. March. Available: https://www.regulations.gov/docketBrowser?rpp=25&so=DESC&sb=commentDueDate&po=0&dct=SR%2BO&D=EERE-2012-BT-STD-0047. Accessed: January 2021.

AFUE = Annual fuel utilization efficiency; MMBtu = one million British Thermal Units; yr = year

[1] "Standard" refers to the minimum AFUE required by the 2016 Conservation Standards for Residential Boilers.

[2] "Max Tech" refers to the maximum technologically feasible improvement in energy efficiency determined by DOE for each type of boiler.

[3] The average annual fuel use is based on historical consumption data.

[4] Gas-fired boilers refer to boilers that use natural gas and/or propane as fuel.

Table E-3-B.1. Average Annual Fuel Use and Savings for Boilers Installed Before January 10, 2023 for Commercial and Industrial Boilers

	Annual Fuel Use		
CE or TE by Boiler Type[1,2]	Total (MMBtu/yr)[3]	Savings (MMBtu/yr)	Change (%)
Gas-fired Hot Water Boiler (≥300,000 Btu/hr and ≤2,500,000 Btu/hr)			
80% TE (Standard)	907.7	—	—
81% TE	896.3	11.4	-1.3%
82% TE	885.2	22.6	-2.5%
84% TE	863.7	44	-4.8%
85% TE	853.4	54.4	-6.0%
93% TE	815.7	92	-10.1%
95% TE	797.3	110.4	-12.2%
99% TE (Max Tech)	762.9	144.8	-16.0%
Gas-fired Hot Water Boiler (≥2,500,000 Btu/hr and ≤10,000,000 Btu/hr)			
82% CE (Standard)	6,008.8	—	—
83% CE	5,929.9	78.9	-1.3%
84% CE	5,853.1	155.7	-2.6%
85% CE	5,778.3	230.5	-3.8%
94% CE	5,442.5	566.3	-9.4%
97% CE (Max Tech)	5,252.2	756.6	-12.6%
Oil-fired Hot Water Boiler (≥300,000 Btu/hr and ≤2,500,000 Btu/hr)			
82% TE (Standard)	807.3	—	—
83% TE	797.4	9.9	-1.2%
84% TE	787.8	19.5	-2.4%
85% TE	778.4	28.9	-3.6%
87% TE	760.2	47.1	-5.8%
88% TE	751.5	55.8	-6.9%
97% TE (Max Tech)	709.5	97.8	-12.1%
Oil-fired Hot Water Boiler (≥2,500,000 Btu/hr and ≤10,000,000 Btu/hr)			
84% CE (Standard)	3,119.1	—	—
86% CE	3,047.7	71.4	-2.3%
88% CE	2,979.5	139.6	-4.5%
89% CE	2,946.5	172.6	-5.5%
97% CE (Max Tech)	2,854.2	264.9	-8.5%
Gas-fired Steam Boiler (≥300,000 Btu/hr and ≤2,500,000 Btu/hr)			
77% TE (Standard)	787.0	—	—
78% TE	776.7	10.3	-1.3%
79% TE	766.7	20.3	-2.6%
80% TE	757	30	-3.8%
81% TE	747.4	39.6	-5.0%
83% TE (Max Tech)	729.1	57.9	-7.4%

Table E-3-B.1. Average Annual Fuel Use and Savings for Boilers Installed Before January 10, 2023 for Commercial and Industrial Boilers (cont.)

	Annual Fuel Use		
CE or TE by Boiler Type[1, 2]	Total (MMBtu/yr)[3]	Savings (MMBtu/yr)	Change (%)
Gas-fired Steam Boiler (≥2,500,000 Btu/hr and ≤10,000,000 Btu/hr)			
77% TE (Standard)	4,956.9	—	—
78% TE	4,892.1	64.8	-1.3%
79% TE	4,829.0	127.9	-2.6%
80% TE	4,767.5	189.4	-3.8%
81% TE	4,707.6	249.3	-5.0%
82% TE	4,649.1	307.8	-6.2%
84% TE (Max Tech)	4,536.4	420.5	-8.5%
Oil-fired Steam Boiler (≥300,000 Btu/hr and ≤2,500,000 Btu/hr)			
81% TE (Standard)	845.7	—	—
83% TE	825.0	20.7	-2.4%
84% TE	815.0	30.7	-3.6%
86% TE (Max Tech)	795.8	49.9	-5.9%
Oil-fired Steam Boiler (≥2,500,000 Btu/hr and ≤10,000,000 Btu/hr)			
81% TE (Standard)	3,730.3	—	—
83% TE	3,639.0	91.3	-2.4%
85% TE	3,552.1	178.2	-4.8%
87% (Max Tech)	3,469.2	261.1	-7.0%

Source: U.S. Department of Energy (U.S. DOE). 2016. Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Packaged Boilers. December. Available: https://www.regulations.gov/docket?D=EERE-2013-BT-STD-0030. Accessed: January 2021.

CE = combustion efficiency; MMBtu = one million British Thermal Unit; TE = thermal efficiency; yr = year; Btu = British Thermal Unit; ≥ = greater than or equal to; ≤ = less than or equal to

[1] "Standard" refers to the minimum CE or TE required by the 2012 Conservation Standards for Commercial Packaged Boilers.

[2] "Max Tech" refers to the maximum technologically feasible improvement in energy efficiency determined by DOE for each type of boiler.

[3] The average annual fuel use is based on historical consumption data.

Table E-3-B.2. Average Annual Fuel Use and Savings for Boilers Installed On or After January 10, 2023

	Annual Fuel Use		
CE or TE by Boiler Type[1, 2]	Total (MMBtu/yr)[3]	Savings (MMBtu/yr)	Change (%)
Gas-fired Hot Water Boiler (≥300,000 Btu/hr and ≤2,500,000 Btu/hr)			
84% TE (Standard)	863.7	—	—
85% TE	853.4	10.3	-1.2%
93% TE	815.7	48.0	-5.6%
95% TE	797.3	66.4	-7.7%
99% TE (Max Tech)	762.9	100.8	-11.7%
Gas-fired Hot Water Boiler (≥2,500,000 Btu/hr and ≤10,000,000 Btu/hr)			
85% CE (Standard)	5,778.3	—	—
94% CE	5,442.5	335.8	-5.8%
97% CE (Max Tech)	5,252.2	526.1	-9.1%
Oil-fired Hot Water Boiler (≥300,000 Btu/hr and ≤2,500,000 Btu/hr)			
87% TE (Standard)	760.2	—	—
88% TE	751.5	8.7	-1.1%
97% TE (Max Tech)	709.5	50.7	-6.7%
Oil-fired Hot Water Boiler (≥2,500,000 Btu/hr and ≤10,000,000 Btu/hr)			
88% CE (Standard)	2,979.5	—	—
89% CE	2,946.5	33.0	-1.1%
97% CE (Max Tech)	2,854.2	125.3	-4.2%
Gas-fired Steam Boiler (≥300,000 Btu/hr and ≤2,500,000 Btu/hr)			
81% TE (Standard)	747.4	—	—
83% TE (Max Tech)	729.1	18.3	-2.4%
Gas-fired Steam Boiler (≥2,500,000 Btu/hr and ≤10,000,000 Btu/hr)			
82% TE (Standard)	4,649.1	—	—
84% TE (Max Tech)	4,536.4	112.7	-2.4%
Oil-fired Steam Boiler (≥300,000 Btu/hr and ≤2,500,000 Btu/hr)			
84% TE (Standard)	815.0	—	—
86% TE (Max Tech)	795.8	19.2	-2.4%
Oil-fired Steam Boiler (≥2,500,000 Btu/hr and ≤10,000,000 Btu/hr)			
81% TE (Standard)	3,730.3	—	—
83% TE	3,639.0	91.3	-2.4%
85% TE	3,552.1	178.2	-4.8%
87% (Max Tech)	3,469.2	261.1	-7.0%

Source: U.S. Department of Energy (U.S. DOE). 2016. Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Commercial Packaged Boilers. December. Available: https://www.regulations.gov/docket?D=EERE-2013-BT-STD-0030. Accessed: January 2021.

CE = combustion efficiency; MMBtu = one million British Thermal Units; TE = thermal efficiency; yr = year; Btu = British Thermal Unit; ≥ = greater than or equal to; ≤ = less than or equal to

[1] "Standard" refers to the minimum CE or TE required by the 2020 Conservation Standards for Commercial Packaged Boilers.

[2] "Max Tech" refers to the maximum technologically feasible improvement in energy efficiency determined by DOE for each type of boiler.

[3] The average annual fuel use is based on historical consumption data.

Table E-4.1. Canyon Aspect Ratios

Ratio	Height (ft)	Width (ft)	Neighboring Building Types Represented
0.2	19.7	98.4	Two-story single-family homes across a residential street
1	19.7	19.7	Two-story single-family homes across small backyards
2	19.7	9.8	Two-story single-family homes on the same street side
10	98.4	9.8	Adjacent 10-story office buildings on the same street side

Source: Levinson, R. 2019. *Using Solar Availability Factors to Adjust Cool-Wall Energy Savings for Shading and Reflection by Neighboring Buildings*. March. Available: https://escholarship.org/content/qt0hf5m90n/qt0hf5m90n.pdf. Accessed: January 2021.

ft = foot

Table E-4.2. Solar Availability Factors by Canyon Aspect Ratio

	Conventional Neighboring Wall (albedo = 0.25)				Cool Neighboring Wall (albedo = 0.60)			
Ratio	North	East	South	West	North	East	South	West
0.2	0.92	0.92	0.95	0.92	1.02	0.95	0.96	0.95
1	0.67	0.62	0.7	0.62	0.94	0.72	0.75	0.72
2	0.47	0.42	0.49	0.42	0.73	0.52	0.55	0.52
10	0.13	0.11	0.13	0.11	0.22	0.15	0.16	0.15

Source: Levinson, R. 2019. *Using Solar Availability Factors to Adjust Cool-Wall Energy Savings for Shading and Reflection by Neighboring Buildings*. March. Available: https://escholarship.org/content/qt0hf5m90n/qt0hf5m90n.pdf. Accessed: January 2021.

Table E-4.3. Greenhouse Gas Intensity Factor by California Electricity Provider by Year (2017–2031)[1]

	Intensity Factor per Total Energy Delivered (lb CO_2e per MWh)												
Electricity Provider	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Alameda Municipal Power	455	0[2]	0	0	0	0	0	0	0	0	0	0	0
Apple Valley Choice Energy	655	655	655	595	595	595	595	526	526	526	526	334	334
Bear Valley Electric Service	914	914	914	567	567	567	567	483	483	483	483	435	435
Burbank Water & Power	1,132	1,008	932	902	884	669	398	224	221	216	218	236	236
Baldwin Park Resident Owned Utility District	—[3]	585	585	598	598	598	598	526	526	526	526	336	336
Central Coast Community Energy	12	137	509	542	528	448	388	313	235	159	83	8	8
City of Anaheim Public Utilities Department	1,037	965	982	1001	985	937	756	568	469	311	304	276	271
City of Commerce	—[4]	—[4]	—[4]	600	600	600	600	518	518	518	518	331	331
City of Palo Alto Utilities Department	0	0	0	0	0	0	0	0	0	0	25	75	75
City of Riverside	875	788	792	791	789	789	602	451	441	432	415	398	398
City of Vernon Municipal Light Department	707	713	567	545	504	508	456	416	420	426	321	326	326
CleanPowerSF	46	19	132	122	108	94	80	9	9	9	9	0	0
Clean Energy Alliance	—[3]	964	964	545	544	544	544	449	449	449	449	431	431
Clean Power Alliance	361	474	474	432	432	432	431	416	416	416	416	332	332
Desert Community Energy	534	47	85	85	81	76	72	68	65	62	60	58	58
Glendale Water and Power	1027	948	951	785	790	693	550	346	357	370	285	304	304
Imperial Irrigation District	459	183	192	189	219	223	225	264	268	277	251	249	249
Lancaster Choice Energy	618	618	618	600	600	600	600	516	516	516	516	333	333
Los Angeles Department of Water & Power	694	694	694	694	694	694	694	694	694	694	694	694	694
MCE	190	292	292	151	151	150	150	184	184	184	184	247	247
Merced Irrigation District	455	293	293	403	403	403	403	405	405	405	405	391	391
Modesto Irrigation District	480	503	455	467	474	481	490	394	408	385	368	373	373
Pacific Gas and Electric Company	206[6]	206	206	206	206	206	206	206	206	206	206	206	206
PacifiCorp	1,501	1,292	1,188	1,228	1,254	1029	978	967	930	808	784	724	722
Pasadena Water and Power	1,030	869	875	869	869	465	82	71	68	68	71	64	64
Peninsula Clean Energy	102	102	0	0	0	0	0	0	0	0	0	0	0
Pico Rivera Innovative Municipal Energy	687	687	686	595	594	594	594	527	527	527	527	335	335
Pioneer Community Energy	767	767	767	624	623	623	623	482	482	482	482	391	391
Pomona Choice Energy	—[3]	618	618	598	598	598	598	517	517	517	517	333	332
Rancho Mirage Energy Authority	648	648	647	591	591	591	591	526	526	526	526	328	328
Redding Electric Utility	377	374	339	339	337	341	350	161	166	173	175	181	181
Redwood Coast Energy Authority	64	317	408	231	181	226	226	200	200	200	200	244	244
Roseville Electric	530	532	474	473	473	448	394	377	360	343	325	309	309
Sacramento Municipal Utility District	376	375	360	344	329	314	297	280	269	254	239	224	210
San Diego Community Power	—[4]	—[4]	—[4]	583	583	582	582	486	486	486	486	324	324
San Diego Gas & Electric	591	542	542	542	542	542	541	47	47	46	46	171	171
San Francisco Public Utilities Commission	0	0	0	0	0	0	0	0	0	0	0	0	0
San Jacinto Power	583	643	643	583	583	582	582	486	486	486	486	324	324
San Jose Clean Energy	811	811	810	390	390	390	390	363	363	363	363	311	311
Silicon Valley Clean Energy	2	2	2	6	5	5	5	5	4	4	4	3	3

Table E-4.3. Greenhouse Gas Intensity Factor by California Electricity Provider by Year (2017–2031) (cont.)[1]

Electricity Provider	Intensity Factor per Total Energy Delivered (lb CO_2e per MWh)												
	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031
Silicon Valley Power	389	357	310	168	187	205	224	224	227	232	239	155	155
Sonoma Clean Power	41	78	122	117	112	107	102	96	91	86	81	76	76
Southern California Edison	534	393	393	351	351	351	351	348	348	348	348	263	263
Turlock Irrigation District	589	702	610	563	694	704	581	547	296	291	336	348	286
Valley Clean Energy	206	961	961	639	639	639	639	520	520	519	519	391	391
Western Community Energy	—[3]	534	534	397	397	330	330	330	330	393	393	392	392
Statewide Average [7]	455	448	430	411	393	375	355	335	321	303	285	268	250

Sources: ICF calculations; California Utilities. 2021. Excel database of GHG emission factors for delivered electricity, provided to the Sacramento Metropolitan Air Quality Management District and ICF. January through March 2021; U.S. Environmental Protection Agency. 2021. Emissions & Generation Resource Integrated Database (eGRID). Last Revised: February 23, 2021. Available: https://www.epa.gov/egrid. Accessed: February 24, 2021.

lb = pounds; MWh = megawatt-hour; CO_2e = carbon dioxide equivalent

[1] All electricity providers gave an emission factor for at least one reported year. Emission factors for remaining years were calculated according to the following method, except where noted below.

- If an electricity provider gave data up until a year before 2045, all years between the last year of data given and 2045 were held constant at the values for the last year of data given. For example, Burbank Water & Power provided emission factors through 2030. Emission factors for years 2031 through 2045 were held constant at value provided for 2030.
- If an electricity provider gave factors for CO_2, but not CH_4 or N_2O, statewide average emission factors for CH_4 and N_2O were assumed to calculate CO_2e emission factors for the utility.

Users should consult their local electricity provider for updated emission factors available at the time of their analysis before proceeding with the defaults provided in this table.

[2] The electricity provider indicated that it began deriving carbon-free power beginning in 2020. This factor was held constant into all future years.

[3] The electricity provider began service in 2020.

[4] The electricity provider is not expected to begin service until 2022.

[5] The electricity providers' GHG emissions reported in their IRP filing change to positive in 2029 and 2030. This may be because they have not yet developed a plan to achieve carbon-free (or negative) power after 2029.

[6] 2018 value (data for 2019 not available).

[7] CO_2, CH_4, and N_2O emission factors for 2019 obtained from USEPA eGRID2019. Future year emission factors were calculated based on the 2019 intensity factors divided by the percent of energy delivered from non-renewable sources in that same year (68%). The calculated non-renewable source emission factors were multiplied by the projected percentage of energy delivered from non-renewable sources in each future year. The percentages of energy delivered from renewable sources in future years is per the requirements of Senate Bill 100: 33% RPS by 2020, 44% RPS by 2024, 50% RPS by 2026, 52% RPS by 2027, 60% RPS by 2030, and 100% carbon-free electricity for 2045. Percentages for non-Senate Bill 100 target years were interpolated.

Table E-4.4. Greenhouse Gas Intensity Factor by California Electricity Provider by Year (2032–2045)[1]

Electricity Provider	Intensity Factor per Total Energy Delivered (lb CO_2e per MWh)													
	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045
Alameda Municipal Power	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Apple Valley Choice Energy	333	333	333	333	333	333	333	333	333	333	333	333	333	332
Bear Valley Electric Service	435	435	435	435	435	435	435	434	434	434	434	434	434	434
Burbank Water & Power	236	236	236	236	236	236	236	236	236	236	236	236	236	236
Baldwin Park Resident Owned Utility District	336	336	335	335	335	335	335	335	335	335	335	335	335	335
Central Coast Community Energy	8	8	7	7	7	7	7	7	7	7	7	7	7	7
City of Anaheim Public Utilities Department	267	267	267	267	267	267	267	267	267	267	267	267	267	267
City of Commerce	331	331	331	331	331	330	330	330	330	330	330	330	330	330
City of Palo Alto Utilities Department	7	7	7	7	7	7	7	7	7	7	7	7	7	7
City of Riverside	398	398	398	398	398	398	398	398	398	398	398	398	398	398
City of Vernon Municipal Light Department	326	326	326	326	326	326	326	326	326	326	326	326	326	326
CleanPowerSF	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Clean Energy Alliance	431	431	431	430	430	430	430	430	430	430	430	430	430	430
Clean Power Alliance	332	332	332	331	331	331	331	331	331	331	331	331	331	331
Desert Community Energy	58	58	58	58	58	58	57	57	57	57	57	57	57	57
Glendale Water and Power	304	304	304	304	304	304	304	304	304	304	304	304	304	304
Imperial Irrigation District	249	249	249	249	249	249	249	249	249	249	249	249	249	249
Lancaster Choice Energy	333	333	333	333	333	333	333	333	332	332	332	332	332	332
Los Angeles Department of Water & Power	694	694	694	694	694	694	694	694	694	694	694	694	694	694
MCE	247	247	247	247	247	247	247	247	247	247	246	246	246	246
Merced Irrigation District	391	391	391	391	391	391	391	391	391	391	390	390	390	390
Modesto Irrigation District	373	373	373	373	373	373	373	373	373	373	373	373	373	373
Pacific Gas and Electric Company	206	206	206	206	206	206	206	206	206	206	206	206	206	206
PacifiCorp	711	706	704	684	686	616	536	499	463	483	479	331	304	304
Pasadena Water and Power	64	64	64	64	64	64	62	62	62	62	62	62	62	62
Peninsula Clean Energy	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pico Rivera Innovative Municipal Energy	335	335	335	335	335	335	335	335	335	335	335	334	334	334
Pioneer Community Energy	391	391	391	391	391	391	391	391	391	391	390	390	390	390

Table E-4.4. Greenhouse Gas Intensity Factor by California Electricity Provider by Year (2032–2045) (cont.)[1]

Electricity Provider	Intensity Factor per Total Energy Delivered (lb CO_2e per MWh)													
	2032	2033	2034	2035	2036	2037	2038	2039	2040	2041	2042	2043	2044	2045
Pomona Choice Energy	332	332	332	332	332	332	332	332	332	332	332	331	331	331
Rancho Mirage Energy Authority	328	328	328	328	328	328	328	328	328	327	327	327	327	327
Redding Electric Utility	181	181	181	181	181	181	181	181	181	181	181	181	181	181
Redwood Coast Energy Authority	243	243	243	243	243	243	243	243	243	243	243	243	243	242
Roseville Electric	309	309	309	309	309	309	309	309	309	309	309	309	309	309
Sacramento Municipal Utility District	195	180	165	150	135	120	106	91	76	61	46	31	16	2
San Diego Community Power	324	324	324	324	324	324	324	324	324	324	324	323	323	323
San Diego Gas & Electric	171	171	171	170	170	170	170	170	170	170	170	170	170	170
San Francisco Public Utilities Commission	0	0	0	0	0	0	0	0	0	0	0	0	0	0
San Jacinto Power	324	324	324	324	324	324	324	324	324	324	324	323	323	323
San Jose Clean Energy	311	311	311	311	311	311	310	310	310	310	310	310	310	310
Silicon Valley Clean Energy	3	3	3	3	3	2	2	2	2	2	2	2	2	2
Silicon Valley Power	155	155	155	155	155	155	155	155	155	155	155	155	155	155
Sonoma Clean Power	76	76	76	76	76	76	76	75	75	75	75	75	75	75
Southern California Edison	263	263	263	263	263	263	263	263	263	263	263	263	263	263
Turlock Irrigation District	263	263	263	263	263	263	263	263	263	263	263	263	263	263
Valley Clean Energy	391	391	391	391	391	391	391	391	391	391	390	390	390	390
Western Community Energy	378	378	378	378	378	378	378	378	377	377	377	377	377	377
Statewide Average [2]	232	214	196	178	161	143	125	107	89	71	54	36	18	0

Sources: ICF calculations; California Utilities. 2021. Excel database of GHG emission factors for delivered electricity, provided to the Sacramento Metropolitan Air Quality Management District and ICF. January through March 2021; U.S. Environmental Protection Agency. 2021. Emissions & Generation Resource Integrated Database (eGRID). Last Revised: February 23, 2021. Available: https://www.epa.gov/egrid. Accessed: February 24, 2021.

lb = pounds; MWh = megawatt-hour; CO_2e = carbon dioxide equivalent

[1] All electricity providers gave an emission factor for at least one reported year. Emission factors for remaining years were calculated according to the following method, except where noted below.

- If an electricity provider gave data up until a year before 2045, all years between the last year of data given and 2045 were held constant at the values for the last year of data given. For example, Burbank Water & Power provided emission factors through 2030. Emission factors for years 2031 through 2045 were held constant at value provided for 2030.
- If electricity provider gave factors for CO_2, but not CH_4 or N_2O, statewide average emission factors for CH_4 and N_2O were assumed to calculate CO_2e emission factors for the utility.

Users should consult their local electricity provider for updated emission factors available at the time of their analysis before proceeding with the defaults provided in this table.

[2] CO_2, CH_4, and N_2O emission factors for 2019 obtained from USEPA eGRID2019. Future year emission factors were calculated based on the 2019 intensity factors divided by the percent of energy delivered from non-renewable sources in that same year (68%). The calculated non-renewable source emission factors were multiplied by the projected percentage of energy delivered from non-renewable sources in each future year. The percentages of energy delivered from renewable sources in future years is per the requirements of Senate Bill 100: 33% RPS by 2020, 44% RPS by 2024, 50% RPS by 2026, 52% RPS by 2027, 60% RPS by 2030, and 100% carbon-free electricity for 2045. Percentages for non-Senate Bill 100 target years were interpolated.

Table E-4.5. Natural Gas Emission Factors

Pollutant	Emission Factor by Land Use Type (lb/MMBtu)	
	Residential	Non-Residential
TOG	0.011	0.011
ROG	0.005	0.005
SO_2	0.001	0.001
NO_x[1]	0.092	0.098
PM10	0.007	0.007
PM2.5	0.007	0.007
CO	0.039	0.082
CO_2	116.977	117.647
CH_4	0.010	0.010
N_2O	0.000	0.002
CO_2e	117.325	118.549

Sources: U.S. Environmental Protection Agency. 1998. AP 42, Fifth Edition, Volume I. Chapter 1: External Combustion Sources. 1.4, Natural Gas Combustion. July. Available: https://www3.epa.gov/ttnchie1/ap42/ch01/final/c01s04.pdf. Accessed: January 2021.

U.S. Environmental Protection Agency. 2020. Emission Factors for Greenhouse Gas Inventories. March. Available: https://www.epa.gov/sites/production/files/2020-04/documents/ghg-emission-factors-hub.pdf. Accessed: March 2021.

TOG = total organic gases; ROG = reactive organic gases; CO = carbon monoxide; SO_2 = sulfur dioxide; NOx = nitrogen oxides; PM10 = particulate matter less than or equal to 10 microns; PM2.5 = particulate matter less than or equal to 2.5 microns; CO_2 = carbon dioxide; CH_4 = methane; N_2O = nitrous oxide; CO_2 = carbon dioxide equivalent; lb = pound; MMBtu = one million British Thermal Units

[1] Both BAAQMD Regulation 9 Rule 6 and SCAQMD Rule 1121 require that natural gas water heaters limit NO_x emissions to 10 nanograms per joule, which equates to 0.023 lb/MMBtu, lower than the generic value of 0.092 lb/MMBtu provided above. Users with a project in BAAQMD or SCAQMD territory that are calculating the NO_x reduction associated with Measure E-11, *Install Alternative Type of Water Heater in Place of Gas Storage Tank Heater in Residences*, should use the value of 0.023 lb/MMBtu.

Table E-5.1. Changes in Energy Use of Green Roof Compared to Dark Roof by Building Type and City[1]

Building Type	Electricity Savings (kWh/yr/KSF)[2]					Gas Savings (therm/yr/KSF)				
	Bakersfield	Fresno	Los Angeles	Sacramento	San Francisco	Bakersfield	Fresno	Los Angeles	Sacramento	San Francisco
Office[3]	106.9	122.9	36.9	126.7	62.9	0.1	0.2	0.0	0.2	0.0
Residential[4]	12.2	31.7	-14.6	37.6	-23.2	7.7	7.9	3.4	8.2	5.2

Source: Sailor, D., Brass, B., Peck, S. 2008. *Green Roof Energy Calculator*. Available: https://sustainability.asu.edu/urban-climate/green-roof-calculator/. Accessed: January 2021.

kWh = kilowatt-hour; KSF = thousand square feet; yr = year

[1] The Green Roof Energy calculator was run for the above building types and cities using conservative values for the remaining tool inputs: growing media depth (2 inches), leaf area index (0.5), irrigation (no), green roof coverage (50%), remaining roof material (dark). A "dark roof" is defined as having an albedo of 0.15.

[2] Negative electricity savings represent an increase in electricity use.

[3] The office building defined for the Green Roof Energy Calculator is a 3-story medium office building with a floor area of 53.6 KSF.

[4] The residential building defined for the Green Roof Energy Calculator is a 4-story midrise apartment complex with a floor area of 33.6 KSF.

Table E-7.1. Outdoor Lighting Power Consumption and Efficacy by Lamp Type[1]

Lamp Type	Typical Power Rating (W)	Source Efficacy (LPW)
High-pressure sodium	70-400	80-120
Low-pressure sodium	55-180	130-170
Ceramic metal halide	20-400	75-110
Metal halide	70-400	40-70
CFL	20-70	80-85
Linear fluorescent	25-32	80-100
Induction	70-250	50-85
LED	40-250	Up to 130

Source: California Lighting Technology Center. 2015. *2013 Title 24, Part 6 Outdoor Lighting Guide. University of California, Davis*. March. Available: https://cltc.ucdavis.edu/sites/default/files/files/publication/2013-title-24-outdoor-lighting-guide-mar15.pdf. Accessed: January 2021.

CFL = compact fluorescent lamp; LED = light emitting diode; LPW = lumens per watt; W = watts

[1] Values are based on lamp sizes typically used in outdoor applications. These numbers are subject to change as technologies improve. Source efficacy is based on initial lumen output; system efficacy depends on the specifications of the luminaires and ballasts or drivers employed. Some outdoor applications may be best served by products with characteristics that fall outside of the ranges listed in this table.

Table E-10-B.1. Estimated Electricity Generation from Typical PV Systems (kilowatt-hours per year)[1]

Air District	Major City	Zip Code	3 kW	5 kW	10 kW
Amador County	Ione	95640	4,696	7,827	15,655
Antelope Valley	Lancaster	93534	5,410	9,017	18,034
Bay Area	San Francisco	94163	4,646	7,744	9,292
Butte County	Chico	95926	4,514	7,524	9,028
Calaveras County	Rancho Calaveras	95252	4,714	7,857	9,428
Colusa County	Colusa	95932	4,641	7,735	9,282
El Dorado County	South Lake Tahoe	96150	5,181	8,635	10,362
Feather River	Yuba City	95991	4,637	7,729	9,274
Glenn County	Orland	95963	4,578	7,630	9,156
Great Basin Unified	Bishop	93514	5,462	9,104	10,924
Imperial County	El Centro	92243	5,191	8,652	10,382
Kern County	Bakersfield	93301	5,000	8,334	10,000
Lake County	Lakeport	95453	4,610	7,684	9,220
Lassen County	Susanville	96130	4,804	8,007	9,608

Table E-10-B.1. Estimated Electricity Generation from Typical PV Systems (kilowatt-hours per year) (cont.)[1]

Air District	Major City	Zip Code	3 kW	5 kW	10 kW
Mariposa County	Mariposa	95338	4,835	8,059	9,670
Mendocino County	Ukiah	95482	4,508	7,514	9,016
Modoc County	Alturas	96101	4,651	7,752	9,302
Mojave Desert	Victorville	92392	5,429	9,049	10,858
Monterey Bay	Monterey	93940	4,629	7,715	9,258
North Coast Unified	Eureka	95501	3,974	6,624	7,948
Northern Sierra	Grass Valley	95949	4,600	7,667	9,200
Northern Sonoma County	Healdsburg	95448	4,638	7,730	9,276
Placer County	Roseville	95678	4,608	7,680	9,216
Sacramento Metro	Sacramento	95864	4,713	7,855	9,426
San Diego County	San Diego	92182	4,999	8,332	9,998
San Joaquin Valley	Fresno	93650	4,819	8,032	9,638
San Luis Obispo County	San Luis Obispo	93405	4,993	8,322	9,986
Santa Barbara County	Santa Barbara	93101	4,923	8,205	9,846
Shasta County	Redding	96001	4,340	7,234	8,680
Siskiyou County	Yreka	96097	4,490	7,484	8,980
South Coast	Los Angeles	90071	4,984	8,307	9,968
Tehama County	Red Bluff	96080	4,513	7,522	9,026
Tuolumne County	Sonora	95370	4,827	8,045	9,654
Ventura County	Oxnard	93030	4,965	8,275	9,930
Yolo-Solano	Davis	95616	4,759	7,932	9,518

Source: National Renewable Energy Laboratory (NREL). 2017. *NREL's PVWatts® Calculator*. August. Available: https://pvwatts.nrel.gov/index.php. Accessed: January 2021.

kW = kilowatt; PV = photovoltaic

[1]Default inputs for system information were used to run the simulation.

Table E-12.1. Energy Consumption by Type of Water Heater, Electricity Demand Forecast Zone, and Housing Type

		Energy (Therm/yr/du for NG and kWh/yr/du for electricity)			
EDFZ[1]	Housing Type[2]	NG Storage Tank	Electric Storage Tank	Solar Water Heater w/ NG Backup[3]	Solar Water Heater w/ Electric Backup[3]
1	Single Family Housing	255	2,309	210	1,319
	Apartments Low Rise	236	1,249	—	—
	Apartments Mid Rise	234	1,139	—	—
	Apartments High Rise	234	1,139	—	—
	Condo/Townhouse	245	1,626	—	—
	Condo/Townhouse High Rise	234	1,139	—	—
	Mobile Home Park	245	2,761	—	—
	Retirement Community	236	1,249	—	—
	Congregate Care	234	1,139	—	—
2	Single Family Housing	279	2,381	180	1,400
	Apartments Low Rise	217	1,014	—	—
	Apartments Mid Rise	211	1,203	—	—
	Apartments High Rise	211	1,203	—	—
	Condo/Townhouse	238	1,280	—	—
	Condo/Townhouse High Rise	211	1,203	—	—
	Mobile Home Park	257	1,790	—	—
	Retirement Community	217	1,014	—	—
	Congregate Care	211	1,203	—	—
3	Single Family Housing	239	2,327	—	1,750
	Apartments Low Rise	218	836	—	—
	Apartments Mid Rise	188	917	—	—
	Apartments High Rise	188	917	—	—
	Condo/Townhouse	214	1,228	—	—
	Condo/Townhouse High Rise	188	917	—	—
	Mobile Home Park	223	2,349	—	—
	Retirement Community	218	836	—	—
	Congregate Care	188	917	—	—
4	Single Family Housing	248	2,502	187	1,238
	Apartments Low Rise	247	1,316	—	—
	Apartments Mid Rise	244	1,299	—	—
	Apartments High Rise	244	1,299	—	—
	Condo/Townhouse	250	1,308	—	—
	Condo/Townhouse High Rise	244	1,299	—	—
	Mobile Home Park	228	2,258	—	—
	Retirement Community	247	1,316	—	—
	Congregate Care	244	1,299	—	—

Table E-12.1. Energy Consumption by Type of Water Heater, Electricity Demand Forecast Zone, and Housing Type (cont.)

		Energy (Therm/yr/du for NG and kWh/yr/du for electricity)			
EDFZ[1]	Housing Type[2]	NG Storage Tank	Electric Storage Tank	Solar Water Heater w/ NG Backup[3]	Solar Water Heater w/ Electric Backup[3]
5	Single Family Housing	309	2,344	272	2,077
	Apartments Low Rise	365	—	—	—
	Apartments Mid Rise	356	1,521	—	—
	Apartments High Rise	356	1,521	—	—
	Condo/Townhouse	352	—	—	—
	Condo/Townhouse High Rise	356	1,521	—	—
	Mobile Home Park	290	1,749	—	—
	Retirement Community	365	—	—	—
	Congregate Care	356	1,521	—	—
6	Single Family Housing	265	2,373	203	1,750
	Apartments Low Rise	352	915	—	—
	Apartments Mid Rise	358	783	—	—
	Apartments High Rise	358	783	—	—
	Condo/Townhouse	352	1,995	—	904
	Condo/Townhouse High Rise	358	783	—	—
	Mobile Home Park	258	2,015	—	—
	Retirement Community	352	915	—	—
	Congregate Care	358	783	—	—
7	Single Family Housing	260	2,676	244	483
	Apartments Low Rise	246	1,238	181	—
	Apartments Mid Rise	245	1,148	—	—
	Apartments High Rise	245	1,148	—	—
	Condo/Townhouse	255	1,233	—	1,475
	Condo/Townhouse High Rise	245	1,148	—	—
	Mobile Home Park	251	2,046	174	—
	Retirement Community	246	1,238	181	—
	Congregate Care	245	1,148	—	—
8	Single Family Housing	272	1,935	213	—
	Apartments Low Rise	286	1,097	—	—
	Apartments Mid Rise	282	1,076	—	—
	Apartments High Rise	282	1,076	—	—
	Condo/Townhouse	273	1,057	—	—
	Condo/Townhouse High Rise	282	1,076	—	—
	Mobile Home Park	245	—	—	—
	Retirement Community	286	1,097	—	—
	Congregate Care	282	1,076	—	—

Table E-12.1. Energy Consumption by Type of Water Heater, Electricity Demand Forecast Zone, and Housing Type (cont.)

EDFZ[1]	Housing Type[2]	Energy (Therm/yr/du for NG and kWh/yr/du for electricity)			
		NG Storage Tank	Electric Storage Tank	Solar Water Heater w/ NG Backup[3]	Solar Water Heater w/ Electric Backup[3]
9	Single Family Housing	272	2,466	278	1,385
	Apartments Low Rise	265	898	—	—
	Apartments Mid Rise	266	1,512	—	—
	Apartments High Rise	266	1,512	—	—
	Condo/Townhouse	267	1,473	—	—
	Condo/Townhouse High Rise	266	1,512	—	—
	Mobile Home Park	262	3,008	—	—
	Retirement Community	265	898	—	—
	Congregate Care	266	1,512	—	—
10	Single Family Housing	231	2,091	199	739
	Apartments Low Rise	204	1,373	—	—
	Apartments Mid Rise	197	1,154	—	—
	Apartments High Rise	197	1,154	—	—
	Condo/Townhouse	210	1,143	—	—
	Condo/Townhouse High Rise	197	1,154	—	—
	Mobile Home Park	224	2,280	—	—
	Retirement Community	204	1,373	—	—
	Congregate Care	197	1,154	—	—
11	Single Family Housing	224	2,595	—	—
	Apartments Low Rise	172	1,297	—	—
	Apartments Mid Rise	194	1,366	—	—
	Apartments High Rise	194	1,366	—	—
	Condo/Townhouse	182	1,400	109	—
	Condo/Townhouse High Rise	194	1,366	—	—
	Mobile Home Park	218	2,055	—	—
	Retirement Community	172	1,297	—	—
	Congregate Care	194	1,366	—	—
12	Single Family Housing	210	2,156	174	1,332
	Apartments Low Rise	203	1,011	220	—
	Apartments Mid Rise	200	1,027	154	—
	Apartments High Rise	200	1,027	154	—
	Condo/Townhouse	204	1,310	164	—
	Condo/Townhouse High Rise	200	1,027	154	—
	Mobile Home Park	203	1,867	—	—
	Retirement Community	203	1,011	220	—
	Congregate Care	200	1,027	154	—

Table E-12.1. Energy Consumption by Type of Water Heater, Electricity Demand Forecast Zone, and Housing Type (cont.)

EDFZ[1]	Housing Type[2]	Energy (Therm/yr/du for NG and kWh/yr/du for electricity) NG Storage Tank	Electric Storage Tank	Solar Water Heater w/ NG Backup[3]	Solar Water Heater w/ Electric Backup[3]
13	Single Family Housing	241	2,803	179	1,479
	Apartments Low Rise	263	1,575	—	—
	Apartments Mid Rise	278	1,608	—	—
	Apartments High Rise	278	1,608	—	—
	Condo/Townhouse	256	1,790	—	—
	Condo/Townhouse High Rise	278	1,608	—	—
	Mobile Home Park	229	2,256	—	—
	Retirement Community	263	1,575	—	—
	Congregate Care	278	1,608	—	—
16	Single Family Housing	359	1,895	331	1,301
	Apartments Low Rise	286	1,640	—	—
	Apartments Mid Rise	267	932	—	—
	Apartments High Rise	267	932	—	—
	Condo/Townhouse	296	740	—	—
	Condo/Townhouse High Rise	267	932	—	—
	Mobile Home Park	319	—	—	—
	Retirement Community	286	1,640	—	—
	Congregate Care	267	932	—	—
17	Single Family Housing	290	2,734	232	—
	Apartments Low Rise	332	—	—	—
	Apartments Mid Rise	330	1,202	—	—
	Apartments High Rise	330	1,202	—	—
	Condo/Townhouse	348	1,664	229	—
	Condo/Townhouse High Rise	330	1,202	—	—
	Mobile Home Park	294	—	—	—
	Retirement Community	332	—	—	—
	Congregate Care	330	1,202	—	—
State	Single Family Housing	250	2,338	195	1,291
	Apartments Low Rise	238	1,215	220	—
	Apartments Mid Rise	245	1,131	—	—
	Apartments High Rise	245	1,131	—	—
	Condo/Townhouse	244	1,344	167	1,190
	Condo/Townhouse High Rise	245	1,131	—	—
	Mobile Home Park	232	2,120	174	—
	Retirement Community	238	1,215	220	—
	Congregate Care	245	1,131	—	—

Source: ICF calculations; California Energy Commission (CEC). 2020. Excel database with the 2019 Residential Appliance Saturation Study (RASS), provided to ICF. November 13, 2020.

EDFZ = Electricity Demand Forecast Zone; kWh = kilowatt-hour; NG = natural gas; yr = year; du = dwelling unit; — = no data

[1] Data for some EDFZ were not available in the RASS, and a representative EDFZ was assumed (refer to Table E-1.1).

[2] The five housing types used by the RASS have been cross walked to the nine residential land use types in CalEEMod, as shown in Table E-1.6.

[3] The sample size in the RASS for solar water heater data was limited. Accordingly, the data should be used with caution.

Table E-14.1. Woodstove and Fireplace Usage

		Wood Stoves							Fireplaces						
Housing	Air District	Convent-ional	Catalytic	Non-catalytic	Pellet	Wood Mass (lb/yr)	Hr/day	Days/yr	Wood	Natural Gas	Propane	None	Wood Mass (lb/yr)	Hr/day	Days/yr
M	Amador County APCD	0%	5%	5%	0%	3,019	3	82	35%	55%	0%	10%	3,078	3	82
M	Antelope Valley AQMD	0%	5%	5%	0%	3,019	3	82	35%	55%	0%	10%	3,078	3	82
M	Bay Area AQMD	0%	0%	0%	0%	0	0	0	0%	51%	0%	49%	0	4	9
M	Butte County AQMD	0%	9%	9%	0%	3,019	7	150	39%	43%	0%	18%	5,158	4	150
M	Calaveras County AQMD	0%	5%	5%	0%	3,019	3	82	35%	55%	0%	10%	3,078	3	82
M	Colusa County APCD	0%	5%	5%	0%	3,019	3	82	35%	55%	0%	10%	3,078	3	82
M	El Dorado County AQMD	0%	5%	5%	0%	3,019	3	82	35%	55%	0%	10%	3,078	3	82
M	Feather River AQMD	0%	5%	5%	0%	3,019	3	82	35%	55%	0%	10%	3,078	3	82
M	Glenn County APCD	0%	5%	5%	0%	3,019	3	82	35%	55%	0%	10%	3,078	3	82
M	Great Basin UAPCD	0%	5%	5%	0%	3,019	3	82	35%	55%	0%	10%	3,078	3	82
M	Imperial County APCD	0%	0%	0%	0%	0	0	0	0%	55%	0%	45%	2,080	3	4
M	Kern County APCD	0%	5%	5%	0%	3,019	3	82	35%	55%	0%	10%	3,078	3	82
M	Lake County AQMD	70%	15%	10%	5%	3,019	12	82	35%	0%	55%	10%	3,078	12	82
M	Lassen County APCD	0%	5%	5%	0%	3,019	3	82	35%	55%	0%	10%	3,078	3	82
M	Mariposa County APCD	0%	5%	5%	0%	3,019	3	82	35%	55%	0%	10%	3,078	3	82
M	Mendocino County AQMD	0%	20%	20%	0%	4,896	3	117	5%	5%	0%	90%	4,992	3	117
M	Modoc County APCD	0%	5%	5%	0%	3,019	3	82	35%	55%	0%	10%	3,078	3	82
M	Mojave Desert AQMD	0%	5%	5%	0%	3,019	3	82	35%	55%	0%	10%	3,078	3	82
M	Monterey Bay ARD	0%	0%	0%	0%	0	0	120	0%	100%	0%	0%	0	0	0
M	North Coast Unified APCD	0%	5%	5%	0%	3,019	3	82	35%	55%	0%	10%	3,078	3	82
M	Northern Sierra AQMD	0%	5%	5%	0%	3,019	3	82	35%	55%	0%	10%	3,078	3	82
M	Northern Sonoma County APCD	0%	5%	5%	0%	3,019	3	82	35%	55%	0%	10%	3,078	3	82
M	Placer County APCD	0%	0%	0%	0%	0	0	0	0%	30%	0%	70%	0	0	0
M	Sacramento Metropolitan AQMD	0%	0%	0%	0%	0	0	0	0%	0%	0%	100%	0	0	0
M	San Diego County APCD	0%	5%	5%	0%	3,019	3	82	35%	55%	0%	10%	3,078	3	82
M	San Joaquin Valley APCD	0%	5%	5%	0%	3,019	3	82	0%	50%	0%	50%	3,078	3	82
M	San Luis Obispo County APCD	0%	0%	0%	0%	2,016	8	60	0%	0%	0%	100%	0	0	0
M	Santa Barbara County APCD	0%	0%	0%	0%	1,400	3	82	0%	0%	0%	100%	417	3	82

Table E-14.1. Woodstove and Fireplace Usage (cont.)

		Wood Stoves							Fireplaces						
Housing	Air District	Conventional	Catalytic	Non-catalytic	Pellet	Wood Mass (lb/yr)	Hr/day	Days/yr	Wood	Natural Gas	Propane	None	Wood Mass (lb/yr)	Hr/day	Days/yr
M	Shasta County AQMD	0%	5%	5%	0%	3,019	3	82	35%	55%	0%	10%	3,078	3	82
M	Siskiyou County APCD	0%	5%	5%	0%	3,019	3	82	35%	55%	0%	10%	3,078	3	82
M	South Coast AQMD	0%	5%	5%	0%	1,000	3	25	5%	85%	0%	10%	1,019	3	25
M	Tehama County APCD	0%	30%	30%	0%	4,558	3	82	20%	20%	0%	60%	4,558	3	82
M	Tuolumne County APCD	0%	5%	5%	0%	3,019	3	82	35%	55%	0%	10%	3,078	3	82
M	Ventura County APCD	0%	0%	0%	0%	0	0	0	0%	0%	0%	100%	0	0	0
M	Yolo/Solano AQMD	0%	0%	0%	0%	0	0	0	0%	0%	0%	100%	0	0	0
M	Statewide	2%	5%	5%	0%	2,380	3	70	23%	44%	2%	31%	2,456	3	65
S	Amador County APCD	0%	5%	5%	0%	3,019	3	82	35%	55%	0%	10%	3,078	3	82
S	Antelope Valley AQMD	0%	5%	5%	0%	3,019	3	82	35%	55%	0%	10%	3,078	3	82
S	Bay Area AQMD	0%	0%	0%	0%	0	0	0	0%	51%	0%	49%	0	4	9
S	Butte County AQMD	0%	9%	9%	0%	3,019	7	150	39%	43%	0%	18%	5,158	4	150
S	Calaveras County AQMD	0%	5%	5%	0%	3,019	3	82	35%	55%	0%	10%	3,078	3	82
S	Colusa County APCD	0%	5%	5%	0%	3,019	3	82	35%	55%	0%	10%	3,078	3	82
S	El Dorado County AQMD	0%	5%	5%	0%	3,019	3	82	35%	55%	0%	10%	3,078	3	82
S	Feather River AQMD	0%	5%	5%	0%	3,019	3	82	35%	55%	0%	10%	3,078	3	82
S	Glenn County APCD	0%	5%	5%	0%	3,019	3	82	35%	55%	0%	10%	3,078	3	82
S	Great Basin UAPCD	0%	5%	5%	0%	3,019	3	82	35%	55%	0%	10%	3,078	3	82
S	Imperial County APCD	0%	0%	0%	0%	0	0	0	0%	55%	0%	45%	2,080	3	4
S	Kern County APCD	0%	5%	5%	0%	3,019	3	82	35%	55%	0%	10%	3,078	3	82
S	Lake County AQMD	70%	15%	10%	5%	3,019	12	82	35%	0%	55%	10%	3,078	12	82
S	Lassen County APCD	0%	5%	5%	0%	3,019	3	82	35%	55%	0%	10%	3,078	3	82
S	Mariposa County APCD	0%	5%	5%	0%	3,019	3	82	35%	55%	0%	10%	3,078	3	82
S	Mendocino County AQMD	0%	20%	20%	0%	4,896	3	117	5%	5%	0%	90%	4,992	3	117
S	Modoc County APCD	0%	5%	5%	0%	3,019	3	82	35%	55%	0%	10%	3,078	3	82
S	Mojave Desert AQMD	0%	5%	5%	0%	3,019	3	82	35%	55%	0%	10%	3,078	3	82
S	Monterey Bay ARD	0%	0%	0%	0%	0	0	120	0%	100%	0%	0%	0	0	0
S	North Coast Unified APCD	0%	5%	5%	0%	3,019	3	82	35%	55%	0%	10%	3,078	3	82

Table E-14.1. Woodstove and Fireplace Usage (cont.)

		Wood Stoves							Fireplaces						
Housing	Air District	Convent-ional	Catalytic	Non-catalytic	Pellet	Wood Mass (lb/yr)	Hr/day	Days/ yr	Wood	Natural Gas	Propane	None	Wood Mass (lb/yr)	Hr/day	Days/yr
S	Northern Sierra AQMD	0%	5%	5%	0%	3,019	3	82	35%	55%	0%	10%	3,078	3	82
S	Northern Sonoma County APCD	0%	5%	5%	0%	3,019	3	82	35%	55%	0%	10%	3,078	3	82
S	Placer County APCD	0%	0%	0%	0%	0	0	0	0%	30%	0%	70%	0	0	0
S	Sacramento Metropolitan AQMD	0%	0%	0%	0%	0	0	0	0%	0%	0%	100%	0	0	0
S	San Diego County APCD	0%	5%	5%	0%	3,019	3	82	35%	55%	0%	10%	3,078	3	82
S	San Joaquin Valley APCD	0%	5%	5%	0%	3,019	3	82	0%	50%	0%	50%	3,078	3	82
S	San Luis Obispo County APCD	0%	0%	0%	0%	2,016	8	60	0%	0%	0%	100%	0	0	0
S	Santa Barbara County APCD	0%	0%	0%	0%	1,400	3	82	0%	0%	0%	100%	417	3	82
S	Shasta County AQMD	0%	5%	5%	0%	3,019	3	82	35%	55%	0%	10%	3,078	3	82
S	Siskiyou County APCD	0%	5%	5%	0%	3,019	3	82	35%	55%	0%	10%	3,078	3	82
S	South Coast AQMD	0%	5%	5%	0%	1,000	3	25	5%	85%	0%	10%	1,019	3	25
S	Tehama County APCD	0%	30%	30%	0%	4,558	3	82	20%	20%	0%	60%	4,558	3	82
S	Tuolumne County APCD	0%	5%	5%	0%	3,019	3	82	35%	55%	0%	10%	3,078	3	82
S	Ventura County APCD	0%	0%	0%	0%	0	0	0	0%	0%	0%	100%	0	0	0
S	Yolo/Solano AQMD	0%	0%	0%	0%	0	0	0	0%	0%	0%	100%	0	0	0
S	Statewide	2%	5%	5%	0%	2,380	3	70	23%	44%	2%	31%	2,456	3	65

Source: California Air Districts. 2021. Excel database of hearth usage and inventory statistics, provided to the Sacramento Metropolitan Air Quality Management District and ICF. April 1, 2021.

M = multi-family housing; S = single-family housing; lb = pound; yr = year; hr = hour; APCD = air pollution control district; AQMD = air quality management district; ARD = air resources district

Table E-14.2. Woodstove and Fireplace Emission Factors (pound per ton of dry wood burned, unless noted)

Type	TOG	ROG	CO	SO_2	NO_x	PM10	PM2.5	CO_2 (BIO)	CO_2 (NBIO)	CH_4	N_2O	CO_2e
Woodstoves Conventional	83	53	230.8	0.4	2.8	30.6	29.5	2,952	0	30	0	3,792
Woodstoves Catalytic	26.6	15	104.4	0.4	2	20.44	19.6	2,952	0	11.6	0	3,277
Woodstoves Noncatalytic	28	12	140.8	0.4	2	14.6	14.1	2,952	0	16	0	3,400
Woodstoves Pellet	0.07	0.04	15.9	0.3	3.8	3.1	2.9	2,952	0	16	0	3,400
Wood Fireplace	229	229	252.6	0.4	2.6	34.6	34.6	3,400	0	0	0.3	3,480
Natural Gas Fireplace (lb/MMBtu)	0.0108	0.0054	0.0392	0.0006	0.0922	0.0075	0.0075	0	11	0.0022	0.0002	117.1
Propane Fireplace (lb/MMBtu)	0.0109	0.0109	0.0820	0.0000	0.1421	0.0077	0.0077	0	135	0.0066	0.0013	136.1

Sources: California Air Resources Board (CARB). 2011. *Section 7.1, Residential Wood Combustion.* Revised October 2015. Available: https://ww3.arb.ca.gov/ei/areasrc/fullpdf/full7-1_2011.pdf. Accessed: March 2021.

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TOG = total organic gases; ROG = reactive organic gases; CO = carbon monoxide; SO_2 = sulfur dioxide; NOx = nitrogen oxides; PM10 = particulate matter less than or equal to 10 microns; PM2.5 = particulate matter less than or equal to 10 microns; CO_2 = carbon dioxide; CH_4 = methane; N_2O = nitrous oxide; BIO = biogenic; NBIO = non-biogenic; lb = pound; MMBtu = one million British Thermal Units

Table E-15.1. Residential Energy Consumption by End Use,[1] Electricity Demand Forecast Zone, and Housing Type

Electricity Demand Forecast Zone[2]	Housing Type[3]	Natural Gas (Therm/yr/DU)									Electricity (kWh/yr/DU)									
		Water Heater	Primary Heat	Range/ Oven	Dryer	Misc.	Aux. Heat	Pool Heat	Spa Heat	Solar Water Heater w/ NG Backup	Water Heater	Primary Heat	Range/ Oven	Dryer	Misc.	Aux. Heat	Pool Heat	Spa Heat	Solar Water Heater w/ Elec. Backup	Heat Pump
	Single Family Housing	255	245	21	11	16	80	168	38	210	2,266	1,485	390	488	1,496	529	—	1,319	1,050	1,190
	Apartments Low Rise	235	93	17	18	16	54	196	—	—	1,282	923	275	389	761	174	—	—	—	732
	Apartments Mid Rise	232	65	14	14	25	52	167	—	—	1,146	757	246	334	563	165	—	—	—	593
	Apartments High Rise	232	65	14	14	25	52	167	—	—	1,146	757	246	334	563	165	—	—	—	593
1	Condo/Townhouse	242	103	19	17	16	53	142	29	—	1,580	1,075	329	387	965	160	—	—	1,163	755
	Condo/Townhouse High Rise	232	65	14	14	25	52	167	—	—	1,146	757	246	334	563	165	—	—	—	593
	Mobile Home Park	246	144	18	17	16	75	182	27	—	2,761	1,314	278	419	714	—	—	—	228	834
	Retirement Community	235	93	17	18	16	54	196	—	—	1,282	923	275	389	761	174	—	—	—	732
	Congregate Care	232	65	14	14	25	52	167	—	—	1,146	757	246	334	563	165	—	—	—	593
	Single Family Housing	278	289	20	12	20	109	202	47	180	2,445	2,073	379	553	1,572	827	—	1,400	1,394	1,564
	Apartments Low Rise	214	72	15	15	—	62	217	—	—	1,003	877	252	475	496	169	—	—	—	1,089
	Apartments Mid Rise	208	56	12	13	14	67	—	—	—	1,226	1,082	172	337	405	269	—	—	—	630
	Apartments High Rise	208	56	12	13	14	67	—	—	—	1,226	1,082	172	337	405	269	—	—	—	630
2	Condo/Townhouse	234	108	13	15	15	78	—	—	—	1,216	1,204	241	424	771	238	—	—	1,290	1,063
	Condo/Townhouse High Rise	208	56	12	13	14	67	—	—	—	1,226	1,082	172	337	405	269	—	—	—	630
	Mobile Home Park	259	227	15	15	—	96	200	—	—	1,790	1,324	208	504	895	—	—	—	633	1,142
	Retirement Community	214	72	15	15	—	62	217	—	—	1,003	877	252	475	496	169	—	—	—	1,089
	Congregate Care	208	56	12	13	14	67	—	—	—	1,226	1,082	172	337	405	269	—	—	—	630
	Single Family Housing	237	183	19	12	16	73	93	31	—	2,353	1,592	328	565	1,374	774	—	1,750	1,260	1,414
	Apartments Low Rise	215	55	21	13	—	—	—	—	—	836	670	115	541	647	160	—	—	—	707
	Apartments Mid Rise	181	37	15	14	14	—	—	—	—	917	667	247	543	529	—	—	—	—	736
	Apartments High Rise	181	37	15	14	14	—	—	—	—	917	667	247	543	529	—	—	—	—	736
3	Condo/Townhouse	221	72	5	21	16	—	—	—	—	1,228	2,158	295	494	776	504	—	—	—	706
	Condo/Townhouse High Rise	181	37	15	14	14	—	—	—	—	917	667	247	543	529	—	—	—	—	736
	Mobile Home Park	228	122	11	15	—	77	178	25	—	2,271	1,451	250	554	812	579	—	—	727	1,104
	Retirement Community	215	55	21	13	—	—	—	—	—	836	670	115	541	647	160	—	—	—	707
	Congregate Care	181	37	15	14	14	—	—	—	—	917	667	247	543	529	—	—	—	—	736

Table E-15.1. Residential Energy Consumption by End Use,[1] Electricity Demand Forecast Zone, and Housing Type (cont.)

Electricity Demand Forecast Zone[2]	Housing Type[3]	Natural Gas (Therm/yr/DU)									Electricity (kWh/yr/DU)									
		Water Heater	Primary Heat	Range/ Oven	Dryer	Misc.	Aux. Heat	Pool Heat	Spa Heat	Solar Water Heater w/ NG Backup	Water Heater	Primary Heat	Range/ Oven	Dryer	Misc.	Aux. Heat	Pool Heat	Spa Heat	Solar Water Heater w/ Elec. Backup	Heat Pump
	Single Family Housing	246	241	20	11	17	83	140	33	187	2,528	1,953	358	565	1,607	756	—	1,238	1,162	1,603
	Apartments Low Rise	239	68	13	15	17	53	205	—	—	1,545	1,205	294	494	621	222	—	—	—	756
	Apartments Mid Rise	244	61	12	15	17	54	197	—	—	1,543	1,062	240	406	601	183	—	—	—	1,014
	Apartments High Rise	244	61	12	15	17	54	197	—	—	1,543	1,062	240	406	601	183	—	—	—	1,014
4	Condo/Townhouse	250	87	23	17	17	—	—	37	—	1,308	956	306	462	891	193	—	—	3	718
	Condo/Townhouse High Rise	244	61	12	15	17	54	197	—	—	1,543	1,062	240	406	601	183	—	—	—	1,014
	Mobile Home Park	230	171	16	14	194	—	179	—	—	2,237	1,344	289	488	933	720	—	—	1,331	1,509
	Retirement Community	239	68	13	15	17	53	205	—	—	1,545	1,205	294	494	621	222	—	—	—	756
	Congregate Care	244	61	12	15	17	54	197	—	—	1,543	1,062	240	406	601	183	—	—	—	1,014
	Single Family Housing	307	244	30	15	20	80	161	46	272	2,419	1,690	362	586	1,517	548	—	2,077	1,076	1,230
	Apartments Low Rise	355	105	35	23	24	75	309	—	—	738	624	273	517	640	121	—	—	—	424
	Apartments Mid Rise	364	99	25	22	25	66	290	—	—	1,479	682	262	405	595	199	—	—	—	557
	Apartments High Rise	364	99	25	22	25	66	290	—	—	1,479	682	262	405	595	199	—	—	—	557
5	Condo/Townhouse	349	92	24	29	25	65	222	32	—	—	622	378	488	733	—	—	—	—	610
	Condo/Townhouse High Rise	364	99	25	22	25	66	290	—	—	1,479	682	262	405	595	199	—	—	—	557
	Mobile Home Park	289	205	24	18	20	66	225	56	—	1,749	922	176	499	871	386	—	—	127	1,580
	Retirement Community	355	105	35	23	24	75	309	—	—	738	624	273	517	640	121	—	—	—	424
	Congregate Care	364	99	25	22	25	66	290	—	—	1,479	682	262	405	595	199	—	—	—	557
	Single Family Housing	264	254	21	12	17	89	186	46	203	2,444	1,848	346	523	1,388	674	—	1,750	1,249	1,584
	Apartments Low Rise	348	107	32	25	21	97	319	—	—	941	1,548	245	402	430	215	—	—	—	563
	Apartments Mid Rise	368	111	29	22	24	113	299	—	—	818	969	200	312	434	181	—	—	—	525
	Apartments High Rise	368	111	29	22	24	113	299	—	—	818	969	200	312	434	181	—	—	—	525
6	Condo/Townhouse	353	131	25	25	23	69	229	—	—	1,995	1,267	277	385	689	243	—	904	766	776
	Condo/Townhouse High Rise	368	111	29	22	24	113	299	—	—	818	969	200	312	434	181	—	—	—	525
	Mobile Home Park	251	244	17	18	115	—	—	—	—	2,015	1,565	185	390	908	525	—	—	991	—
	Retirement Community	348	107	32	25	21	97	319	—	—	941	1,548	245	402	430	215	—	—	—	563
	Congregate Care	368	111	29	22	24	113	299	—	—	818	969	200	312	434	181	—	—	—	525

Table E-15.1. Residential Energy Consumption by End Use,[1] Electricity Demand Forecast Zone, and Housing Type (cont.)

Electricity Demand Forecast Zone[2]	Housing Type[3]	Natural Gas (Therm/yr/DU)									Electricity (kWh/yr/DU)									
		Water Heater	Primary Heat	Range/ Oven	Dryer	Misc.	Aux. Heat	Pool Heat	Spa Heat	Solar Water Heater w/ NG Backup	Water Heater	Primary Heat	Range/ Oven	Dryer	Misc.	Aux. Heat	Pool Heat	Spa Heat	Solar Water Heater w/ Elec. Backup	Heat Pump
	Single Family Housing	260	136	24	12	17	39	168	36	244	2,810	972	411	528	1,552	375	—	483	993	713
	Apartments Low Rise	246	43	23	17	37	25	200	—	181	1,185	538	293	441	665	92	—	—	—	330
	Apartments Mid Rise	244	42	19	17	17	27	188	—	—	1,164	451	243	360	594	99	—	—	—	392
	Apartments High Rise	244	42	19	17	17	27	188	—	—	1,164	451	243	360	594	99	—	—	—	392
7	Condo/Townhouse	253	57	21	19	17	30	148	31	—	1,365	609	292	422	953	125	—	1,475	405	413
	Condo/Townhouse High Rise	244	42	19	17	17	27	188	—	—	1,164	451	243	360	594	99	—	—	—	392
	Mobile Home Park	250	115	17	16	17	30	—	—	174	2,046	806	172	416	786	—	—	—	17	211
	Retirement Community	246	43	23	17	37	25	200	—	181	1,185	538	293	441	665	92	—	—	—	330
	Congregate Care	244	42	19	17	17	27	188	—	—	1,164	451	243	360	594	99	—	—	—	392
	Single Family Housing	273	173	22	12	17	51	188	41	213	2,014	1,052	383	515	1,483	486	—	—	1,044	702
	Apartments Low Rise	284	56	29	19	17	52	—	—	—	1,130	524	271	387	735	112	—	—	—	586
	Apartments Mid Rise	278	54	15	18	101	48	217	—	—	1,090	582	226	311	522	68	—	—	—	355
	Apartments High Rise	278	54	15	18	101	48	217	—	—	1,090	582	226	311	522	68	—	—	—	355
8	Condo/Townhouse	269	78	20	20	18	31	176	26	—	1,049	768	268	487	890	121	—	—	—	831
	Condo/Townhouse High Rise	278	54	15	18	101	48	217	—	—	1,090	582	226	311	522	68	—	—	—	355
	Mobile Home Park	243	121	15	16	—	51	—	—	—	—	—	154	361	670	—	—	—	—	325
	Retirement Community	284	56	29	19	17	52	—	—	—	1,130	524	271	387	735	112	—	—	—	586
	Congregate Care	278	54	15	18	101	48	217	—	—	1,090	582	226	311	522	68	—	—	—	355
	Single Family Housing	268	222	23	14	17	90	144	32	278	2,434	1,765	372	614	1,517	699	—	1,385	1,172	1,646
	Apartments Low Rise	272	63	24	23	—	—	—	—	—	898	529	314	529	630	—	—	—	—	376
	Apartments Mid Rise	267	65	9	16	—	—	—	—	—	1,354	923	280	417	629	390	—	—	—	998
	Apartments High Rise	267	65	9	16	—	—	—	—	—	1,354	923	280	417	629	390	—	—	—	998
9	Condo/Townhouse	263	77	16	17	19	54	—	—	—	1,473	1,209	303	483	689	—	—	—	1,030	527
	Condo/Townhouse High Rise	267	65	9	16	—	—	—	—	—	1,354	923	280	417	629	390	—	—	—	998
	Mobile Home Park	262	207	22	17	17	—	—	106	—	2,667	1,037	281	564	976	—	—	—	446	1,276
	Retirement Community	272	63	24	23	—	—	—	—	—	898	529	314	529	630	—	—	—	—	376
	Congregate Care	267	65	9	16	—	—	—	—	—	1,354	923	280	417	629	390	—	—	—	998

Table E-15.1. Residential Energy Consumption by End Use,[1] Electricity Demand Forecast Zone, and Housing Type (cont.)

Electricity Demand Forecast Zone[2]	Housing Type[3]	Natural Gas (Therm/yr/DU)									Electricity (kWh/yr/DU)									
		Water Heater	Primary Heat	Range/ Oven	Dryer	Misc.	Aux. Heat	Pool Heat	Spa Heat	Solar Water Heater w/ NG Backup	Water Heater	Primary Heat	Range/ Oven	Dryer	Misc.	Aux. Heat	Pool Heat	Spa Heat	Solar Water Heater w/ Elec. Backup	Heat Pump
	Single Family Housing	231	136	22	12	15	39	152	32	199	2,120	982	386	546	1,391	129	—	739	1,025	823
	Apartments Low Rise	203	34	17	14	14	23	170	—	—	1,529	813	389	431	612	160	—	—	—	515
	Apartments Mid Rise	197	37	16	14	14	36	—	—	—	1,138	678	280	375	598	99	—	—	—	477
	Apartments High Rise	197	37	16	14	14	36	—	—	—	1,138	678	280	375	598	99	—	—	—	477
10	Condo/Townhouse	211	48	18	14	14	27	157	22	—	1,143	987	320	392	832	—	—	—	—	807
	Condo/Townhouse High Rise	197	37	16	14	14	36	—	—	—	1,138	678	280	375	598	99	—	—	—	477
	Mobile Home Park	224	113	12	15	—	—	—	—	—	2,280	580	310	415	750	—	—	—	—	—
	Retirement Community	203	34	17	14	14	23	170	—	—	1,529	813	389	431	612	160	—	—	—	515
	Congregate Care	197	37	16	14	14	36	—	—	—	1,138	678	280	375	598	99	—	—	—	477
	Single Family Housing	222	152	21	10	15	45	146	33	—	2,647	1,389	422	559	1,709	143	—	—	916	1,045
	Apartments Low Rise	175	46	14	16	15	32	195	—	—	1,297	612	280	480	962	—	—	—	—	408
	Apartments Mid Rise	198	36	13	14	15	25	184	—	—	1,366	512	296	437	832	70	—	—	—	397
	Apartments High Rise	198	36	13	14	15	25	184	—	—	1,366	512	296	437	832	70	—	—	—	397
11	Condo/Townhouse	182	51	14	14	15	19	94	43	109	1,261	828	354	506	1,181	198	—	—	—	1,009
	Condo/Townhouse High Rise	198	36	13	14	15	25	184	—	—	1,366	512	296	437	832	70	—	—	—	397
	Mobile Home Park	217	114	15	15	15	—	168	23	—	2,055	999	215	456	956	161	—	—	528	495
	Retirement Community	175	46	14	16	15	32	195	—	—	1,297	612	280	480	962	—	—	—	—	408
	Congregate Care	198	36	13	14	15	25	184	—	—	1,366	512	296	437	832	70	—	—	—	397
	Single Family Housing	210	118	17	10	14	36	122	31	174	2,235	933	375	498	1,442	252	—	1,332	985	778
	Apartments Low Rise	199	39	17	14	14	24	163	—	220	1,002	405	246	420	622	97	—	—	—	337
	Apartments Mid Rise	198	38	12	13	14	22	170	—	154	1,134	410	228	352	524	88	—	—	—	346
	Apartments High Rise	198	38	12	13	14	22	170	—	154	1,134	410	228	352	524	88	—	—	—	346
12	Condo/Townhouse	202	51	15	14	14	25	—	28	164	1,321	556	283	398	869	114	—	—	1,067	378
	Condo/Townhouse High Rise	198	38	12	13	14	22	170	—	154	1,134	410	228	352	524	88	—	—	—	346
	Mobile Home Park	201	100	14	14	14	43	156	22	—	1,867	1,011	211	432	840	—	—	—	1,785	680
	Retirement Community	199	39	17	14	14	24	163	—	220	1,002	405	246	420	622	97	—	—	—	337
	Congregate Care	198	38	12	13	14	22	170	—	154	1,134	410	228	352	524	88	—	—	—	346

Table E-15.1. Residential Energy Consumption by End Use,[1] Electricity Demand Forecast Zone, and Housing Type (cont.)

		Natural Gas (Therm/yr/DU)									Electricity (kWh/yr/DU)									
Electricity Demand Forecast Zone[2]	Housing Type[3]	Water Heater	Primary Heat	Range/ Oven	Dryer	Misc.	Aux. Heat	Pool Heat	Spa Heat	Solar Water Heater w/ NG Backup	Water Heater	Primary Heat	Range/ Oven	Dryer	Misc.	Aux. Heat	Pool Heat	Spa Heat	Solar Water Heater w/ Elec. Backup	Heat Pump
13	Single Family Housing	240	232	18	11	15	77	123	31	179	2,845	1,877	407	617	1,753	767	—	1,479	1,245	1,501
	Apartments Low Rise	260	66	16	20	15	53	212	—	—	1,589	1,117	253	544	673	202	—	—	—	1,002
	Apartments Mid Rise	277	65	18	18	20	57	—	—	—	1,584	979	246	457	654	205	—	—	—	870
	Apartments High Rise	277	65	18	18	20	57	—	—	—	1,584	979	246	457	654	205	—	—	—	870
	Condo/Townhouse	253	90	18	17	18	63	172	29	—	1,726	1,456	314	514	1,000	230	—	—	1,620	1,279
	Condo/Townhouse High Rise	277	65	18	18	20	57	—	—	—	1,584	979	246	457	654	205	—	—	—	870
	Mobile Home Park	229	186	11	13	15	—	171	—	—	2,256	—	145	517	932	—	—	—	655	685
	Retirement Community	260	66	16	20	15	53	212	—	—	1,589	1,117	253	544	673	202	—	—	—	1,002
	Congregate Care	277	65	18	18	20	57	—	—	—	1,584	979	246	457	654	205	—	—	—	870
16	Single Family Housing	363	196	31	16	26	53	247	61	331	2,509	1,062	400	512	1,603	—	—	1,301	1,047	787
	Apartments Low Rise	285	58	25	21	19	29	—	—	—	1,640	521	311	619	740	—	—	—	—	861
	Apartments Mid Rise	268	48	20	17	35	31	239	—	—	1,052	350	262	365	560	—	—	—	—	397
	Apartments High Rise	268	48	20	17	35	31	239	—	—	1,052	350	262	365	560	—	—	—	—	397
	Condo/Townhouse	297	74	25	19	20	29	169	31	—	968	658	369	441	916	—	—	—	35	361
	Condo/Townhouse High Rise	268	48	20	17	35	31	239	—	—	1,052	350	262	365	560	—	—	—	—	397
	Mobile Home Park	301	118	16	22	—	—	—	—	—	—	—	—	457	693	—	—	—	—	—
	Retirement Community	285	58	25	21	19	29	—	—	—	1,640	521	311	619	740	—	—	—	—	861
	Congregate Care	268	48	20	17	35	31	239	—	—	1,052	350	262	365	560	—	—	—	—	397
17	Single Family Housing	290	153	27	13	21	46	172	37	232	2,529	783	407	556	1,513	—	—	—	1,144	845
	Apartments Low Rise	325	63	29	22	—	—	—	—	—	—	983	332	440	558	—	—	—	—	260
	Apartments Mid Rise	328	57	30	29	24	40	244	—	—	1,182	457	266	343	586	—	—	—	—	290
	Apartments High Rise	328	57	30	29	24	40	244	—	—	1,182	457	266	343	586	—	—	—	—	290
	Condo/Townhouse	345	85	33	24	23	42	—	38	229	1,815	864	361	441	984	—	—	—	—	569
	Condo/Townhouse High Rise	328	57	30	29	24	40	244	—	—	1,182	457	266	343	586	—	—	—	—	290
	Mobile Home Park	294	121	32	16	—	—	—	—	—	—	—	256	—	710	—	—	—	—	—
	Retirement Community	325	63	29	22	—	—	—	—	—	—	983	332	440	558	—	—	—	—	260
	Congregate Care	328	57	30	29	24	40	244	—	—	1,182	457	266	343	586	—	—	—	—	290

Table E-15.1. Residential Energy Consumption by End Use,[1] Electricity Demand Forecast Zone, and Housing Type (cont.)

Electricity Demand Forecast Zone[2]	Housing Type[3]	Natural Gas (Therm/yr/DU)									Electricity (kWh/yr/DU)									
		Water Heater	Primary Heat	Range/ Oven	Dryer	Misc.	Aux. Heat	Pool Heat	Spa Heat	Solar Water Heater w/ NG Backup	Water Heater	Primary Heat	Range/ Oven	Dryer	Misc.	Aux. Heat	Pool Heat	Spa Heat	Solar Water Heater w/ Elec. Backup	Heat Pump
Statewide	Single Family Housing	254	191	22	12	17	64	162	36	210	2,473	1,507	384	544	1,535	663	—	1,395	1,114	1,198
	Apartments Low Rise	244	65	21	17	20	43	216	—	201	1,220	751	275	439	678	132	—	—	—	561
	Apartments Mid Rise	248	54	18	17	22	38	201	—	154	1,195	619	241	360	568	136	—	—	—	490
	Apartments High Rise	248	54	18	17	22	38	201	—	154	1,195	619	241	360	568	136	—	—	—	490
	Condo/Townhouse	247	79	20	18	17	41	167	31	167	1,402	888	305	424	915	191	—	1,190	912	704
	Condo/Townhouse High Rise	248	54	18	17	22	38	201	—	154	1,195	619	241	360	568	136	—	—	—	490
	Mobile Home Park	238	148	16	16	32	58	181	38	174	2,136	1,208	228	486	864	530	—	—	763	1,000
	Retirement Community	244	65	21	17	20	43	216	—	201	1,220	751	275	439	678	132	—	—	—	561
	Congregate Care	248	54	18	17	22	38	201	—	154	1,195	619	241	360	568	136	—	—	—	490

Source: ICF calculations; California Energy Commission. 2020. Excel database with the 2019 Residential Appliance Saturation Study (RASS), provided to ICF. November 13, 2020.

EDFZ = Electricity Demand Forecast Zone; yr = year; du = dwelling unit; kWh = kilowatt-hour; — = no data

[1] The sample size in the RASS data for several end uses and housing types was limited. Accordingly, the data should be used with caution.

[2] Data for some EDFZ were not available in the RASS, and a representative EDFZ was assumed (refer to Table E-1.1).

[3] The five housing types used by the RASS have been cross walked to the nine residential land use types in CalEEMod, as shown in Table E-1.6.

Table E-15.2. Commercial Energy Consumption by End Use,[1] Electricity Demand Forecast Zone, and Building Type

Building Type	EDFZ[1]	Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)					
		Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.
Arena		42	136	1	6	252	—	52	40	6	1,033	5,703	162
Automobile Care Center		42	136	1	6	252	—	52	40	6	1,033	5,703	162
Bank (with Drive-Through)		42	136	1	6	252	—	52	40	6	1,033	5,703	162
Convenience Market (24 hour)		16	184	1	7	63	—	253	606	84	2,466	19,227	12,001
Convenience Market with Gas Pumps		16	184	1	7	63	—	253	606	84	2,466	19,227	12,001
Day-Care Center		13	393	4	<1	—	—	427	77	34	105	430	124
Discount Club		<1	53	<1	2	1	—	35	118	9	413	1,811	135
Electronic Superstore		<1	53	<1	2	1	—	35	118	9	413	1,811	135
Elementary School		13	393	4	<1	—	—	427	77	34	105	430	124
Fast Food Restaurant w/o Drive Thru		137	90	1,031	8	84	—	93	804	5,459	3,211	17,827	5,732
Fast Food Restaurant with Drive Thru	1	137	90	1,031	8	84	—	93	804	5,459	3,211	17,827	5,732
Free-Standing Discount store		<1	53	<1	2	1	—	35	118	9	413	1,811	135
Free-Standing Discount Superstore		<1	53	<1	2	1	—	35	118	9	413	1,811	135
Gasoline/Service Station		42	136	1	6	252	—	52	40	6	1,033	5,703	162
General Heavy Industry		42	136	1	6	252	—	52	40	6	1,033	5,703	162
General Light Industry		42	136	1	6	252	—	52	40	6	1,033	5,703	162
General Office Building		1	168	<1	18	50	—	82	385	28	2,934	5,800	14
Government (Civic Center)		1	168	<1	18	50	—	82	385	28	2,934	5,800	14
Government Office Building		1	168	<1	18	50	—	82	385	28	2,934	5,800	14
Hardware/Paint Store		<1	53	<1	2	1	—	35	118	9	413	1,811	135
Health Club		42	136	1	6	252	—	52	40	6	1,033	5,703	162
High School		13	393	4	<1	—	—	427	77	34	105	430	124

Building Type	EDFZ[1]	Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)					
		Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.
Arena		42	131	1	7	245	—	51	49	11	1,058	5,551	159
Automobile Care Center		42	131	1	7	245	—	51	49	11	1,058	5,551	159
Bank (with Drive-Through)		42	131	1	7	245	—	51	49	11	1,058	5,551	159
Convenience Market (24 hour)		15	207	1	5	61	—	259	702	81	3,436	18,605	11,745
Convenience Market with Gas Pumps		15	207	1	5	61	—	259	702	81	3,436	18,605	11,745
Day-Care Center		12	422	4	<1	—	—	449	75	34	126	430	125
Discount Club		<1	61	<1	2	1	—	35	132	9	450	1,756	132
Electronic Superstore		<1	61	<1	2	1	—	35	132	9	450	1,756	132
Elementary School		12	422	4	<1	—	—	449	75	34	126	430	125
Fast Food Restaurant w/o Drive Thru		129	131	974	12	80	—	82	1,171	5,156	3,825	16,835	5,416
Fast Food Restaurant with Drive Thru	2	129	131	974	12	80	—	82	1,171	5,156	3,825	16,835	5,416
Free-Standing Discount store		<1	61	<1	2	1	—	35	132	9	450	1,756	132
Free-Standing Discount Superstore		<1	61	<1	2	1	—	35	132	9	450	1,756	132
Gasoline/Service Station		42	131	1	7	245	—	51	49	11	1,058	5,551	159
General Heavy Industry		42	131	1	7	245	—	51	49	11	1,058	5,551	159
General Light Industry		42	131	1	7	245	—	51	49	11	1,058	5,551	159
General Office Building		1	169	<1	14	49	—	83	438	27	3,089	5,714	14
Government (Civic Center)		1	169	<1	14	49	—	83	438	27	3,089	5,714	14
Government Office Building		1	169	<1	14	49	—	83	438	27	3,089	5,714	14
Hardware/Paint Store		<1	61	<1	2	1	—	35	132	9	450	1,756	132
Health Club		42	131	1	7	245	—	51	49	11	1,058	5,551	159
High School		12	422	4	<1	—	—	449	75	34	126	430	125

Table E-15.2. Commercial Energy Consumption by End Use,[1] Electricity Demand Forecast Zone, and Building Type (cont.)

		Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)							Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)					
Building Type	EDFZ[1]	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	EDFZ[1]	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.
High Turnover (Sit Down Restaurant)		137	90	1,031	8	84	—	93	804	5,459	3,211	17,827	5,732		129	131	974	12	80	—	82	1,171	5,156	3,825	16,835	5,416
Home Improvement Superstore		<1	53	<1	2	1	—	35	118	9	413	1,811	135		<1	61	<1	2	1	—	35	132	9	450	1,756	132
Hospital		284	260	9	7	177	—	13	3	101	6,250	19,922	135		282	284	9	7	175	—	14	2	100	7,043	19,727	134
Hotel		67	190	14	10	20	—	52	183	20	477	2,847	264		67	179	13	11	18	—	54	210	20	455	2,798	263
Industrial Park		1	168	<1	18	50	—	82	385	28	2,934	5,800	14		1	169	<1	14	49	—	83	438	27	3,089	5,714	14
Junior College (2yr)		9	366	1	5	14	—	117	190	18	1,082	596	18		9	353	1	5	14	—	117	202	18	1,087	596	18
Junior High School		13	393	4	<1	—	—	427	77	34	105	430	124		12	422	4	<1	—	—	449	75	34	126	430	125
Library		42	136	1	6	252	—	52	40	6	1,033	5,703	162		42	131	1	7	245	—	51	49	11	1,058	5,551	159
Manufacturing		42	136	1	6	252	—	52	40	6	1,033	5,703	162		42	131	1	7	245	—	51	49	11	1,058	5,551	159
Medical Office Building		1	168	<1	18	50	—	82	385	28	2,934	5,800	14		1	169	<1	14	49	—	83	438	27	3,089	5,714	14
Motel		67	190	14	10	20	—	52	183	20	477	2,847	264		67	179	13	11	18	—	54	210	20	455	2,798	263
Movie Theater (No Matinee)		42	136	1	6	252	—	52	40	6	1,033	5,703	162		42	131	1	7	245	—	51	49	11	1,058	5,551	159
Office Park		1	168	<1	18	50	—	82	385	28	2,934	5,800	14		1	169	<1	14	49	—	83	438	27	3,089	5,714	14
Pharmacy/Drugstore w/o Drive Thru		<1	53	<1	2	1	—	35	118	9	413	1,811	135		<1	61	<1	2	1	—	35	132	9	450	1,756	132
Pharmacy/Drugstore with Drive Thru		<1	53	<1	2	1	—	35	118	9	413	1,811	135		<1	61	<1	2	1	—	35	132	9	450	1,756	132
Place of Worship		42	136	1	6	252	—	52	40	6	1,033	5,703	162		42	131	1	7	245	—	51	49	11	1,058	5,551	159
Quality Restaurant		137	90	1,031	8	84	—	93	804	5,459	3,211	17,827	5,732		129	131	974	12	80	—	82	1,171	5,156	3,825	16,835	5,416
Racquet Club		42	136	1	6	252	—	52	40	6	1,033	5,703	162		42	131	1	7	245	—	51	49	11	1,058	5,551	159
Refrigerated Warehouse-No Rail		<1	4	<1	—	8	7	6	14	<1	28	6,364	14,769		<1	5	<1	—	8	7	6	16	<1	48	6,253	14,673
Refrigerated Warehouse-Rail		<1	4	<1	—	8	7	6	14	<1	28	6,364	14,769		<1	5	<1	—	8	7	6	16	<1	48	6,253	14,673
Regional Shopping Center		<1	53	<1	2	1	—	35	118	9	413	1,811	135		<1	61	<1	2	1	—	35	132	9	450	1,756	132
Research & Development		1	168	<1	18	50	—	82	385	28	2,934	5,800	14		1	169	<1	14	49	—	83	438	27	3,089	5,714	14

Table E-15.2. Commercial Energy Consumption by End Use,[1] Electricity Demand Forecast Zone, and Building Type (cont.)

Building Type	EDFZ[1]	Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)						EDFZ[1]	Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)					
		Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.		Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.
Strip Mall		<1	53	<1	2	1	—	35	118	9	413	1,811	135		<1	61	<1	2	1	—	35	132	9	450	1,756	132
Supermarket		16	184	1	7	63	—	253	606	84	2,466	19,227	12,001		15	207	1	5	61	—	259	702	81	3,436	18,605	11,745
University/College (4yr)		9	366	1	5	14	—	117	190	18	1,082	596	18		9	353	1	5	14	—	117	202	18	1,087	596	18
Unrefrigerated Warehouse-No Rail		<1	42	<1	2	8	—	2	286	<1	383	6,354	—		<1	49	<1	3	8	—	2	351	<1	657	6,222	—
Unrefrigerated Warehouse-Rail		<1	42	<1	2	8	—	2	286	<1	383	6,354	—		<1	49	<1	3	8	—	2	351	<1	657	6,222	—
Arena		31	130	1	4	244	—	193	264	15	2,550	5,569	161		36	130	1	5	244	—	136	171	9	1,147	5,555	160
Automobile Care Center		31	130	1	4	244	—	193	264	15	2,550	5,569	161		36	130	1	5	244	—	136	171	9	1,147	5,555	160
Bank (with Drive-Through)		31	130	1	4	244	—	193	264	15	2,550	5,569	161		36	130	1	5	244	—	136	171	9	1,147	5,555	160
Convenience Market (24 hour)		21	188	1	24	61	42	118	237	80	9,140	18,400	11,925		19	191	1	8	60	25	179	385	79	3,650	18,247	12,001
Convenience Market with Gas Pumps		21	188	1	24	61	42	118	237	80	9,140	18,400	11,925		19	191	1	8	60	25	179	385	79	3,650	18,247	12,001
Day-Care Center		23	425	4	1	—	—	179	72	34	236	429	130		19	409	4	<1	<1	—	291	63	34	143	429	130
Discount Club		1	93	<1	2	1	—	14	416	9	1,972	1,732	132		16	68	<1	2	1	—	23	248	9	816	1,719	131
Electronic Superstore		1	93	<1	2	1	—	14	416	9	1,972	1,732	132		16	68	<1	2	1	—	23	248	9	816	1,719	131
Elementary School	3	23	425	4	1	—	—	179	72	34	236	429	130	4	19	409	4	<1	<1	—	291	63	34	143	429	130
Fast Food Restaurant w/o Drive Thru		114	174	928	1	76	—	263	338	4,918	6,231	16,105	5,303		115	145	883	3	72	—	174	603	4,684	3,282	15,344	5,074
Fast Food Restaurant with Drive Thru		114	174	928	1	76	—	263	338	4,918	6,231	16,105	5,303		115	145	883	3	72	—	174	603	4,684	3,282	15,344	5,074
Free-Standing Discount store		1	93	<1	2	1	—	14	416	9	1,972	1,732	132		16	68	<1	2	1	—	23	248	9	816	1,719	131
Free-Standing Discount Superstore		1	93	<1	2	1	—	14	416	9	1,972	1,732	132		16	68	<1	2	1	—	23	248	9	816	1,719	131
Gasoline/Service Station		31	130	1	4	244	—	193	264	15	2,550	5,569	161		36	130	1	5	244	—	136	171	9	1,147	5,555	160
General Heavy Industry		31	130	1	4	244	—	193	264	15	2,550	5,569	161		36	130	1	5	244	—	136	171	9	1,147	5,555	160
General Light Industry		31	130	1	4	244	—	193	264	15	2,550	5,569	161		36	130	1	5	244	—	136	171	9	1,147	5,555	160
General Office Building		1	291	<1	50	49	—	15	146	27	4,926	5,646	13		1	219	<1	20	48	—	50	292	27	3,207	5,605	13

Table E-15.2. Commercial Energy Consumption by End Use,[1] Electricity Demand Forecast Zone, and Building Type (cont.)

		Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)							Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)					
Building Type	EDFZ[1]	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	EDFZ[1]	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.
Government (Civic Center)		1	291	<1	50	49	—	15	146	27	4,926	5,646	13		1	219	<1	20	48	—	50	292	27	3,207	5,605	13
Government Office Building		1	291	<1	50	49	—	15	146	27	4,926	5,646	13		1	219	<1	20	48	—	50	292	27	3,207	5,605	13
Hardware/Paint Store		1	93	<1	2	1	—	14	416	9	1,972	1,732	132		16	68	<1	2	1	—	23	248	9	816	1,719	131
Health Club		31	130	1	4	244	—	193	264	15	2,550	5,569	161		36	130	1	5	244	—	136	171	9	1,147	5,555	160
High School		23	425	4	1	—	—	179	72	34	236	429	130		19	409	4	<1	<1	—	291	63	34	143	429	130
High Turnover (Sit Down Restaurant)		114	174	928	1	76	—	263	338	4,918	6,231	16,105	5,303		115	145	883	3	72	—	174	603	4,684	3,282	15,344	5,074
Home Improvement Superstore		1	93	<1	2	1	—	14	416	9	1,972	1,732	132		16	68	<1	2	1	—	23	248	9	816	1,719	131
Hospital		217	228	9	<1	174	—	226	152	99	9,658	19,656	136		239	240	9	3	172	—	153	79	98	7,115	19,508	135
Hotel		86	243	13	2	16	—	5	106	20	614	2,769	260		78	212	9	4	16	—	102	143	20	323	2,743	260
Industrial Park		1	291	<1	50	49	—	15	146	27	4,926	5,646	13		1	219	<1	20	48	—	50	292	27	3,207	5,605	13
Junior College (2yr)		11	92	1	7	14	—	46	57	18	1,444	596	18		10	319	<1	7	14	—	70	123	18	1,214	596	18
Junior High School		23	425	4	1	—	—	179	72	34	236	429	130		19	409	4	<1	<1	—	291	63	34	143	429	130
Library		31	130	1	4	244	—	193	264	15	2,550	5,569	161		36	130	1	5	244	—	136	171	9	1,147	5,555	160
Manufacturing		31	130	1	4	244	—	193	264	15	2,550	5,569	161		36	130	1	5	244	—	136	171	9	1,147	5,555	160
Medical Office Building		1	291	<1	50	49	—	15	146	27	4,926	5,646	13		1	219	<1	20	48	—	50	292	27	3,207	5,605	13
Motel		86	243	13	2	16	—	5	106	20	614	2,769	260		78	212	9	4	16	—	102	143	20	323	2,743	260
Movie Theater (No Matinee)		31	130	1	4	244	—	193	264	15	2,550	5,569	161		36	130	1	5	244	—	136	171	9	1,147	5,555	160
Office Park		1	291	<1	50	49	—	15	146	27	4,926	5,646	13		1	219	<1	20	48	—	50	292	27	3,207	5,605	13
Pharmacy/Drugstore w/o Drive Thru		1	93	<1	2	1	—	14	416	9	1,972	1,732	132		16	68	<1	2	1	—	23	248	9	816	1,719	131
Pharmacy/Drugstore with Drive Thru		1	93	<1	2	1	—	14	416	9	1,972	1,732	132		16	68	<1	2	1	—	23	248	9	816	1,719	131
Place of Worship		31	130	1	4	244	—	193	264	15	2,550	5,569	161		36	130	1	5	244	—	136	171	9	1,147	5,555	160
Quality Restaurant		114	174	928	1	76	—	263	338	4,918	6,231	16,105	5,303		115	145	883	3	72	—	174	603	4,684	3,282	15,344	5,074
Racquet Club		31	130	1	4	244	—	193	264	15	2,550	5,569	161		36	130	1	5	244	—	136	171	9	1,147	5,555	160

Table E-15.2. Commercial Energy Consumption by End Use,[1] Electricity Demand Forecast Zone, and Building Type (cont.)

Building Type	EDFZ[1]	Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)					
		Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.
Refrigerated Warehouse-No Rail		<1	13	<1	7	8	7	7	16	<1	76	6,225	14,860
Refrigerated Warehouse-Rail		<1	13	<1	7	8	7	7	16	<1	76	6,225	14,860
Regional Shopping Center		1	93	<1	2	1	—	14	416	9	1,972	1,732	132
Research & Development		1	291	<1	50	49	—	15	146	27	4,926	5,646	13
Strip Mall		1	93	<1	2	1	—	14	416	9	1,972	1,732	132
Supermarket		21	188	1	24	61	42	118	237	80	9,140	18,400	11,925
University/College (4yr)		11	92	1	7	14	—	46	57	18	1,444	596	18
Unrefrigerated Warehouse-No Rail		<1	35	<1	8	8	—	3	375	<1	646	6,236	—
Unrefrigerated Warehouse-Rail		<1	35	<1	8	8	—	3	375	<1	646	6,236	—
Arena	5	31	130	1	5	244	—	200	256	15	2,674	5,573	161
Automobile Care Center	5	31	130	1	5	244	—	200	256	15	2,674	5,573	161
Bank (with Drive-Through)	5	31	130	1	5	244	—	200	256	15	2,674	5,573	161
Convenience Market (24 hour)	5	21	180	1	25	61	45	110	204	80	9,488	18,433	11,954
Convenience Market with Gas Pumps	5	21	180	1	25	61	45	110	204	80	9,488	18,433	11,954
Day-Care Center	5	24	423	4	1	—	—	163	70	34	236	429	130
Discount Club	5	1	94	<1	2	1	—	13	425	9	2,095	1,735	132
Electronic Superstore	5	1	94	<1	2	1	—	13	425	9	2,095	1,735	132
Elementary School	5	24	423	4	1	—	—	163	70	34	236	429	130
Fast Food Restaurant w/o Drive Thru	5	113	164	900	—	74	—	257	258	4,776	6,342	15,654	5,197
Fast Food Restaurant with Drive Thru	5	113	164	900	—	74	—	257	258	4,776	6,342	15,654	5,197
Free-Standing Discount store	5	1	94	<1	2	1	—	13	425	9	2,095	1,735	132

Building Type	EDFZ[1]	Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)					
		Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.
Refrigerated Warehouse-No Rail		<1	7	<1	1	34	7	7	17	<1	51	6,563	15,631
Refrigerated Warehouse-Rail		<1	7	<1	1	34	7	7	17	<1	51	6,563	15,631
Regional Shopping Center		16	68	<1	2	1	—	23	248	9	816	1,719	131
Research & Development		1	219	<1	20	48	—	50	292	27	3,207	5,605	13
Strip Mall		16	68	<1	2	1	—	23	248	9	816	1,719	131
Supermarket		19	191	1	8	60	25	179	385	79	3,650	18,247	12,001
University/College (4yr)		10	319	<1	7	14	—	70	123	18	1,214	596	18
Unrefrigerated Warehouse-No Rail		<1	43	<1	4	8	—	3	447	<1	414	6,610	—
Unrefrigerated Warehouse-Rail		<1	43	<1	4	8	—	3	447	<1	414	6,610	—
Arena	6	42	126	1	7	246	—	51	40	11	1,069	5,564	160
Automobile Care Center	6	42	126	1	7	246	—	51	40	11	1,069	5,564	160
Bank (with Drive-Through)	6	42	126	1	7	246	—	51	40	11	1,069	5,564	160
Convenience Market (24 hour)	6	15	164	1	6	61	—	259	542	80	3,356	18,439	11,678
Convenience Market with Gas Pumps	6	15	164	1	6	61	—	259	542	80	3,356	18,439	11,678
Day-Care Center	6	12	394	4	<1	—	—	447	72	34	116	430	125
Discount Club	6	<1	56	<1	2	1	—	35	119	9	493	1,736	130
Electronic Superstore	6	<1	56	<1	2	1	—	35	119	9	493	1,736	130
Elementary School	6	12	394	4	<1	—	—	447	72	34	116	430	125
Fast Food Restaurant w/o Drive Thru	6	129	88	933	12	76	—	85	790	4,944	4,072	16,186	5,317
Fast Food Restaurant with Drive Thru	6	129	88	933	12	76	—	85	790	4,944	4,072	16,186	5,317
Free-Standing Discount store	6	<1	56	<1	2	1	—	35	119	9	493	1,736	130

Table E-15.2. Commercial Energy Consumption by End Use,[1] Electricity Demand Forecast Zone, and Building Type (cont.)

Building Type	EDFZ[1]	Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)						EDFZ[1]	Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)					
		Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.		Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.
Free-Standing Discount Superstore		1	94	<1	2	1	—	13	425	9	2,095	1,735	132		<1	56	<1	2	1	—	35	119	9	493	1,736	130
Gasoline/Service Station		31	130	1	5	244	—	200	256	15	2,674	5,573	161		42	126	1	7	246	—	51	40	11	1,069	5,564	160
General Heavy Industry		31	130	1	5	244	—	200	256	15	2,674	5,573	161		42	126	1	7	246	—	51	40	11	1,069	5,564	160
General Light Industry		31	130	1	5	244	—	200	256	15	2,674	5,573	161		42	126	1	7	246	—	51	40	11	1,069	5,564	160
General Office Building		1	297	<1	52	49	—	12	129	27	5,059	5,660	13		1	162	<1	14	49	—	83	422	27	3,128	5,653	14
Government (Civic Center)		1	297	<1	52	49	—	12	129	27	5,059	5,660	13		1	162	<1	14	49	—	83	422	27	3,128	5,653	14
Government Office Building		1	297	<1	52	49	—	12	129	27	5,059	5,660	13		1	162	<1	14	49	—	83	422	27	3,128	5,653	14
Hardware/Paint Store		1	94	<1	2	1	—	13	425	9	2,095	1,735	132		<1	56	<1	2	1	—	35	119	9	493	1,736	130
Health Club		31	130	1	5	244	—	200	256	15	2,674	5,573	161		42	126	1	7	246	—	51	40	11	1,069	5,564	160
High School		24	423	4	1	—	—	163	70	34	236	429	130		12	394	4	<1	—	—	447	72	34	116	430	125
High Turnover (Sit Down Restaurant)		113	164	900	—	74	—	257	258	4,776	6,342	15,654	5,197		129	88	933	12	76	—	85	790	4,944	4,072	16,186	5,317
Home Improvement Superstore		1	94	<1	2	1	—	13	425	9	2,095	1,735	132		<1	56	<1	2	1	—	35	119	9	493	1,736	130
Hospital		215	219	9	—	174	—	237	153	99	9,901	19,677	136		284	228	9	7	174	—	14	2	99	7,567	19,644	135
Hotel		87	240	13	<1	16	—	2	94	20	622	2,770	260		68	149	13	11	17	—	55	165	20	416	2,762	262
Industrial Park		1	297	<1	52	49	—	12	129	27	5,059	5,660	13		1	162	<1	14	49	—	83	422	27	3,128	5,653	14
Junior College (2yr)		11	74	1	7	14	—	43	48	18	1,446	597	18		9	329	1	5	14	—	120	178	18	1,026	596	18
Junior High School		24	423	4	1	—	—	163	70	34	236	429	130		12	394	4	<1	—	—	447	72	34	116	430	125
Library		31	130	1	5	244	—	200	256	15	2,674	5,573	161		42	126	1	7	246	—	51	40	11	1,069	5,564	160
Manufacturing		31	130	1	5	244	—	200	256	15	2,674	5,573	161		42	126	1	7	246	—	51	40	11	1,069	5,564	160
Medical Office Building		1	297	<1	52	49	—	12	129	27	5,059	5,660	13		1	162	<1	14	49	—	83	422	27	3,128	5,653	14
Motel		87	240	13	<1	16	—	2	94	20	622	2,770	260		68	149	13	11	17	—	55	165	20	416	2,762	262
Movie Theater (No Matinee)		31	130	1	5	244	—	200	256	15	2,674	5,573	161		42	126	1	7	246	—	51	40	11	1,069	5,564	160
Office Park		1	297	<1	52	49	—	12	129	27	5,059	5,660	13		1	162	<1	14	49	—	83	422	27	3,128	5,653	14

Table E-15.2. Commercial Energy Consumption by End Use,[1] Electricity Demand Forecast Zone, and Building Type (cont.)

Building Type	EDFZ[1]	Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)						EDFZ[1]	Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)					
		Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.		Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.
Pharmacy/Drugstore w/o Drive Thru		1	94	<1	2	1	—	13	425	9	2,095	1,735	132		<1	56	<1	2	1	—	35	119	9	493	1,736	130
Pharmacy/Drugstore with Drive Thru		1	94	<1	2	1	—	13	425	9	2,095	1,735	132		<1	56	<1	2	1	—	35	119	9	493	1,736	130
Place of Worship		31	130	1	5	244	—	200	256	15	2,674	5,573	161		42	126	1	7	246	—	51	40	11	1,069	5,564	160
Quality Restaurant		113	164	900	—	74	—	257	258	4,776	6,342	15,654	5,197		129	88	933	12	76	—	85	790	4,944	4,072	16,186	5,317
Racquet Club		31	130	1	5	244	—	200	256	15	2,674	5,573	161		42	126	1	7	246	—	51	40	11	1,069	5,564	160
Refrigerated Warehouse-No Rail		<1	14	<1	8	8	8	7	16	—	79	6,563	15,671		<1	5	<1	—	8	8	7	16	<1	49	6,563	15,373
Refrigerated Warehouse-Rail		<1	14	<1	8	8	8	7	16	—	79	6,563	15,671		<1	5	<1	—	8	8	7	16	<1	49	6,563	15,373
Regional Shopping Center		1	94	<1	2	1	—	13	425	9	2,095	1,735	132		<1	56	<1	2	1	—	35	119	9	493	1,736	130
Research & Development		1	297	<1	52	49	—	12	129	27	5,059	5,660	13		1	162	<1	14	49	—	83	422	27	3,128	5,653	14
Strip Mall		1	94	<1	2	1	—	13	425	9	2,095	1,735	132		<1	56	<1	2	1	—	35	119	9	493	1,736	130
Supermarket		21	180	1	25	61	45	110	204	80	9,488	18,433	11,954		15	164	1	6	61	—	259	542	80	3,356	18,439	11,678
University/College (4yr)		11	74	1	7	14	—	43	48	18	1,446	597	18		9	329	1	5	14	—	120	178	18	1,026	596	18
Unrefrigerated Warehouse-No Rail		<1	36	<1	8	8	—	3	383	<1	662	6,562	—		1	48	<1	3	8	—	2	347	<1	709	6,562	—
Unrefrigerated Warehouse-Rail		<1	36	<1	8	8	—	3	383	<1	662	6,562	—		1	48	<1	3	8	—	2	347	<1	709	6,562	—
Arena	7	29	89	3	43	263	1	94	490	15	2,363	909	50	8	28	92	3	38	265	1	85	490	15	2,209	812	50
Automobile Care Center		29	89	3	43	263	1	94	490	15	2,363	909	50		28	92	3	38	265	1	85	490	15	2,209	812	50
Bank (with Drive-Through)		29	89	3	43	263	1	94	490	15	2,363	909	50		28	92	3	38	265	1	85	490	15	2,209	812	50
Convenience Market (24 hour)		6	23	5	2	132	1	32	290	43	417	1,849	18,389		5	22	5	2	133	—	31	263	42	290	1,830	18,451
Convenience Market with Gas Pumps		6	23	5	2	132	1	32	290	43	417	1,849	18,389		5	22	5	2	133	—	31	263	42	290	1,830	18,451
Day-Care Center		16	81	1	9	102	—	58	95	55	856	384	88		16	85	1	10	102	—	51	97	55	824	381	86
Discount Club		2	6	<1	7	41	4	33	60	35	1,262	1,287	216		1	6	<1	7	42	4	32	59	35	1,193	1,281	213

Table E-15.2. Commercial Energy Consumption by End Use,[1] Electricity Demand Forecast Zone, and Building Type (cont.)

Building Type	EDFZ[1]	Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)						EDFZ[1]	Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)					
		Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.		Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.
Electronic Superstore		2	6	<1	7	41	4	33	60	35	1,262	1,287	216		1	6	<1	7	42	4	32	59	35	1,193	1,281	213
Elementary School		16	81	1	9	102	—	58	95	55	856	384	88		16	85	1	10	102	—	51	97	55	824	381	86
Fast Food Restaurant w/o Drive Thru		116	46	855	49	81	5	46	386	1,841	3,427	5,399	8,281		113	45	857	48	82	5	44	379	1,750	3,246	5,352	8,150
Fast Food Restaurant with Drive Thru		116	46	855	49	81	5	46	386	1,841	3,427	5,399	8,281		113	45	857	48	82	5	44	379	1,750	3,246	5,352	8,150
Free-Standing Discount store		2	6	<1	7	41	4	33	60	35	1,262	1,287	216		1	6	<1	7	42	4	32	59	35	1,193	1,281	213
Free-Standing Discount Superstore		2	6	<1	7	41	4	33	60	35	1,262	1,287	216		1	6	<1	7	42	4	32	59	35	1,193	1,281	213
Gasoline/Service Station		29	89	3	43	263	1	94	490	15	2,363	909	50		28	92	3	38	265	1	85	490	15	2,209	812	50
General Heavy Industry		29	89	3	43	263	1	94	490	15	2,363	909	50		28	92	3	38	265	1	85	490	15	2,209	812	50
General Light Industry		29	89	3	43	263	1	94	490	15	2,363	909	50		28	92	3	38	265	1	85	490	15	2,209	812	50
General Office Building		27	150	1	23	52	<1	71	594	13	3,699	2,381	16		26	163	1	23	52	<1	70	630	12	3,661	2,352	14
Government (Civic Center)		27	150	1	23	52	<1	71	594	13	3,699	2,381	16		26	163	1	23	52	<1	70	630	12	3,661	2,352	14
Government Office Building		27	150	1	23	52	<1	71	594	13	3,699	2,381	16		26	163	1	23	52	<1	70	630	12	3,661	2,352	14
Hardware/Paint Store		2	6	<1	7	41	4	33	60	35	1,262	1,287	216		1	6	<1	7	42	4	32	59	35	1,193	1,281	213
Health Club		29	89	3	43	263	1	94	490	15	2,363	909	50		28	92	3	38	265	1	85	490	15	2,209	812	50
High School		16	81	1	9	102	—	58	95	55	856	384	88		16	85	1	10	102	—	51	97	55	824	381	86
High Turnover (Sit Down Restaurant)		116	46	855	49	81	5	46	386	1,841	3,427	5,399	8,281		113	45	857	48	82	5	44	379	1,750	3,246	5,352	8,150
Home Improvement Superstore		2	6	<1	7	41	4	33	60	35	1,262	1,287	216		1	6	<1	7	42	4	32	59	35	1,193	1,281	213
Hospital		188	156	9	13	180	<1	414	802	98	7,640	8,052	330		183	163	9	16	181	—	354	796	98	7,290	8,043	322
Hotel		75	72	25	—	117	—	199	3,830	70	2,663	1,838	1,172		74	76	25	—	117	—	199	3,890	69	2,602	1,832	1,167
Industrial Park		27	150	1	23	52	<1	71	594	13	3,699	2,381	16		26	163	1	23	52	<1	70	630	12	3,661	2,352	14
Junior College (2yr)		51	360	1	11	75	<1	353	1,078	70	2,488	1,462	403		49	361	1	11	75	—	333	996	69	2,178	1,444	387
Junior High School		16	81	1	9	102	—	58	95	55	856	384	88		16	85	1	10	102	—	51	97	55	824	381	86
Library		29	89	3	43	263	1	94	490	15	2,363	909	50		28	92	3	38	265	1	85	490	15	2,209	812	50

Table E-15.2. Commercial Energy Consumption by End Use,[1] Electricity Demand Forecast Zone, and Building Type (cont.)

Building Type	EDFZ[1]	Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)						EDFZ[1]	Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)					
		Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.		Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.
Manufacturing		29	89	3	43	263	1	94	490	15	2,363	909	50		28	92	3	38	265	1	85	490	15	2,209	812	50
Medical Office Building		27	150	1	23	52	<1	71	594	13	3,699	2,381	16		26	163	1	23	52	<1	70	630	12	3,661	2,352	14
Motel		75	72	25	—	117	—	199	3,830	70	2,663	1,838	1,172		74	76	25	—	117	—	199	3,890	69	2,602	1,832	1,167
Movie Theater (No Matinee)		29	89	3	43	263	1	94	490	15	2,363	909	50		28	92	3	38	265	1	85	490	15	2,209	812	50
Office Park		27	150	1	23	52	<1	71	594	13	3,699	2,381	16		26	163	1	23	52	<1	70	630	12	3,661	2,352	14
Pharmacy/Drugstore w/o Drive Thru		2	6	<1	7	41	4	33	60	35	1,262	1,287	216		1	6	<1	7	42	4	32	59	35	1,193	1,281	213
Pharmacy/Drugstore with Drive Thru		2	6	<1	7	41	4	33	60	35	1,262	1,287	216		1	6	<1	7	42	4	32	59	35	1,193	1,281	213
Place of Worship		29	89	3	43	263	1	94	490	15	2,363	909	50		28	92	3	38	265	1	85	490	15	2,209	812	50
Quality Restaurant		116	46	855	49	81	5	46	386	1,841	3,427	5,399	8,281		113	45	857	48	82	5	44	379	1,750	3,246	5,352	8,150
Racquet Club		29	89	3	43	263	1	94	490	15	2,363	909	50		28	92	3	38	265	1	85	490	15	2,209	812	50
Refrigerated Warehouse-No Rail		3	1	<1	—	186	61	9	1	<1	84	1,664	15,484		3	1	<1	—	186	56	9	1	<1	77	1,656	14,520
Refrigerated Warehouse-Rail		3	1	<1	—	186	61	9	1	<1	84	1,664	15,484		3	1	<1	—	186	56	9	1	<1	77	1,656	14,520
Regional Shopping Center		2	6	<1	7	41	4	33	60	35	1,262	1,287	216		1	6	<1	7	42	4	32	59	35	1,193	1,281	213
Research & Development		27	150	1	23	52	<1	71	594	13	3,699	2,381	16		26	163	1	23	52	<1	70	630	12	3,661	2,352	14
Strip Mall		2	6	<1	7	41	4	33	60	35	1,262	1,287	216		1	6	<1	7	42	4	32	59	35	1,193	1,281	213
Supermarket		6	23	5	2	132	1	32	290	43	417	1,849	18,389		5	22	5	2	133	—	31	263	42	290	1,830	18,451
University/College (4yr)		51	360	1	11	75	<1	353	1,078	70	2,488	1,462	403		49	361	1	11	75	—	333	996	69	2,178	1,444	387
Unrefrigerated Warehouse-No Rail		4	2	<1	1	185	—	9	26	<1	128	1,251	—		4	2	<1	2	186	—	9	25	<1	118	1,242	—
Unrefrigerated Warehouse-Rail		4	2	<1	1	185	—	9	26	<1	128	1,251	—		4	2	<1	2	186	—	9	25	<1	118	1,242	—
Arena		34	103	2	49	260	1	128	503	15	2,870	1,226	76		36	76	3	54	259	1	118	404	15	2,491	913	54
Automobile Care Center	9	34	103	2	49	260	1	128	503	15	2,870	1,226	76	10	36	76	3	54	259	1	118	404	15	2,491	913	54
Bank (with Drive-Through)		34	103	2	49	260	1	128	503	15	2,870	1,226	76		36	76	3	54	259	1	118	404	15	2,491	913	54

Table E-15.2. Commercial Energy Consumption by End Use,[1] Electricity Demand Forecast Zone, and Building Type (cont.)

		Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)							Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)					
Building Type	EDFZ[1]	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	EDFZ[1]	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.
Convenience Market (24 hour)		7	37	5	6	126	5	36	395	47	1,460	2,628	17,583		7	22	5	5	130	<1	32	286	42	909	1,989	18,138
Convenience Market with Gas Pumps		7	37	5	6	126	5	36	395	47	1,460	2,628	17,583		7	22	5	5	130	<1	32	286	42	909	1,989	18,138
Day-Care Center		17	152	2	7	91	—	89	191	55	1,062	391	99		16	118	1	6	99	—	102	145	55	1,052	418	100
Discount Club		2	7	<1	10	38	3	35	72	33	1,839	1,304	211		2	3	<1	10	41	4	40	35	35	1,589	1,313	218
Electronic Superstore		2	7	<1	10	38	3	35	72	33	1,839	1,304	211		2	3	<1	10	41	4	40	35	35	1,589	1,313	218
Elementary School		17	152	2	7	91	—	89	191	55	1,062	391	99		16	118	1	6	99	—	102	145	55	1,052	418	100
Fast Food Restaurant w/o Drive Thru		129	75	866	39	81	5	63	559	2,665	4,172	6,421	8,407		128	46	839	44	80	5	40	415	2,243	3,460	5,538	9,070
Fast Food Restaurant with Drive Thru		129	75	866	39	81	5	63	559	2,665	4,172	6,421	8,407		128	46	839	44	80	5	40	415	2,243	3,460	5,538	9,070
Free-Standing Discount store		2	7	<1	10	38	3	35	72	33	1,839	1,304	211		2	3	<1	10	41	4	40	35	35	1,589	1,313	218
Free-Standing Discount Superstore		2	7	<1	10	38	3	35	72	33	1,839	1,304	211		2	3	<1	10	41	4	40	35	35	1,589	1,313	218
Gasoline/Service Station		34	103	2	49	260	1	128	503	15	2,870	1,226	76		36	76	3	54	259	1	118	404	15	2,491	913	54
General Heavy Industry		34	103	2	49	260	1	128	503	15	2,870	1,226	76		36	76	3	54	259	1	118	404	15	2,491	913	54
General Light Industry		34	103	2	49	260	1	128	503	15	2,870	1,226	76		36	76	3	54	259	1	118	404	15	2,491	913	54
General Office Building		25	258	1	30	52	<1	64	838	15	4,239	2,482	15		28	168	1	25	52	<1	86	731	12	3,604	2,406	15
Government (Civic Center)		25	258	1	30	52	<1	64	838	15	4,239	2,482	15		28	168	1	25	52	<1	86	731	12	3,604	2,406	15
Government Office Building		25	258	1	30	52	<1	64	838	15	4,239	2,482	15		28	168	1	25	52	<1	86	731	12	3,604	2,406	15
Hardware/Paint Store		2	7	<1	10	38	3	35	72	33	1,839	1,304	211		2	3	<1	10	41	4	40	35	35	1,589	1,313	218
Health Club		34	103	2	49	260	1	128	503	15	2,870	1,226	76		36	76	3	54	259	1	118	404	15	2,491	913	54
High School		17	152	2	7	91	—	89	191	55	1,062	391	99		16	118	1	6	99	—	102	145	55	1,052	418	100
High Turnover (Sit Down Restaurant)		129	75	866	39	81	5	63	559	2,665	4,172	6,421	8,407		128	46	839	44	80	5	40	415	2,243	3,460	5,538	9,070
Home Improvement Superstore		2	7	<1	10	38	3	35	72	33	1,839	1,304	211		2	3	<1	10	41	4	40	35	35	1,589	1,313	218
Hospital		206	218	9	4	178	—	593	1,051	101	8,315	9,011	306		197	215	9	6	179	—	507	1,232	98	7,844	8,108	347

Table E-15.2. Commercial Energy Consumption by End Use,[1] Electricity Demand Forecast Zone, and Building Type (cont.)

Building Type	EDFZ[1]	Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)						EDFZ[1]	Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)					
		Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.		Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.
Hotel		79	102	23	<1	98	—	160	4,156	69	2,953	1,759	1,035		78	82	24	<1	115	—	232	5,338	69	3,299	1,844	1,213
Industrial Park		25	258	1	30	52	<1	64	838	15	4,239	2,482	15		28	168	1	25	52	<1	86	731	12	3,604	2,406	15
Junior College (2yr)		45	328	1	15	58	—	350	1,034	63	2,367	1,230	315		52	416	1	17	73	—	536	1,650	68	2,286	1,516	422
Junior High School		17	152	2	7	91	—	89	191	55	1,062	391	99		16	118	1	6	99	—	102	145	55	1,052	418	100
Library		34	103	2	49	260	1	128	503	15	2,870	1,226	76		36	76	3	54	259	1	118	404	15	2,491	913	54
Manufacturing		34	103	2	49	260	1	128	503	15	2,870	1,226	76		36	76	3	54	259	1	118	404	15	2,491	913	54
Medical Office Building		25	258	1	30	52	<1	64	838	15	4,239	2,482	15		28	168	1	25	52	<1	86	731	12	3,604	2,406	15
Motel		79	102	23	<1	98	—	160	4,156	69	2,953	1,759	1,035		78	82	24	<1	115	—	232	5,338	69	3,299	1,844	1,213
Movie Theater (No Matinee)		34	103	2	49	260	1	128	503	15	2,870	1,226	76		36	76	3	54	259	1	118	404	15	2,491	913	54
Office Park		25	258	1	30	52	<1	64	838	15	4,239	2,482	15		28	168	1	25	52	<1	86	731	12	3,604	2,406	15
Pharmacy/Drugstore w/o Drive Thru		2	7	<1	10	38	3	35	72	33	1,839	1,304	211		2	3	<1	10	41	4	40	35	35	1,589	1,313	218
Pharmacy/Drugstore with Drive Thru		2	7	<1	10	38	3	35	72	33	1,839	1,304	211		2	3	<1	10	41	4	40	35	35	1,589	1,313	218
Place of Worship		34	103	2	49	260	1	128	503	15	2,870	1,226	76		36	76	3	54	259	1	118	404	15	2,491	913	54
Quality Restaurant		129	75	866	39	81	5	63	559	2,665	4,172	6,421	8,407		128	46	839	44	80	5	40	415	2,243	3,460	5,538	9,070
Racquet Club		34	103	2	49	260	1	128	503	15	2,870	1,226	76		36	76	3	54	259	1	118	404	15	2,491	913	54
Refrigerated Warehouse-No Rail		1	2	<1	2	159	59	3	4	<1	100	2,052	18,137		4	<1	<1	—	184	75	11	1	<1	96	1,755	18,119
Refrigerated Warehouse-Rail		1	2	<1	2	159	59	3	4	<1	100	2,052	18,137		4	<1	<1	—	184	75	11	1	<1	96	1,755	18,119
Regional Shopping Center		2	7	<1	10	38	3	35	72	33	1,839	1,304	211		2	3	<1	10	41	4	40	35	35	1,589	1,313	218
Research & Development		25	258	1	30	52	<1	64	838	15	4,239	2,482	15		28	168	1	25	52	<1	86	731	12	3,604	2,406	15
Strip Mall		2	7	<1	10	38	3	35	72	33	1,839	1,304	211		2	3	<1	10	41	4	40	35	35	1,589	1,313	218
Supermarket		7	37	5	6	126	5	36	395	47	1,460	2,628	17,583		7	22	5	5	130	<1	32	286	42	909	1,989	18,138
University/College (4yr)		45	328	1	15	58	—	350	1,034	63	2,367	1,230	315		52	416	1	17	73	—	536	1,650	68	2,286	1,516	422
Unrefrigerated Warehouse-No Rail		4	8	<1	2	152	—	11	121	<1	190	1,742	—		5	2	<1	1	182	—	14	32	<1	110	1,304	—

Table E-15.2. Commercial Energy Consumption by End Use,[1] Electricity Demand Forecast Zone, and Building Type (cont.)

Building Type	EDFZ[1]	Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)						EDFZ[1]	Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)					
		Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.		Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.
Unrefrigerated Warehouse-Rail		4	8	<1	2	152	—	11	121	<1	190	1,742	—		5	2	<1	1	182	—	14	32	<1	110	1,304	—
Arena	11	36	76	3	55	259	1	118	406	15	2,540	875	52	12	32	162	3	13	193	<1	80	608	47	1,835	938	48
Automobile Care Center		36	76	3	55	259	1	118	406	15	2,540	875	52		32	162	3	13	193	<1	80	608	47	1,835	938	48
Bank (with Drive-Through)		36	76	3	55	259	1	118	406	15	2,540	875	52		32	162	3	13	193	<1	80	608	47	1,835	938	48
Convenience Market (24 hour)		7	20	5	5	131	—	31	252	42	899	1,875	18,180		5	56	24	1	97	—	45	184	492	479	1,793	16,782
Convenience Market with Gas Pumps		7	20	5	5	131	—	31	252	42	899	1,875	18,180		5	56	24	1	97	—	45	184	492	479	1,793	16,782
Day-Care Center		16	116	1	6	100	—	99	137	55	1,067	420	99		12	71	1	4	70	—	180	299	171	936	446	84
Discount Club		2	2	<1	10	41	4	40	31	35	1,611	1,311	218		1	7	<1	5	30	1	49	20	24	1,090	904	176
Electronic Superstore		2	2	<1	10	41	4	40	31	35	1,611	1,311	218		1	7	<1	5	30	1	49	20	24	1,090	904	176
Elementary School		16	116	1	6	100	—	99	137	55	1,067	420	99		12	71	1	4	70	—	180	299	171	936	446	84
Fast Food Restaurant w/o Drive Thru		127	44	839	45	80	5	39	392	2,199	3,515	5,451	9,121		99	74	890	4	57	1	170	470	3,641	2,812	5,370	7,874
Fast Food Restaurant with Drive Thru		127	44	839	45	80	5	39	392	2,199	3,515	5,451	9,121		99	74	890	4	57	1	170	470	3,641	2,812	5,370	7,874
Free-Standing Discount store		2	2	<1	10	41	4	40	31	35	1,611	1,311	218		1	7	<1	5	30	1	49	20	24	1,090	904	176
Free-Standing Discount Superstore		2	2	<1	10	41	4	40	31	35	1,611	1,311	218		1	7	<1	5	30	1	49	20	24	1,090	904	176
Gasoline/Service Station		36	76	3	55	259	1	118	406	15	2,540	875	52		32	162	3	13	193	<1	80	608	47	1,835	938	48
General Heavy Industry		36	76	3	55	259	1	118	406	15	2,540	875	52		32	162	3	13	193	<1	80	608	47	1,835	938	48
General Light Industry		36	76	3	55	259	1	118	406	15	2,540	875	52		32	162	3	13	193	<1	80	608	47	1,835	938	48
General Office Building		29	169	1	25	52	<1	86	731	12	3,629	2,396	15		25	230	1	26	39	<1	108	646	30	2,664	2,328	36
Government (Civic Center)		29	169	1	25	52	<1	86	731	12	3,629	2,396	15		25	230	1	26	39	<1	108	646	30	2,664	2,328	36
Government Office Building		29	169	1	25	52	<1	86	731	12	3,629	2,396	15		25	230	1	26	39	<1	108	646	30	2,664	2,328	36
Hardware/Paint Store		2	2	<1	10	41	4	40	31	35	1,611	1,311	218		1	7	<1	5	30	1	49	20	24	1,090	904	176
Health Club		36	76	3	55	259	1	118	406	15	2,540	875	52		32	162	3	13	193	<1	80	608	47	1,835	938	48

Table E-15.2. Commercial Energy Consumption by End Use,[1] Electricity Demand Forecast Zone, and Building Type (cont.)

Building Type	EDFZ[1]	Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)						EDFZ[1]	Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)					
		Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.		Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.
High School		16	116	1	6	100	—	99	137	55	1,067	420	99		12	71	1	4	70	—	180	299	171	936	446	84
High Turnover (Sit Down Restaurant)		127	44	839	45	80	5	39	392	2,199	3,515	5,451	9,121		99	74	890	4	57	1	170	470	3,641	2,812	5,370	7,874
Home Improvement Superstore		2	2	<1	10	41	4	40	31	35	1,611	1,311	218		1	7	<1	5	30	1	49	20	24	1,090	904	176
Hospital		196	211	9	6	179	—	520	1,255	98	7,939	8,024	351		221	111	9	204	126	—	1,593	2,670	202	5,658	6,328	452
Hotel		78	81	24	—	116	—	233	5,394	69	3,353	1,850	1,227		85	259	15	<1	83	—	33	2,013	235	2,307	2,038	1,135
Industrial Park		29	169	1	25	52	<1	86	731	12	3,629	2,396	15		25	230	1	26	39	<1	108	646	30	2,664	2,328	36
Junior College (2yr)		53	418	1	18	74	—	540	1,675	69	2,307	1,534	429		33	432	1	103	53	—	1,280	2,459	158	1,915	1,741	367
Junior High School		16	116	1	6	100	—	99	137	55	1,067	420	99		12	71	1	4	70	—	180	299	171	936	446	84
Library		36	76	3	55	259	1	118	406	15	2,540	875	52		32	162	3	13	193	<1	80	608	47	1,835	938	48
Manufacturing		36	76	3	55	259	1	118	406	15	2,540	875	52		32	162	3	13	193	<1	80	608	47	1,835	938	48
Medical Office Building		29	169	1	25	52	<1	86	731	12	3,629	2,396	15		25	230	1	26	39	<1	108	646	30	2,664	2,328	36
Motel		78	81	24	—	116	—	233	5,394	69	3,353	1,850	1,227		85	259	15	<1	83	—	33	2,013	235	2,307	2,038	1,135
Movie Theater (No Matinee)		36	76	3	55	259	1	118	406	15	2,540	875	52		32	162	3	13	193	<1	80	608	47	1,835	938	48
Office Park		29	169	1	25	52	<1	86	731	12	3,629	2,396	15		25	230	1	26	39	<1	108	646	30	2,664	2,328	36
Pharmacy/Drugstore w/o Drive Thru		2	2	<1	10	41	4	40	31	35	1,611	1,311	218		1	7	<1	5	30	1	49	20	24	1,090	904	176
Pharmacy/Drugstore with Drive Thru		2	2	<1	10	41	4	40	31	35	1,611	1,311	218		1	7	<1	5	30	1	49	20	24	1,090	904	176
Place of Worship		36	76	3	55	259	1	118	406	15	2,540	875	52		32	162	3	13	193	<1	80	608	47	1,835	938	48
Quality Restaurant		127	44	839	45	80	5	39	392	2,199	3,515	5,451	9,121		99	74	890	4	57	1	170	470	3,641	2,812	5,370	7,874
Racquet Club		36	76	3	55	259	1	118	406	15	2,540	875	52		32	162	3	13	193	<1	80	608	47	1,835	938	48
Refrigerated Warehouse-No Rail		4	<1	<1	—	185	75	11	1	<1	96	1,746	18,101		4	<1	<1	—	123	68	12	2	<1	67	1,544	16,519
Refrigerated Warehouse-Rail		4	<1	<1	—	185	75	11	1	<1	96	1,746	18,101		4	<1	<1	—	123	68	12	2	<1	67	1,544	16,519
Regional Shopping Center		2	2	<1	10	41	4	40	31	35	1,611	1,311	218		1	7	<1	5	30	1	49	20	24	1,090	904	176
Research & Development		29	169	1	25	52	<1	86	731	12	3,629	2,396	15		25	230	1	26	39	<1	108	646	30	2,664	2,328	36

Table E-15.2. Commercial Energy Consumption by End Use,[1] Electricity Demand Forecast Zone, and Building Type (cont.)

Building Type	EDFZ[1]	Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)						EDFZ[1]	Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)					
		Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.		Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.
Strip Mall		2	2	<1	10	41	4	40	31	35	1,611	1,311	218		1	7	<1	5	30	1	49	20	24	1,090	904	176
Supermarket		7	20	5	5	131	—	31	252	42	899	1,875	18,180		5	56	24	1	97	—	45	184	492	479	1,793	16,782
University/College (4yr)		53	418	1	18	74	—	540	1,675	69	2,307	1,534	429		33	432	1	103	53	—	1,280	2,459	158	1,915	1,741	367
Unrefrigerated Warehouse-No Rail		5	2	<1	1	183	—	14	27	<1	110	1,288	—		2	2	<1	2	141	—	33	28	<1	133	1,158	—
Unrefrigerated Warehouse-Rail		5	2	<1	1	183	—	14	27	<1	110	1,288	—		2	2	<1	2	141	—	33	28	<1	133	1,158	—
Arena	13	31	135	1	—	229	—	204	113	—	862	4,668	171	14	28	111	1	4	226	—	201	246	15	2,352	4,226	154
Automobile Care Center		31	135	1	—	229	—	204	113	—	862	4,668	171		28	111	1	4	226	—	201	246	15	2,352	4,226	154
Bank (with Drive-Through)		31	135	1	—	229	—	204	113	—	862	4,668	171		28	111	1	4	226	—	201	246	15	2,352	4,226	154
Convenience Market (24 hour)		22	78	1	<1	55	45	117	184	82	3,764	14,809	12,946		19	151	1	23	53	40	107	188	71	8,026	12,948	11,137
Convenience Market with Gas Pumps		22	78	1	<1	55	45	117	184	82	3,764	14,809	12,946		19	151	1	23	53	40	107	188	71	8,026	12,948	11,137
Day-Care Center		24	197	4	—	<1	—	192	2,940	35	217	455	139		23	398	4	1	—	—	164	72	34	242	449	132
Discount Club		60	27	<1	<1	1	—	9	306	9	1,367	1,498	141		1	76	<1	2	1	—	12	429	8	1,878	1,308	123
Electronic Superstore		60	27	<1	<1	1	—	9	306	9	1,367	1,498	141		1	76	<1	2	1	—	12	429	8	1,878	1,308	123
Elementary School		24	197	4	—	<1	—	192	2,940	35	217	455	139		23	398	4	1	—	—	164	72	34	242	449	132
Fast Food Restaurant w/o Drive Thru		140	134	865	—	65	—	118	506	4,833	4,041	12,650	5,830		95	109	651	—	54	—	148	183	3,621	4,433	9,442	4,176
Fast Food Restaurant with Drive Thru		140	134	865	—	65	—	118	506	4,833	4,041	12,650	5,830		95	109	651	—	54	—	148	183	3,621	4,433	9,442	4,176
Free-Standing Discount store		60	27	<1	<1	1	—	9	306	9	1,367	1,498	141		1	76	<1	2	1	—	12	429	8	1,878	1,308	123
Free-Standing Discount Superstore		60	27	<1	<1	1	—	9	306	9	1,367	1,498	141		1	76	<1	2	1	—	12	429	8	1,878	1,308	123
Gasoline/Service Station		31	135	1	—	229	—	204	113	—	862	4,668	171		28	111	1	4	226	—	201	246	15	2,352	4,226	154
General Heavy Industry		31	135	1	—	229	—	204	113	—	862	4,668	171		28	111	1	4	226	—	201	246	15	2,352	4,226	154
General Light Industry		31	135	1	—	229	—	204	113	—	862	4,668	171		28	111	1	4	226	—	201	246	15	2,352	4,226	154
General Office Building		1	285	<1	—	46	—	14	395	29	4,356	4,969	15		1	236	<1	42	42	—	11	81	24	4,424	4,233	12

Table E-15.2. Commercial Energy Consumption by End Use,[1] Electricity Demand Forecast Zone, and Building Type (cont.)

Building Type	EDFZ[1]	Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)						EDFZ[1]	Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)					
		Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.		Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.
Government (Civic Center)		1	285	<1	—	46	—	14	395	29	4,356	4,969	15		1	236	<1	42	42	—	11	81	24	4,424	4,233	12
Government Office Building		1	285	<1	—	46	—	14	395	29	4,356	4,969	15		1	236	<1	42	42	—	11	81	24	4,424	4,233	12
Hardware/Paint Store		60	27	<1	<1	1	—	9	306	9	1,367	1,498	141		1	76	<1	2	1	—	12	429	8	1,878	1,308	123
Health Club		31	135	1	—	229	—	204	113	—	862	4,668	171		28	111	1	4	226	—	201	246	15	2,352	4,226	154
High School		24	197	4	—	<1	—	192	2,940	35	217	455	139		23	398	4	1	—	—	164	72	34	242	449	132
High Turnover (Sit Down Restaurant)		140	134	865	—	65	—	118	506	4,833	4,041	12,650	5,830		95	109	651	—	54	—	148	183	3,621	4,433	9,442	4,176
Home Improvement Superstore		60	27	<1	<1	1	—	9	306	9	1,367	1,498	141		1	76	<1	2	1	—	12	429	8	1,878	1,308	123
Hospital		217	170	9	—	161	—	279	292	104	9,484	16,339	147		209	203	9	—	170	—	250	139	102	9,273	15,907	140
Hotel		96	357	3	—	15	—	—	259	21	495	2,341	287		82	199	12	<1	15	—	2	92	19	534	2,083	253
Industrial Park		1	285	<1	—	46	—	14	395	29	4,356	4,969	15		1	236	<1	42	42	—	11	81	24	4,424	4,233	12
Junior College (2yr)		13	296	—	24	13	—	3	50	19	1,372	518	20		11	63	1	7	14	—	63	44	18	1,515	504	18
Junior High School		24	197	4	—	<1	—	192	2,940	35	217	455	139		23	398	4	1	—	—	164	72	34	242	449	132
Library		31	135	1	—	229	—	204	113	—	862	4,668	171		28	111	1	4	226	—	201	246	15	2,352	4,226	154
Manufacturing		31	135	1	—	229	—	204	113	—	862	4,668	171		28	111	1	4	226	—	201	246	15	2,352	4,226	154
Medical Office Building		1	285	<1	—	46	—	14	395	29	4,356	4,969	15		1	236	<1	42	42	—	11	81	24	4,424	4,233	12
Motel		96	357	3	—	15	—	—	259	21	495	2,341	287		82	199	12	<1	15	—	2	92	19	534	2,083	253
Movie Theater (No Matinee)		31	135	1	—	229	—	204	113	—	862	4,668	171		28	111	1	4	226	—	201	246	15	2,352	4,226	154
Office Park		1	285	<1	—	46	—	14	395	29	4,356	4,969	15		1	236	<1	42	42	—	11	81	24	4,424	4,233	12
Pharmacy/Drugstore w/o Drive Thru		60	27	<1	<1	1	—	9	306	9	1,367	1,498	141		1	76	<1	2	1	—	12	429	8	1,878	1,308	123
Pharmacy/Drugstore with Drive Thru		60	27	<1	<1	1	—	9	306	9	1,367	1,498	141		1	76	<1	2	1	—	12	429	8	1,878	1,308	123
Place of Worship		31	135	1	—	229	—	204	113	—	862	4,668	171		28	111	1	4	226	—	201	246	15	2,352	4,226	154
Quality Restaurant		140	134	865	—	65	—	118	506	4,833	4,041	12,650	5,830		95	109	651	—	54	—	148	183	3,621	4,433	9,442	4,176
Racquet Club		31	135	1	—	229	—	204	113	—	862	4,668	171		28	111	1	4	226	—	201	246	15	2,352	4,226	154

Table E-15.2. Commercial Energy Consumption by End Use,[1] Electricity Demand Forecast Zone, and Building Type (cont.)

Building Type	EDFZ[1]	Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)						EDFZ[1]	Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)					
		Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.		Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.
Refrigerated Warehouse-No Rail		<1	3	<1	<1	52	8	6	8	<1	117	4,305	15,847		<1	15	<1	5	9	8	8	18	—	62	4,595	17,064
Refrigerated Warehouse-Rail		<1	3	<1	<1	52	8	6	8	<1	117	4,305	15,847		<1	15	<1	5	9	8	8	18	—	62	4,595	17,064
Regional Shopping Center		60	27	<1	<1	1	—	9	306	9	1,367	1,498	141		1	76	<1	2	1	—	12	429	8	1,878	1,308	123
Research & Development		1	285	<1	—	46	—	14	395	29	4,356	4,969	15		1	236	<1	42	42	—	11	81	24	4,424	4,233	12
Strip Mall		60	27	<1	<1	1	—	9	306	9	1,367	1,498	141		1	76	<1	2	1	—	12	429	8	1,878	1,308	123
Supermarket		22	78	1	<1	55	45	117	184	82	3,764	14,809	12,946		19	151	1	23	53	40	107	188	71	8,026	12,948	11,137
University/College (4yr)		13	296	—	24	13	—	3	50	19	1,372	518	20		11	63	1	7	14	—	63	44	18	1,515	504	18
Unrefrigerated Warehouse-No Rail		<1	25	<1	—	8	—	3	328	<1	758	4,279	—		<1	32	<1	6	8	—	3	372	—	521	3,934	—
Unrefrigerated Warehouse-Rail		<1	25	<1	—	8	—	3	328	<1	758	4,279	—		<1	32	<1	6	8	—	3	372	—	521	3,934	—
Arena	15	28	110	1	4	227	—	198	240	11	2,130	4,241	154	16	23	69	2	43	215	1	79	379	12	1,996	2,220	39
Automobile Care Center		28	110	1	4	227	—	198	240	11	2,130	4,241	154		23	69	2	43	215	1	79	379	12	1,996	2,220	39
Bank (with Drive-Through)		28	110	1	4	227	—	198	240	11	2,130	4,241	154		23	69	2	43	215	1	79	379	12	1,996	2,220	39
Convenience Market (24 hour)		19	150	1	17	53	38	116	200	72	6,949	13,007	11,303		4	17	4	2	109	—	24	179	32	367	1,654	13,782
Convenience Market with Gas Pumps		19	150	1	17	53	38	116	200	72	6,949	13,007	11,303		4	17	4	2	109	—	24	179	32	367	1,654	13,782
Day-Care Center		23	388	4	1	<1	—	178	64	34	231	449	132		16	77	1	7	98	—	51	82	51	894	1,130	81
Discount Club		12	69	<1	1	1	—	13	395	8	1,649	1,315	123		1	4	<1	7	34	3	24	28	27	1,249	2,867	162
Electronic Superstore		12	69	<1	1	1	—	13	395	8	1,649	1,315	123		1	4	<1	7	34	3	24	28	27	1,249	2,867	162
Elementary School		23	388	4	1	<1	—	178	64	34	231	449	132		16	77	1	7	98	—	51	82	51	894	1,130	81
Fast Food Restaurant w/o Drive Thru		94	105	645	<1	53	—	142	199	3,590	4,116	9,362	4,145		90	37	702	48	67	4	35	268	1,279	3,254	8,965	6,236
Fast Food Restaurant with Drive Thru		94	105	645	<1	53	—	142	199	3,590	4,116	9,362	4,145		90	37	702	48	67	4	35	268	1,279	3,254	8,965	6,236
Free-Standing Discount store		12	69	<1	1	1	—	13	395	8	1,649	1,315	123		1	4	<1	7	34	3	24	28	27	1,249	2,867	162

Table E-15.2. Commercial Energy Consumption by End Use,[1] Electricity Demand Forecast Zone, and Building Type (cont.)

		Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)							Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)					
Building Type	EDFZ[1]	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	EDFZ[1]	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.
Free-Standing Discount Superstore		12	69	<1	1	1	—	13	395	8	1,649	1,315	123		1	4	<1	7	34	3	24	28	27	1,249	2,867	162
Gasoline/Service Station		28	110	1	4	227	—	198	240	11	2,130	4,241	154		23	69	2	43	215	1	79	379	12	1,996	2,220	39
General Heavy Industry		28	110	1	4	227	—	198	240	11	2,130	4,241	154		23	69	2	43	215	1	79	379	12	1,996	2,220	39
General Light Industry		28	110	1	4	227	—	198	240	11	2,130	4,241	154		23	69	2	43	215	1	79	379	12	1,996	2,220	39
General Office Building		1	234	<1	39	43	—	13	83	25	4,208	4,327	13		20	119	1	18	43	<1	46	396	9	3,103	2,714	11
Government (Civic Center)		1	234	<1	39	43	—	13	83	25	4,208	4,327	13		20	119	1	18	43	<1	46	396	9	3,103	2,714	11
Government Office Building		1	234	<1	39	43	—	13	83	25	4,208	4,327	13		20	119	1	18	43	<1	46	396	9	3,103	2,714	11
Hardware/Paint Store		12	69	<1	1	1	—	13	395	8	1,649	1,315	123		1	4	<1	7	34	3	24	28	27	1,249	2,867	162
Health Club		28	110	1	4	227	—	198	240	11	2,130	4,241	154		23	69	2	43	215	1	79	379	12	1,996	2,220	39
High School		23	388	4	1	<1	—	178	64	34	231	449	132		16	77	1	7	98	—	51	82	51	894	1,130	81
High Turnover (Sit Down Restaurant)		94	105	645	<1	53	—	142	199	3,590	4,116	9,362	4,145		90	37	702	48	67	4	35	268	1,279	3,254	8,965	6,236
Home Improvement Superstore		12	69	<1	1	1	—	13	395	8	1,649	1,315	123		1	4	<1	7	34	3	24	28	27	1,249	2,867	162
Hospital		210	204	9	<1	170	—	245	124	101	8,897	15,857	140		184	121	9	14	181	—	290	610	93	8,688	18,450	297
Hotel		82	201	10	1	15	—	8	93	19	502	2,076	253		60	66	20	—	96	—	145	2,805	54	2,226	2,059	903
Industrial Park		1	234	<1	39	43	—	13	83	25	4,208	4,327	13		20	119	1	18	43	<1	46	396	9	3,103	2,714	11
Junior College (2yr)		11	140	1	8	14	—	40	51	18	1,481	505	18		43	364	1	4	75	—	276	682	65	3,268	3,761	362
Junior High School		23	388	4	1	<1	—	178	64	34	231	449	132		16	77	1	7	98	—	51	82	51	894	1,130	81
Library		28	110	1	4	227	—	198	240	11	2,130	4,241	154		23	69	2	43	215	1	79	379	12	1,996	2,220	39
Manufacturing		28	110	1	4	227	—	198	240	11	2,130	4,241	154		23	69	2	43	215	1	79	379	12	1,996	2,220	39
Medical Office Building		1	234	<1	39	43	—	13	83	25	4,208	4,327	13		20	119	1	18	43	<1	46	396	9	3,103	2,714	11
Motel		82	201	10	1	15	—	8	93	19	502	2,076	253		60	66	20	—	96	—	145	2,805	54	2,226	2,059	903
Movie Theater (No Matinee)		28	110	1	4	227	—	198	240	11	2,130	4,241	154		23	69	2	43	215	1	79	379	12	1,996	2,220	39
Office Park		1	234	<1	39	43	—	13	83	25	4,208	4,327	13		20	119	1	18	43	<1	46	396	9	3,103	2,714	11

Table E-15.2. Commercial Energy Consumption by End Use,[1] Electricity Demand Forecast Zone, and Building Type (cont.)

Building Type	EDFZ[1]	Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)						EDFZ[1]	Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)					
		Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.		Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.
Pharmacy/Drugstore w/o Drive Thru		12	69	<1	1	1	—	13	395	8	1,649	1,315	123		1	4	<1	7	34	3	24	28	27	1,249	2,867	162
Pharmacy/Drugstore with Drive Thru		12	69	<1	1	1	—	13	395	8	1,649	1,315	123		1	4	<1	7	34	3	24	28	27	1,249	2,867	162
Place of Worship		28	110	1	4	227	—	198	240	11	2,130	4,241	154		23	69	2	43	215	1	79	379	12	1,996	2,220	39
Quality Restaurant		94	105	645	<1	53	—	142	199	3,590	4,116	9,362	4,145		90	37	702	48	67	4	35	268	1,279	3,254	8,965	6,236
Racquet Club		28	110	1	4	227	—	198	240	11	2,130	4,241	154		23	69	2	43	215	1	79	379	12	1,996	2,220	39
Refrigerated Warehouse-No Rail		<1	13	<1	3	18	8	8	17	<1	61	4,537	16,845		3	<1	<1	—	150	57	7	<1	<1	68	1,931	13,133
Refrigerated Warehouse-Rail		<1	13	<1	3	18	8	8	17	<1	61	4,537	16,845		3	<1	<1	—	150	57	7	<1	<1	68	1,931	13,133
Regional Shopping Center		12	69	<1	1	1	—	13	395	8	1,649	1,315	123		1	4	<1	7	34	3	24	28	27	1,249	2,867	162
Research & Development		1	234	<1	39	43	—	13	83	25	4,208	4,327	13		20	119	1	18	43	<1	46	396	9	3,103	2,714	11
Strip Mall		12	69	<1	1	1	—	13	395	8	1,649	1,315	123		1	4	<1	7	34	3	24	28	27	1,249	2,867	162
Supermarket		19	150	1	17	53	38	116	200	72	6,949	13,007	11,303		4	17	4	2	109	—	24	179	32	367	1,654	13,782
University/College (4yr)		11	140	1	8	14	—	40	51	18	1,481	505	18		43	364	1	4	75	—	276	682	65	3,268	3,761	362
Unrefrigerated Warehouse-No Rail		<1	33	<1	6	8	—	3	393	<1	487	4,060	—		3	2	<1	1	152	—	7	21	<1	120	1,905	—
Unrefrigerated Warehouse-Rail		<1	33	<1	6	8	—	3	393	<1	487	4,060	—		3	2	<1	1	152	—	7	21	<1	120	1,905	—
Arena		26	57	2	50	214	1	79	268	12	2,533	2,164	40		23	93	2	12	206	<1	141	443	14	2,753	10,260	46
Automobile Care Center		26	57	2	50	214	1	79	268	12	2,533	2,164	40		23	93	2	12	206	<1	141	443	14	2,753	10,260	46
Bank (with Drive-Through)		26	57	2	50	214	1	79	268	12	2,533	2,164	40		23	93	2	12	206	<1	141	443	14	2,753	10,260	46
Convenience Market (24 hour)	17	5	17	4	3	108	—	22	158	32	666	1,650	13,737	18	5	75	5	—	102	36	26	348	61	1,082	3,498	13,311
Convenience Market with Gas Pumps		5	17	4	3	108	—	22	158	32	666	1,650	13,737		5	75	5	—	102	36	26	348	61	1,082	3,498	13,311
Day-Care Center		16	75	1	11	100	—	37	82	52	1,077	1,066	78		15	156	1	57	98	<1	107	887	72	2,397	1,135	109
Discount Club		1	2	<1	8	34	3	26	12	27	1,520	2,796	164		3	18	<1	3	32	1	8	118	25	1,770	1,932	197

Table E-15.2. Commercial Energy Consumption by End Use,[1] Electricity Demand Forecast Zone, and Building Type (cont.)

		Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)							Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)					
Building Type	EDFZ[1]	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	EDFZ[1]	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.
Electronic Superstore		1	2	<1	8	34	3	26	12	27	1,520	2,796	164		3	18	<1	3	32	1	8	118	25	1,770	1,932	197
Elementary School		16	75	1	11	100	—	37	82	52	1,077	1,066	78		15	156	1	57	98	<1	107	887	72	2,397	1,135	109
Fast Food Restaurant w/o Drive Thru		92	33	698	44	67	4	29	270	1,390	4,098	8,344	6,443		90	55	755	16	64	2	66	233	1,739	4,338	10,345	6,772
Fast Food Restaurant with Drive Thru		92	33	698	44	67	4	29	270	1,390	4,098	8,344	6,443		90	55	755	16	64	2	66	233	1,739	4,338	10,345	6,772
Free-Standing Discount store		1	2	<1	8	34	3	26	12	27	1,520	2,796	164		3	18	<1	3	32	1	8	118	25	1,770	1,932	197
Free-Standing Discount Superstore		1	2	<1	8	34	3	26	12	27	1,520	2,796	164		3	18	<1	3	32	1	8	118	25	1,770	1,932	197
Gasoline/Service Station		26	57	2	50	214	1	79	268	12	2,533	2,164	40		23	93	2	12	206	<1	141	443	14	2,753	10,260	46
General Heavy Industry		26	57	2	50	214	1	79	268	12	2,533	2,164	40		23	93	2	12	206	<1	141	443	14	2,753	10,260	46
General Light Industry		26	57	2	50	214	1	79	268	12	2,533	2,164	40		23	93	2	12	206	<1	141	443	14	2,753	10,260	46
General Office Building		21	120	1	18	43	<1	49	411	9	3,032	2,608	11		30	11	1	<1	41	<1	13	46	17	3,240	5,482	29
Government (Civic Center)		21	120	1	18	43	<1	49	411	9	3,032	2,608	11		30	11	1	<1	41	<1	13	46	17	3,240	5,482	29
Government Office Building		21	120	1	18	43	<1	49	411	9	3,032	2,608	11		30	11	1	<1	41	<1	13	46	17	3,240	5,482	29
Hardware/Paint Store		1	2	<1	8	34	3	26	12	27	1,520	2,796	164		3	18	<1	3	32	1	8	118	25	1,770	1,932	197
Health Club		26	57	2	50	214	1	79	268	12	2,533	2,164	40		23	93	2	12	206	<1	141	443	14	2,753	10,260	46
High School		16	75	1	11	100	—	37	82	52	1,077	1,066	78		15	156	1	57	98	<1	107	887	72	2,397	1,135	109
High Turnover (Sit Down Restaurant)		92	33	698	44	67	4	29	270	1,390	4,098	8,344	6,443		90	55	755	16	64	2	66	233	1,739	4,338	10,345	6,772
Home Improvement Superstore		1	2	<1	8	34	3	26	12	27	1,520	2,796	164		3	18	<1	3	32	1	8	118	25	1,770	1,932	197
Hospital		187	99	9	6	180	—	341	492	92	10,138	16,824	305		178	230	10	12	167	1	1,241	497	98	7,896	19,788	358
Hotel		60	52	20	—	96	—	155	2,418	54	2,450	2,030	922		72	238	14	—	85	—	6	3,116	124	1,467	4,319	956
Industrial Park		21	120	1	18	43	<1	49	411	9	3,032	2,608	11		30	11	1	<1	41	<1	13	46	17	3,240	5,482	29
Junior College (2yr)		43	388	1	13	76	—	182	360	66	3,894	3,546	347		52	422	1	5	74	2	36	491	80	3,253	4,385	521
Junior High School		16	75	1	11	100	—	37	82	52	1,077	1,066	78		15	156	1	57	98	<1	107	887	72	2,397	1,135	109
Library		26	57	2	50	214	1	79	268	12	2,533	2,164	40		23	93	2	12	206	<1	141	443	14	2,753	10,260	46

Table E-15.2. Commercial Energy Consumption by End Use,[1] Electricity Demand Forecast Zone, and Building Type (cont.)

Building Type	EDFZ[1]	Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)						EDFZ[1]	Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)					
		Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.		Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.
Manufacturing		26	57	2	50	214	1	79	268	12	2,533	2,164	40		23	93	2	12	206	<1	141	443	14	2,753	10,260	46
Medical Office Building		21	120	1	18	43	<1	49	411	9	3,032	2,608	11		30	11	1	<1	41	<1	13	46	17	3,240	5,482	29
Motel		60	52	20	—	96	—	155	2,418	54	2,450	2,030	922		72	238	14	—	85	—	6	3,116	124	1,467	4,319	956
Movie Theater (No Matinee)		26	57	2	50	214	1	79	268	12	2,533	2,164	40		23	93	2	12	206	<1	141	443	14	2,753	10,260	46
Office Park		21	120	1	18	43	<1	49	411	9	3,032	2,608	11		30	11	1	<1	41	<1	13	46	17	3,240	5,482	29
Pharmacy/Drugstore w/o Drive Thru		1	2	<1	8	34	3	26	12	27	1,520	2,796	164		3	18	<1	3	32	1	8	118	25	1,770	1,932	197
Pharmacy/Drugstore with Drive Thru		1	2	<1	8	34	3	26	12	27	1,520	2,796	164		3	18	<1	3	32	1	8	118	25	1,770	1,932	197
Place of Worship		26	57	2	50	214	1	79	268	12	2,533	2,164	40		23	93	2	12	206	<1	141	443	14	2,753	10,260	46
Quality Restaurant		92	33	698	44	67	4	29	270	1,390	4,098	8,344	6,443		90	55	755	16	64	2	66	233	1,739	4,338	10,345	6,772
Racquet Club		26	57	2	50	214	1	79	268	12	2,533	2,164	40		23	93	2	12	206	<1	141	443	14	2,753	10,260	46
Refrigerated Warehouse-No Rail		2	<1	<1	—	150	60	7	<1	<1	92	1,896	12,896		4	<1	<1	—	137	65	7	<1	<1	109	2,911	5,213
Refrigerated Warehouse-Rail		2	<1	<1	—	150	60	7	<1	<1	92	1,896	12,896		4	<1	<1	—	137	65	7	<1	<1	109	2,911	5,213
Regional Shopping Center		1	2	<1	8	34	3	26	12	27	1,520	2,796	164		3	18	<1	3	32	1	8	118	25	1,770	1,932	197
Research & Development		21	120	1	18	43	<1	49	411	9	3,032	2,608	11		30	11	1	<1	41	<1	13	46	17	3,240	5,482	29
Strip Mall		1	2	<1	8	34	3	26	12	27	1,520	2,796	164		3	18	<1	3	32	1	8	118	25	1,770	1,932	197
Supermarket		5	17	4	3	108	—	22	158	32	666	1,650	13,737		5	75	5	—	102	36	26	348	61	1,082	3,498	13,311
University/College (4yr)		43	388	1	13	76	—	182	360	66	3,894	3,546	347		52	422	1	5	74	2	36	491	80	3,253	4,385	521
Unrefrigerated Warehouse-No Rail		3	2	<1	2	151	—	8	19	<1	144	1,860	—		4	3	<1	1	135	—	7	47	<1	761	2,087	—
Unrefrigerated Warehouse-Rail		3	2	<1	2	151	—	8	19	<1	144	1,860	—		4	3	<1	1	135	—	7	47	<1	761	2,087	—
Arena	19	27	42	2	—	254	—	305	929	75	12,990	8,428	47	State	32	105	2	21	239	<1	132	334	17	2,603	3,968	102
Automobile Care Center	19	27	42	2	—	254	—	305	929	75	12,990	8,428	47	State	32	105	2	21	239	<1	132	334	17	2,603	3,968	102
Bank (with Drive-Through)	19	27	42	2	—	254	—	305	929	75	12,990	8,428	47	State	32	105	2	21	239	<1	132	334	17	2,603	3,968	102

Table E-15.2. Commercial Energy Consumption by End Use,[1] Electricity Demand Forecast Zone, and Building Type (cont.)

Building Type	EDFZ[1]	Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)						EDFZ[1]	Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)					
		Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.		Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.
Convenience Market (24 hour)		7	31	6	—	131	42	96	249	520	2,495	10,826	16,764		12	95	4	7	91	17	100	308	109	3,123	9,564	14,306
Convenience Market with Gas Pumps		7	31	6	—	131	42	96	249	520	2,495	10,826	16,764		12	95	4	7	91	17	100	308	109	3,123	9,564	14,306
Day-Care Center		20	32	1	—	96	—	139	1,730	397	9,644	45	198		18	232	2	6	50	<1	179	382	70	1,130	513	115
Discount Club		1	27	<1	2	38	—	10	175	24	6,035	2,601	301		6	36	<1	4	20	1	26	168	20	1,594	1,695	171
Electronic Superstore		1	27	<1	2	38	—	10	175	24	6,035	2,601	301		6	36	<1	4	20	1	26	168	20	1,594	1,695	171
Elementary School		20	32	1	—	96	—	139	1,730	397	9,644	45	198		18	232	2	6	50	<1	179	382	70	1,130	513	115
Fast Food Restaurant w/o Drive Thru		74	60	849	—	78	—	194	257	7,180	11,975	19,627	10,585		112	87	840	20	72	2	110	446	3,574	4,413	11,064	6,691
Fast Food Restaurant with Drive Thru		74	60	849	—	78	—	194	257	7,180	11,975	19,627	10,585		112	87	840	20	72	2	110	446	3,574	4,413	11,064	6,691
Free-Standing Discount store		1	27	<1	2	38	—	10	175	24	6,035	2,601	301		6	36	<1	4	20	1	26	168	20	1,594	1,695	171
Free-Standing Discount Superstore		1	27	<1	2	38	—	10	175	24	6,035	2,601	301		6	36	<1	4	20	1	26	168	20	1,594	1,695	171
Gasoline/Service Station		27	42	2	—	254	—	305	929	75	12,990	8,428	47		32	105	2	21	239	<1	132	334	17	2,603	3,968	102
General Heavy Industry		27	42	2	—	254	—	305	929	75	12,990	8,428	47		32	105	2	21	239	<1	132	334	17	2,603	3,968	102
General Light Industry		27	42	2	—	254	—	305	929	75	12,990	8,428	47		32	105	2	21	239	<1	132	334	17	2,603	3,968	102
General Office Building		47	8	1	—	51	—	20	51	366	10,998	11,371	58		15	182	1	23	47	<1	51	392	39	4,063	4,428	18
Government (Civic Center)		47	8	1	—	51	—	20	51	366	10,998	11,371	58		15	182	1	23	47	<1	51	392	39	4,063	4,428	18
Government Office Building		47	8	1	—	51	—	20	51	366	10,998	11,371	58		15	182	1	23	47	<1	51	392	39	4,063	4,428	18
Hardware/Paint Store		1	27	<1	2	38	—	10	175	24	6,035	2,601	301		6	36	<1	4	20	1	26	168	20	1,594	1,695	171
Health Club		27	42	2	—	254	—	305	929	75	12,990	8,428	47		32	105	2	21	239	<1	132	334	17	2,603	3,968	102
High School		20	32	1	—	96	—	139	1,730	397	9,644	45	198		18	232	2	6	50	<1	179	382	70	1,130	513	115
High Turnover (Sit Down Restaurant)		74	60	849	—	78	—	194	257	7,180	11,975	19,627	10,585		112	87	840	20	72	2	110	446	3,574	4,413	11,064	6,691
Home Improvement Superstore		1	27	<1	2	38	—	10	175	24	6,035	2,601	301		6	36	<1	4	20	1	26	168	20	1,594	1,695	171

Table E-15.2. Commercial Energy Consumption by End Use,[1] Electricity Demand Forecast Zone, and Building Type (cont.)

Building Type	EDFZ[1]	Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)						EDFZ[1]	Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)					
		Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.		Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.
Hospital		257	151	9	3	173	—	1,725	519	1,043	14,329	113	2,899		219	195	9	16	172	<1	474	572	154	8,470	14,157	379
Hotel		91	126	14	—	114	—	525	1,650	1,322	3,475	89	316		77	164	16	2	62	—	114	1,892	122	1,644	2,255	653
Industrial Park		47	8	1	—	51	—	20	51	366	10,998	11,371	58		15	182	1	23	47	<1	51	392	39	4,063	4,428	18
Junior College (2yr)		87	90	1	2	72	—	347	1,428	1,684	12,069	138	1,183		32	295	1	14	44	<1	255	673	135	2,510	1,361	258
Junior High School		20	32	1	—	96	—	139	1,730	397	9,644	45	198		18	232	2	6	50	<1	179	382	70	1,130	513	115
Library		27	42	2	—	254	—	305	929	75	12,990	8,428	47		32	105	2	21	239	<1	132	334	17	2,603	3,968	102
Manufacturing		27	42	2	—	254	—	305	929	75	12,990	8,428	47		32	105	2	21	239	<1	132	334	17	2,603	3,968	102
Medical Office Building		47	8	1	—	51	—	20	51	366	10,998	11,371	58		15	182	1	23	47	<1	51	392	39	4,063	4,428	18
Motel		91	126	14	—	114	—	525	1,650	1,322	3,475	89	316		77	164	16	2	62	—	114	1,892	122	1,644	2,255	653
Movie Theater (No Matinee)		27	42	2	—	254	—	305	929	75	12,990	8,428	47		32	105	2	21	239	<1	132	334	17	2,603	3,968	102
Office Park		47	8	1	—	51	—	20	51	366	10,998	11,371	58		15	182	1	23	47	<1	51	392	39	4,063	4,428	18
Pharmacy/Drugstore w/o Drive Thru		1	27	<1	2	38	—	10	175	24	6,035	2,601	301		6	36	<1	4	20	1	26	168	20	1,594	1,695	171
Pharmacy/Drugstore with Drive Thru		1	27	<1	2	38	—	10	175	24	6,035	2,601	301		6	36	<1	4	20	1	26	168	20	1,594	1,695	171
Place of Worship		27	42	2	—	254	—	305	929	75	12,990	8,428	47		32	105	2	21	239	<1	132	334	17	2,603	3,968	102
Quality Restaurant		74	60	849	—	78	—	194	257	7,180	11,975	19,627	10,585		112	87	840	20	72	2	110	446	3,574	4,413	11,064	6,691
Racquet Club		27	42	2	—	254	—	305	929	75	12,990	8,428	47		32	105	2	21	239	<1	132	334	17	2,603	3,968	102
Refrigerated Warehouse-No Rail		5	<1	<1	—	182	—	13	1	<1	109	3,803	15,490		2	4	<1	1	95	34	8	8	<1	77	3,838	15,176
Refrigerated Warehouse-Rail		5	<1	<1	—	182	—	13	1	<1	109	3,803	15,490		2	4	<1	1	95	34	8	8	<1	77	3,838	15,176
Regional Shopping Center		1	27	<1	2	38	—	10	175	24	6,035	2,601	301		6	36	<1	4	20	1	26	168	20	1,594	1,695	171
Research & Development		47	8	1	—	51	—	20	51	366	10,998	11,371	58		15	182	1	23	47	<1	51	392	39	4,063	4,428	18
Strip Mall		1	27	<1	2	38	—	10	175	24	6,035	2,601	301		6	36	<1	4	20	1	26	168	20	1,594	1,695	171
Supermarket		7	31	6	—	131	42	96	249	520	2,495	10,826	16,764		12	95	4	7	91	17	100	308	109	3,123	9,564	14,306
University/College (4yr)		87	90	1	2	72	—	347	1,428	1,684	12,069	138	1,183		32	295	1	14	44	<1	255	673	135	2,510	1,361	258

Table E-15.2. Commercial Energy Consumption by End Use,[1] Electricity Demand Forecast Zone, and Building Type (cont.)

Building Type	EDFZ[1]	Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)						EDFZ[1]	Natural Gas (Therm/yr/KSF)						Electricity (kWh/yr/KSF)					
		Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.		Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.	Water Heater	Primary Heat	Cooking	Cooling	Misc.	Refrig.
Unrefrigerated Warehouse-No Rail		5	5	<1	—	181	—	11	63	<1	1,459	7,338	—		2	20	<1	3	91	—	8	194	<1	448	3,789	—
Unrefrigerated Warehouse-Rail		5	5	<1	—	181	—	11	63	<1	1,459	7,338	—		2	20	<1	3	91	—	8	194	<1	448	3,789	—

Source: ICF calculations; California Energy Commission (CEC). 2021. Excel database with the 2018-2030 Uncalibrated Commercial Sector Forecast, provided to ICF. January 21, 2021.

EDFZ = Electricity Demand Forecast Zone; yr = year; yr = year; KSF = thousand square feet

[1] The sample size in the commercial end use forecast data for several end uses and building types was limited. Accordingly, the data should be used with caution.

[2] Data for some EDFZ were not available in the commercial end use forecast, and a representative EDFZ was assumed (refer to Table E-1.1).

[3] The 12 building types used by the commercial end use forecast have been cross walked to the 49 non-residential land types in CalEEMod, as shown in Table E-1.6.

Table E-21.1. Cool Pavement Maximum Yearly Electricity Savings

EDFZ Zone	Cooling Savings ($kWh/m^2/year$)[1]
4	0.8
5	0.1
7	1.2
11	0.9
12	0.8
16	0.2
17	1.2
18	1.6

Sources: Lawrence Berkely National Laboratory. 2017a. *Are Cooler Surfaces a Cost-Effect Mitigation of Urban Heat Islands?* April. Available: https://eta-publications.lbl.gov/sites/default/files/cooler_surfaces.pdf. Accessed: August 2023.

Lawrence Berkely National Laboratory. 2017b. *Energy and Environmental Consequences of a Cool Pavement Campaign*. May. Available: https://eta-publications.lbl.gov/sites/default/files/e-b-cool-pavement-campaign.pdf. Accessed: August 2023.

EDFZ = Electricity Demand Forecast Zone, kWh = kilowatt-hour, m^2 = square meters.

[1] An average Cooling Savings was calculated for cities that were in the same EDFZs.

Table E-26.1. Capacity Factors for Biomass Electricity Generation in the United States

Fuel Type	Capacity Factor [1]
Other Biomass [2]	62%
Wood	59%

Source: Energy Information Agency. 2023. *Table 6.07.B. Capacity Factors for Utility Scale Generators Primarily Using Non-Fossil Fuels, Electric Power Monthly*. Available: https://www.eia.gov/electricity/monthly/epm_table_grapher.php?t=table_6_07_b. Accessed: December 2023.

[1] Capacity factors are based on an average of the last 5 years of generation.

[2] Other biomass includes landfill gas, non-biogenic municipal solid waste, sludge waste, biogenic municipal solid waste, black liquor, and agricultural byproducts.

Table E-26.2. Lifecycle Emission Factors for Biomass Electricity Generation in the United States

	Life Cycle GHG Emission Factors (lbs CO_2e/MWh)[1]		
Fuel Type	Mean	Median	Standard Deviation
Dedicated Woody Crops	189.6	114.7	308.7
Dedicated Herbaceous Crops	617.4	119.1	882
Agricultural Residues	573.3	123.5	882
Forest Residues	374.8	79.4	683.6

Fuel Type	Life Cycle GHG Emission Factors (lbs CO_2e/MWh)[1]		
	Mean	Median	Standard Deviation
Urban Residues	904.1	108	859.9
Mill Residues	202.9	33.1	485.1
Animal Wastes & Processing Residues	1,367.1	286.6	859.9
Other Wastes & Residues	132.3	92.6	108

Source: Electric Power Research Institute. 2013. Literature Review and Sensitivity Analysis of Biopower Life-Cycle Assessments and Greenhouse Gas Emissions. Available: https://www.epri.com/research/products/1026852. Accessed: December 2023.

[1] Emission factors exclude the effects of land use change. Use the mean value.

Table W-1.1. Water Energy Intensity Factors by Hydrologic Region and Process

Hydrologic Region[1]	Water Energy Intensity Factors (kWh per AF)			
	Extraction + Conveyance	Pre-Treatment[2]	Distribution	Total
North Coast	54	144	163	362
San Francisco Bay	233	144	318	695
Central Coast	449	144	163	757
South Coast	1,591	144	163	1,898
Sacramento River	45	144	18	207
San Joaquin River	90	144	18	252
Tulare Lake	263	144	18	425
North Lahontan	43	144	18	205
South Lahontan	724	144	163	1,031
Colorado River	105	144	18	267

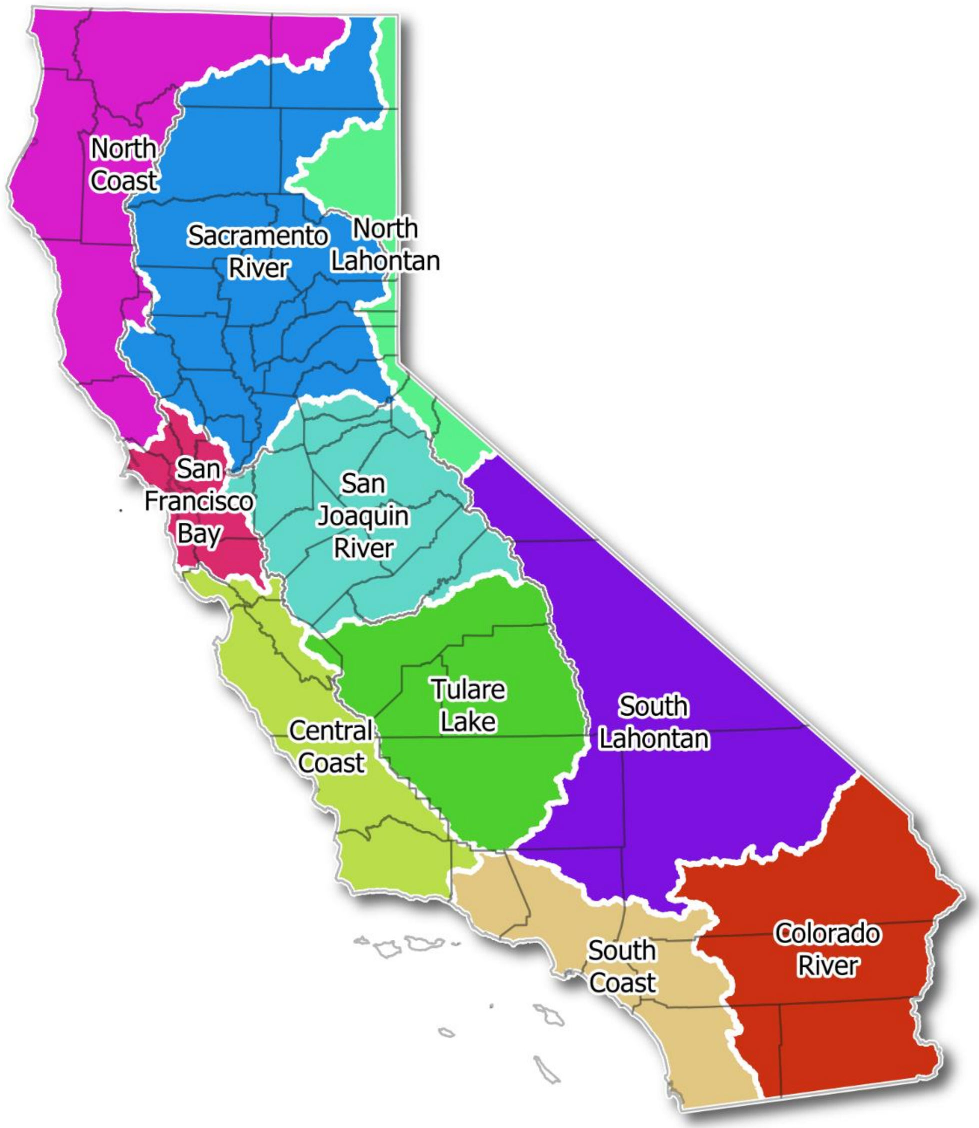
Source: ICF calculations; Navigant 2014. Water-Energy Calculator. Version 1.05. Prepared for the California Public Utilities Commission.

kWh = kilowatt-hours; AF = acre feet

[1] See Figure W-1.1.

[2] Pre-treatment factor assumes conventional treatment.

Figure W-1.1. Hydrologic Regions in California



Source: California Department of Water Resources (DWR). 2021. Hydrologic Regions. Available: https://atlas-dwr.opendata.arcgis.com/datasets/2a572a181e094020bdaeb5203162de15_0/explore?location=35.989124%2C-119.270000%2C5.96. Accessed: July 2021.

Table W-4.1. Residential Water Consumption Percentages by End Use

End-Use/Fixture (z)	% of Indoor Water Use[1]
Toilet	24%
Showerhead	19%
Bathroom and Kitchen Faucet	19%
Dishwashers	1%
Clothes Washers	16%
Leaks & Other	18%
Bath	3%

Source: Water Research Foundation 2016. Residential End Uses of Water, Version 2. Available: https://www.waterrf.org/research/projects/residential-end-uses-water-version-2. Accessed: January 2021

[1] Indoor water use percentages calculated based on data from the Water Research Foundation 2016.

Table W-4.2. Non-Residential Water Consumption Percentages by End Use

End-Use/Fixture (z)	Office		Hotel		Restaurant		Grocery Store		Non-Grocery Retail Store		K-12 School		Other School	
	Total[1]	Indoor[2]	Total[1]	Indoor[2]	Total[1]	Indoor[2]	Total[1]	Indoor[2]	Total[1]	Indoor[2]	Total[1]	Indoor[2]	Total[1]	Indoor[2]
Restroom	26%	—	51%	—	34%	—	17%	—	26%	—	20%	—	20%	—
Toilets (72% of Restroom)	—	48%	—	46%	—	27%	—	26%	—	46%	—	51%	—	37%
Urinals (17% of Restroom)	—	11%	—	11%	—	6%	—	6%	—	11%	—	12%	—	9%
Faucets (4% of Restroom)	—	3%	—	3%	—	1%	—	1%	—	3%	—	3%	—	2%
Showers (7% of Restroom)	—	5%	—	4%	—	3%	—	2%	—	4%	—	5%	—	4%
Kitchen	3%	—	10%	—	46%	—	9%	—	4%	—	2%	—	1%	—
Faucets (57% of Kitchen)	—	4%	—	7%	—	29%	—	11%	—	6%	—	4%	—	1%
Dishwashers (24% of Kitchen)	—	2%	—	3%	—	12%	—	5%	—	2%	—	2%	—	1%
Ice Making (19% of Kitchen)	—	1%	—	2%	—	10%	—	4%	—	2%	—	1%	—	0%
Laundry	0%	0%	14%	18%	0%	0%	0%	0%	0%	0%	0%	0%	1%	3%
Other	10%	26%	5%	6%	12%	13%	22%	46%	11%	27%	6%	21%	17%	44%
Landscaping	38%	—	10%	—	6%	—	3%	—	38%	—	72%	—	61%	—
Cooling	23%	—	10%	—	2%	—	49%	—	21%	—	*3	—	*3	—
Total[4]	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

Source: Pacific Institute. 2003. Waste Not, Want Not: The Potential for Urban Water Conservation in California. November. Available: https://pacinst.org/wp-content/uploads/2013/02/waste_not_want_not_full_report3.pdf. Accessed: January 2021.

[1] Water end-use data from Figures E-1, E-2, E-5, E-6, E-7, E-8, and E-9 of Appendix E of the Pacific Institute report.

[2] Indoor end-use data calculated based on the total water use data for the relevant building category and Figure 4-3 and Figure 4-4 of the Pacific Institute report. Figure 4-3 shows the breakdown of restroom water use by end-use in the commercial & industry sector. Figure 4-4 shows the breakdown of kitchen water-use by end-use in the commercial & industry sector; it was assumed that all end-uses except dishwashing and ice making are associated with faucet water use.

[3] No data.

[4] Totals may not add to 100% due to rounding.

Table W-4.3. Residential Baseline and Reduced Flow Rates for End Uses

End-Use/Fixture (z)	Existing Rate[1]	Reduced Rate	Applicable Standards[2]	Units
Toilet	1.28	—	—	gal/flush
Showerhead	1.8	—	—	gal/min @ 80 psi
Bathroom Faucet	1.2	—	—	gal/min @ 60 psi
Kitchen Faucet	1.8	1.5	2019 GBC Voluntary	gal/min @ 60 psi
Dishwashers				
Standard	5.0	3.5 or 4.25	EnergyStar or 2019 GBC Voluntary	gal/cycle
Compact	3.5	3.1 or 3.5	EnergyStar or 2019 GBC Voluntary	gal/cycle
Clothes Washers				
Top-loading, Compact	12.0	4.2	EnergyStar	gal/cycle/ft^3
Top-loading, Standard	6.5	4.3	EnergyStar	gal/cycle/ft^3
Front-loading, Compact	8.3	4.2	EnergyStar	gal/cycle/ft^3
Front-loading, Standard	4.7	3.2	EnergyStar	gal/cycle/ft^3

Sources: 2019 California Green Building Standards Code. Title 24, Part 11. Available: https://codes.iccsafe.org/content/CAGBSC2019. Accessed: January 2021.

EnergyStar. Clothes Washers Key Product Criteria. Available: https://www.energystar.gov/products/appliances/clothes_washers/key_product_criteria. Accessed: January 2021.

EnergyStar. Commercial Dishwashers Key Product Criteria. Available: https://www.energystar.gov/products/commercial_food_service_equipment/commercial_dishwashers/key_product_criteria. Accessed: January 2021.

EnergyStar. Commercial Kitchen Equipment Calculator. Available: http://www.energystar.gov/buildings/sites/default/uploads/files/commercial_kitchen_equipment_calculator.xlsx. Accessed: January 2021.

EnergyStar. Dishwashers Key Product Criteria. Available: https://www.energystar.gov/products/appliances/dishwashers/key_product_criteria. Accessed: January 2021.

gal = gallons; min = minute; psi = pounds per square inch = ft^3 = cubic feet; GBC = Green Building Code; @ = at

[1] Existing rates are calculated from (1) the 2019 Green Building Code Mandatory Measures – for toilet, showerhead, faucets; and (2) California Code of Regulations, Title 20, Division 2, Article 4, 1605.1. Federal and State Standards for Federally-Regulated Appliances – for dishwashers and clothes washers.

[2] 2019 GBC = 2019 California Green Building Code, voluntary measures

Table W-4.4. Non-Residential Baseline and Reduced Flow Rates for End Uses

End-Use/Fixture (z)	Existing Rate[1]	Reduced Rate	Applicable Standards[2]	Units
Toilet	1.28	1.12	2019 GBC Voluntary	gal/flush
Urinals				
Wall-Mounted	0.125	0.11	2019 GBC Voluntary	gal/flush
Floor-Mounted	0.5	0.44	2019 GBC Voluntary	gal/flush
Showerhead	1.8	—	2019 GBC Voluntary	gal/min. @ 80 psi
Bathroom Faucet	0.5	0.35	2019 GBC Voluntary	gal/min. @ 60 psi
Kitchen Faucet	1.8	1.6	2019 GBC Voluntary	gal/min. @ 60 psi
Dishwashers - High Temperature				
Under Counter	1.09	0.86	2019 GBC Voluntary	gal/rack
Single Tank Door	1.29	0.89	2019 GBC Voluntary	gal/rack
Single Tank Conveyor	0.87	0.70	2019 GBC Voluntary	gal/rack
Multi-Tank Conveyor	0.97	0.54	2019 GBC Voluntary	gal/rack
Dishwashers - Low Temperature				
Under Counter	1.73	1.19	2019 GBC Voluntary	gal/rack
Single Tank Door	2.1	1.18	2019 GBC Voluntary	gal/rack
Single Tank Conveyor	1.31	0.79	2019 GBC Voluntary	gal/rack
Multi-Tank Conveyor	1.04	0.54	2019 GBC Voluntary	gal/rack
Clothes Washer				
Top-loading	8.8	7.9	2019 GBC Voluntary	gal/cycle/ft^3
Front-loading	4.1	3.7 or 4.0	2019 GBC Voluntary or EnergyStar	gal/cycle/ft^3

Sources: 2019 California Green Building Standards Code. Title 24, Part 11. Available: https://codes.iccsafe.org/content/CAGBSC2019. Accessed: January 2021.

EnergyStar. Clothes Washers Key Product Criteria. Available: https://www.energystar.gov/products/appliances/clothes_washers/key_product_criteria. Accessed: January 2021.

gal = gallons; min = minute; psi = pounds per square inch = ft^3 = cubic feet; GBC = Green Building Code; @ = at

[1] Baseline rates are calculated from (1) the 2019 Green Building Code Mandatory Measures (and 2019 California Plumbing Code) – for toilet, urinal, showerhead, faucets; (2) EnergyStar calculator for commercial kitchen equipment – for dishwashers, and (3) California Code of Regulations, Title 20, Division 2, Article 4, 1605.1. Federal and State Standards for Federally-Regulated Appliances – for clothes washers.

[2] 2019 GBC = 2019 California Green Building Code, voluntary measures

Table LL-1.1. Landscape Equipment Horsepower and Load Factors by Equipment Type

Equipment	Tech Type	Average HP	Load Factor
Chainsaws	G2	2	0.70
Chainsaws Preempt	G2	2	0.70
Chippers/Stump Grinders	G4	5	0.78
Lawn Mowers	G4	4	0.36
Leaf Blowers/Vacuums	G2	2	0.94
Leaf Blowers/Vacuums	G4	4	0.94
Other Lawn & Garden Equipment	G4	6	0.58
Riding Mowers	G4	21	0.38
Tillers	G2	1	0.40
Tillers	G4	4	0.40
Trimmers/Edgers/Brush Cutters	G2	1	0.91
Trimmers/Edgers/Brush Cutters	G4	2	0.91
Wood Splitters	G4	7	0.69

Source: California Air Resources Board (CARB). 2020. 2020 Emissions Model for Small Off-Road Engines—SORE2020. Version 1.1. September. Available: https://ww2.arb.ca.gov/our-work/programs/mobile-source-emissions-inventory/msei-announcements. Database queried by Ramboll and provided electronically to ICF. September 2021.

HP = horsepower; G2 = two-stroke gasoline; G4= four-stroke gasoline

Table S-1.1. Annual Residential Waste Disposal Rates by Location

County	Single-Family	Multi-Family	County	Single-Family	Multi-Family
Alameda	0.25	0.26	Placer	0.26	0.28
Alpine	0.19	0.29	Plumas	0.26	0.35
Amador	0.26	0.33	Riverside	0.26	0.23
Butte	0.23	0.29	Sacramento	0.25	0.26
Calaveras	0.24	0.31	San Benito	0.26	0.23
Colusa	0.27	0.26	San Bernardino	0.26	0.22
Contra Costa	0.25	0.26	San Diego	0.25	0.27
Del Norte	0.24	0.31	San Francisco	0.20	0.32
El Dorado	0.26	0.29	San Joaquin	0.25	0.23
Fresno	0.26	0.23	San Luis Obispo	0.26	0.31
Glenn	0.26	0.27	San Mateo	0.26	0.26
Humboldt	0.25	0.33	Santa Barbara	0.26	0.26
Imperial	0.27	0.21	Santa Clara	0.26	0.25
Inyo	0.23	0.33	Santa Cruz	0.26	0.28
Kern	0.26	0.23	Shasta	0.25	0.30
Kings	0.26	0.24	Sierra	0.24	0.32
Lake	0.24	0.31	Siskiyou	0.24	0.33
Lassen	0.24	0.32	Solano	0.26	0.26
Los Angeles	0.27	0.25	Sonoma	0.25	0.29
Madera	0.26	0.23	Stanislaus	0.26	0.23
Marin	0.25	0.31	Sutter	0.25	0.24
Mariposa	0.24	0.35	Tehama	0.25	0.29
Mendocino	0.26	0.31	Trinity	0.24	0.35
Merced	0.26	0.22	Tulare	0.26	0.22
Modoc	0.22	0.31	Tuolumne	0.25	0.33
Mono	0.21	0.31	Ventura	0.27	0.25
Monterey	0.26	0.22	Yolo	0.26	0.27
Napa	0.25	0.27	Yuba	0.26	0.26
Nevada	0.26	0.33	All counties (statewide)	0.26	0.25
Orange	0.27	0.25			

Source: CalRecycle. n.d. Residential Waste Stream by Material Type. Available: https://www2.calrecycle.ca.gov/WasteCharacterization/ResidentialStreams. Accessed: April 2021.

Table S-1.2. Annual Statewide Non-Residential Waste Disposal Rates by Business Type

Business Type	Tons/employee/year
Arts, Entertainment, & Recreation	1.94
Durable Wholesale & Trucking	0.57
Education	0.38
Hotels & Lodging	1.40
Manufacturing -Electronic Equipment	0.31
Manufacturing - Food & Nondurable Wholesale	1.23
Manufacturing - All Other	0.44
Medical & Health	0.57
Public Administration	0.30
Restaurants	1.57
Retail Trade - Food & Beverage Stores	0.94
Retail Trade - All Other	1.74
Services - Management, Administrative, Support, & Social	0.60
Services - Professional, Technical, & Financial	1.61
Services - Repair & Personal	0.85
Not Elsewhere Classified[1]	0.46
Multifamily (administrative services)	0.74

Source: CalRecycle. n.d. Business Group Waste Stream Calculator. Available https://www2.calrecycle.ca.gov/WasteCharacterization/BusinessGroupCalculator. Accessed: January 2021.

[1] Represents a large and varied business group, ranging from farming through resource extraction, utilities, and transportation to waste management.

Table S-1.3. Waste Profile by Building Type

Building Type	Material															
	Mixed Paper (general)	Glass	Mixed Metals	Mixed Electronics	Mixed Plastics	Food Waste	Yard Trimmings	Mixed Organics	Mixed MSW	Carpet	Concrete	Asphalt Concrete	Asphalt Shingles	Dimensional Lumber	Fly Ash	Tires
Arts, Entertainment, & Recreation	21%	3%	2%	0%	14%	34%	12%	5%	6%	1%	2%	0%	0%	1%	1%	0%
Durable Wholesale & Trucking	26%	2%	4%	1%	14%	10%	3%	3%	29%	0%	2%	0%	2%	5%	0%	0%
Education	33%	0%	2%	0%	13%	34%	5%	4%	5%	3%	0%	0%	0%	0%	0%	0%
Hotels & Lodging	22%	7%	4%	0%	11%	32%	6%	4%	10%	0%	0%	2%	0%	0%	1%	0%
Manufacturing -Electronic Equipment	30%	0%	4%	2%	19%	11%	3%	5%	23%	0%	0%	0%	0%	2%	0%	0%
Manufacturing - Food & Nondurable Wholesale	23%	1%	2%	1%	17%	38%	4%	4%	10%	0%	0%	0%	0%	1%	0%	0%
Manufacturing - All Other	25%	1%	8%	1%	14%	7%	3%	6%	30%	0%	0%	0%	0%	5%	0%	0%
Medical & Health	26%	0%	2%	0%	9%	22%	4%	25%	10%	2%	0%	0%	0%	0%	0%	0%
Public Administration	35%	1%	7%	0%	13%	17%	3%	5%	16%	1%	2%	0%	0%	1%	0%	0%
Restaurants	26%	3%	2%	0%	12%	51%	2%	1%	2%	0%	0%	0%	0%	0%	1%	0%
Retail Trade - Food & Beverage Stores	28%	2%	2%	0%	16%	42%	1%	2%	5%	1%	1%	0%	0%	0%	0%	0%
Retail Trade - All Other	26%	2%	6%	0%	14%	18%	3%	7%	22%	2%	0%	0%	0%	0%	0%	0%
Services - Management, Administrative, Support, & Social	24%	1%	4%	2%	11%	25%	9%	8%	14%	1%	0%	0%	0%	1%	0%	0%
Services - Professional, Technical, & Financial	29%	1%	4%	2%	13%	8%	7%	5%	24%	1%	2%	1%	1%	1%	0%	0%

Table S-1.3. Waste Profile by Building Type (cont.)

	Material															
Building Type	Mixed Paper (general)	Glass	Mixed Metals	Mixed Electronics	Mixed Plastics	Food Waste	Yard Trimmings	Mixed Organics	Mixed MSW	Carpet	Concrete	Asphalt Concrete	Asphalt Shingles	Dimensional Lumber	Fly Ash	Tires
Services - Repair & Personal	30%	3%	9%	1%	15%	7%	4%	5%	21%	1%	0%	0%	2%	1%	0%	1%
Not Elsewhere Classified[1]	28%	5%	3%	0%	12%	16%	11%	9%	15%	0%	1%	0%	0%	1%	0%	0%
Multi Family	19%	9%	0%	1%	10%	25%	4%	1%	31%	0%	0%	0%	0%	0%	0%	0%
Single Family	20%	2%	4%	1%	14%	20%	8%	2%	28%	1%	0%	0%	0%	1%	0%	0%

Sources: CalRecycle. n.d. Business Group Waste Stream Calculator. Available https://www2.calrecycle.ca.gov/WasteCharacterization/BusinessGroupCalculator.

CalRecycle. 2020. 2018 Facility-Based Characterization of Solid Waste in California. https://www2.calrecycle.ca.gov/WasteCharacterization/Study. Accessed: January 2021.

[1] Represents a large and varied business group, ranging from farming through resource extraction, utilities, and transportation to waste management.

Table S-3.1. Solid Waste Emission Factors

Food Waste Prevention [1]		
Refrigeration & Freezer Equipment - Energy Consumption [2]	Emission Reduction Factor	Unit
Food waste prevention	1.78	MTCO2e/short ton feedstock
Residential Refrigerator/Freezer Combination	8.46	kWh/year per ft^3 of volume
	335.7	kWh/year
Residential Freezer Only	7.85	kWh/year by ft^3 of volume
	172.3	kWh/year
Residential Refrigerator Only	7.28	kWh/year by ft^3 of volume
	206.7	kWh/year
Commercial Refrigerator with solid doors or Walk-in Commercial Refrigerator with Solid Doors	36.5	kWh/year per ft^3 of volume
	744.6	kWh/year
Commercial Refrigerator with transparent doors or Walk-in Commercial Refrigerator with Transparent doors	43.8	kWh/year by ft^3 of volume
	1,219.1	kWh/year
Commercial Freezer with solid doors or Walk-in Commercial Freezer with Solid Doors	146.0	kWh/year by ft^3 of volume
	503.7	kWh/year
Commercial Freezer with transparent doors or Walk-in Commercial Freezer with transparent doors	273.8	kWh/year by ft^3 of volume
	1,496.5	kWh/year
Commercial Refrigerator/freezer with solid doors or Walk-in Commercial Refrigerator/freezer with solid doors	98.6	kWh/year by ft^3 of volume
	-259.2	kWh/year
	255.5	minimum value kWh/year

Refrigerant Leakage Assumptions [3]	Average Annual Leak Rate	Unit
Residential Refrigerator/Freezer Combination	1%	%
Residential Freezer Only	1%	%
Residential Refrigerator Only	1%	%
Commercial Refrigeration systems with charge < 50 lbs	15.0%	%
Commercial Refrigeration systems with charge 50 lbs to < 200 lbs	15.0%	%

Table S-3.1. Solid Waste Emission Factors (cont.)

Refrigerant Leakage Assumptions [3]	Average Annual Leak Rate	Unit
Commercial Refrigeration systems with charge 200 lbs to < 2,000 lbs	17.6%	%
Commercial Refrigeration systems with charge ≥ 2,000 lbs	16.6%	%
Transportation Vehicle	24.0%	%
Default Refrigerant Charge Sizes [3]	**Average Annual Leak Rate**	**Unit**
Residential refrigerators/freezers and chest freezers	0.34	lbs
Commercial Refrigerator/Freezers	7.10	lbs
Small Walk In Refrigerator/Freezer	31.40	lbs
Large Walk In Refrigerator/Freezer	122.00	lbs
Refrigerated Van	4.00	lbs
Refrigerated Box Truck	12.00	lbs
Refrigerated Heavy Duty Truck	22.00	lbs

Supported Delivery Vehicle Types [4]	
Vehicle Category	**Fuel Type**
LDA	Gasoline
	Gasoline hybrid
	Flex fuel (E85)
	PHEV10
	BEV
LDT1	Gasoline
	Gasoline hybrid
	Flex fuel (E85)
	PHEV10
	BEV
LDT2	Gasoline
	Diesel

Table S-3.1. Solid Waste Emission Factors (cont.)

Supported Delivery Vehicle Types [4]	
Vehicle Category	Fuel Type
MDV	Gasoline
	Diesel
LHDT1	Gasoline
	Diesel
	BEV
LHDT2	Gasoline
	Diesel
	BEV
MHDT	Gasoline
	Composite Diesel
	BEV
HHDT	Composite Diesel
	Natural gas
	BEV

Sources: See footnotes.

LDA = light-duty automobile; light-duty truck 1 (LDT1); light-duty truck 2 (LDT2); MDV = medium-duty vehicle; light-heavy duty truck 1 (LHDT1); light-heavy duty truck 2 (LHDT2); MHDV = medium-heavy duty vehicle; HHDV = heavy-heavy duty vehicle; MJ = megajoules; mpg = miles per gallon; mpgde = miles per gallon of diesel equivalent; gal = gallon; kWh = kilowatt-hours; CO_2e = carbon dioxide equivalent; g = grams

[1] Kumar Venkat. 2012. *The Climate Change and Economy Impacts of Food Waste in the United States.* April. Available: https://www.cleanmetrics.com/pages/ClimateChangeImpactofUSFoodWaste.pdf. Accessed: December 2023.

[2] Code of Federal Regulations. 2023. *10 CFR 431.66 – Energy Conservation standards and their effective dates.* Available: https://www.ecfr.gov/current/title-10/chapter-II/subchapter-D/part-431/subpart-C/subject-group-ECFR8115bf7451f830f/section-431.66. Accessed December: 2023.

[3] California Air Resources Board. 2016. California's High Global Warming Potential Gases Emission Inventory: Emission Inventory Methodology and Technical Support Document. April. Available: https://ww2.arb.ca.gov/sites/default/files/classic/cc/inventory/slcp/doc/hfc_inventory_tsd_20160411.pdf. Accessed: December 2023.

[4] California Air Pollution Control Officers Association. 2021. Handbook for Analyzing Greenhouse Gas Emissions Reductions, Assessing Climate Vulnerabilities, and Advancing Health and Equity: Appendix C – Table 30.2.

Table S-3.2. Solid Waste Emission Factors

Grid Electricity Emission Factors [1]		
Product	Emission Reduction Factor	Unit
ROG Electricity Emission Factor	0.000021	lbs/kWh
NOx Electricity Emission Factor	0.000131	lbs/kWh
PM2.5 Electricity Emission Factor	0.000033	lbs/kWh
Avoided Landfill Flare Emissions [1]		
ROG Flare Combustion Emission Factor – Food Waste	0.092	lbs/wet short ton of food waste
NOx Flare Combustion Emission Factor – Food Waste	0.033	lbs/wet short ton of food waste
PM2.5 Flare Combustion Emission Factor – Food Waste	0.014	lbs/wet short ton of food waste
Food Waste Prevention - Avoided Food Transportation [1,2]		
ROG Avoided Transportation Emission Factor	0.016	lbs/short ton of food waste
NOx Avoided Transportation Emission Factor	0.299	lbs/short ton of food waste
PM2.5 Avoided Transportation Emission Factor	0.009	lbs/short ton of food waste
Diesel PM Avoided Transportation Emission Factor	0.001	lbs/short ton of food waste

Sources: See footnotes.

ROG = reactive organic gases; NO_X = nitrous oxides; $PM_{2.5}$ = fine particulate matter; PM = particulate.

[1] California Air Resources Board. 2020. *Benefits Calculator Tool for the Food Waste Prevention and Rescue Program*. Available: https://ww2.arb.ca.gov/sites/default/files/auction-proceeds/calrecycle_finalfoodcalc_19-20.xlsx. Accessed: August 2023.

[2] Kumar Venkat. 2012. *The Climate Change and Economy Impacts of Food Waste in the United States*. April. Available: https://www.cleanmetrics.com/pages/ClimateChangeImpactofUSFoodWaste.pdf. Accessed: December 2023.

Table N-1.1 Above- and Below-ground Biomass Carbon Accumulation (metric tons) per Hectare by Land Cover Type and Air Basin

Air Basin[1]	Cover Type	MT C/ha	Accumulation Period (Yr)	MT C/ha/yr
Great Basin Valleys	Broadleaf Forest	94.2	60	1.57
Great Basin Valleys	Conifer Forest	118.4	60	1.97
Great Basin Valleys	Grassland	6.5	20	0.32
Great Basin Valleys	Mixed Forest (Conifer Broadleaf)	111.2	60	1.85
Great Basin Valleys	Shrubland	5.6	35	0.16
Lake County	Broadleaf Forest	134.0	60	2.23
Lake County	Conifer Forest	171.9	60	2.87
Lake County	Grassland	7.2	20	0.36
Lake County	Mixed Forest (Conifer Broadleaf)	131.0	60	2.18
Lake County	Shrubland	76.0	35	2.17
Lake Tahoe	Broadleaf Forest	101.5	60	1.69
Lake Tahoe	Conifer Forest	203.6	60	3.39
Lake Tahoe	Grassland	6.1	20	0.31
Lake Tahoe	Mixed Forest (Conifer Broadleaf)	181.6	60	3.03
Lake Tahoe	Shrubland	66.1	35	1.89
Mojave Desert	Broadleaf Forest	97.7	60	1.63
Mojave Desert	Conifer Forest	113.1	60	1.89
Mojave Desert	Grassland	6.3	20	0.31
Mojave Desert	Mixed Forest (Conifer Broadleaf)	107.3	60	1.79
Mojave Desert	Shrubland	6.9	35	0.20
Mountain Counties	Broadleaf Forest	99.2	60	1.65
Mountain Counties	Conifer Forest	183.5	60	3.06
Mountain Counties	Grassland	5.8	20	0.29
Mountain Counties	Mixed Forest (Conifer Broadleaf)	169.2	60	2.82
Mountain Counties	Shrubland	62.1	35	1.77
North Central Coast	Broadleaf Forest	92.9	60	1.55
North Central Coast	Conifer Forest	152.4	60	2.54
North Central Coast	Grassland	5.7	20	0.29
North Central Coast	Mixed Forest (Conifer Broadleaf)	113.1	60	1.88

Table N-1.1 Above- and Belowground Biomass Carbon Accumulation (metric tons) per Hectare by Land Cover Type and Air Basin (cont.)

Air Basin	Cover Type	MT C/ha	Accumulation Period (Yr)	MT C/ha/yr
North Central Coast	Shrubland	68.9	35	1.97
North Coast	Broadleaf Forest	92.9	60	1.55
North Coast	Conifer Forest	152.4	60	2.54
North Coast	Grassland	5.7	20	0.29
North Coast	Mixed Forest (Conifer Broadleaf)	113.1	60	1.88
North Coast	Shrubland	68.9	35	1.97
Northeast Plateau	Broadleaf Forest	102.9	60	1.72
Northeast Plateau	Conifer Forest	167.7	60	2.80
Northeast Plateau	Grassland	6.6	20	0.33
Northeast Plateau	Mixed Forest (Conifer Broadleaf)	139.6	60	2.33
Northeast Plateau	Shrubland	17.4	35	0.50
Sacramento Valley	Broadleaf Forest	112.3	60	1.87
Sacramento Valley	Conifer Forest	168.5	60	2.81
Sacramento Valley	Grassland	6.7	20	0.33
Sacramento Valley	Mixed Forest (Conifer Broadleaf)	157.7	60	2.63
Sacramento Valley	Shrubland	73.5	35	2.10
Salton Sea	Broadleaf Forest	82.2	60	1.37
Salton Sea	Conifer Forest	108.0	60	1.80
Salton Sea	Grassland	5.9	20	0.30
Salton Sea	Mixed Forest (Conifer Broadleaf)	103.0	60	1.72
Salton Sea	Shrubland	18.8	35	0.54
San Diego County	Broadleaf Forest	104.3	60	1.74
San Diego County	Conifer Forest	104.6	60	1.74
San Diego County	Grassland	6.6	20	0.33
San Diego County	Mixed Forest (Conifer Broadleaf)	93.4	60	1.56
San Diego County	Shrubland	56.0	35	1.60
San Francisco Bay	Broadleaf Forest	130.3	60	2.17
San Francisco Bay	Conifer Forest	178.8	60	2.98
San Francisco Bay	Grassland	6.3	20	0.31
San Francisco Bay	Mixed Forest (Conifer Broadleaf)	123.7	60	2.06

Table N-1.1 Above- and Belowground Biomass Carbon Accumulation (metric tons) per Hectare by Land Cover Type and Air Basin (cont.)

Air Basin	Cover Type	MT C/ha	Accumulation Period (Yr)	MT C/ha/yr
San Francisco Bay	Shrubland	65.3	35	1.86
San Joaquin Valley	Broadleaf Forest	90.3	60	1.50
San Joaquin Valley	Conifer Forest	154.5	60	2.57
San Joaquin Valley	Grassland	5.9	20	0.29
San Joaquin Valley	Mixed Forest (Conifer Broadleaf)	138.1	60	2.30
San Joaquin Valley	Shrubland	51.3	35	1.46
South Central Coast	Broadleaf Forest	99.0	60	1.65
South Central Coast	Conifer Forest	104.2	60	1.74
South Central Coast	Grassland	6.0	20	0.30
South Central Coast	Mixed Forest (Conifer Broadleaf)	103.9	60	1.73
South Central Coast	Shrubland	54.1	35	1.55
South Coast	Broadleaf Forest	91.1	60	1.52
South Coast	Conifer Forest	118.1	60	1.97
South Coast	Grassland	6.5	20	0.33
South Coast	Mixed Forest (Conifer Broadleaf)	98.2	60	1.64
South Coast	Shrubland	59.8	35	1.71

Source: California Air Resources Board (CARB). 2021. Carbon Accumulation Values for Major Cover Types for Each California Air Basin. Database provided to ICF in March 2021.

MT = metric tons; C = carbon; ha = hectare; yr = year

[1] Refer to Figure N-1.1 for a graphic illustrating the air basin boundaries.

Figure N-1.1. California Air Basins

Source: California Air Resources Board (CARB). 2021. California Air Basin Map. Available: https://www.arb.ca.gov/ei/maps/statemap/abmap.htm. Accessed: July 2021.

Table N-1.2. Annualized Soil Carbon Accumulation (metric tons) per Hectare by Soil Type and Land Use Type

		Soil Carbon Accumulation (MT C/ha/yr[1,2])		
Soil Type	IPCC Soil Classification	Conversion to Cropland	Conversion to Grazing Land	Conversion to Forest
Alfisols	High Activity Clay Soils	1.85	2.37	2.53
Andisols	Volcanic Soils	6.20	7.95	8.49
Aquic	Wetland Soils	2.40	3.08	3.29
Aridisols	High Activity Clay Soils	1.85	2.37	2.53
Entisols	Low Activity Clay Soils	1.25	1.60	1.71
Gelisols	Low Activity Clay Soils	1.25	1.60	1.71
Inceptisols	High Activity Clay Soils	1.85	2.37	2.53
Mollisols	High Activity Clay Soils	1.85	2.37	2.53
Oxisols	Low Activity Clay Soils	1.25	1.60	1.71
>70% Sand	Sandy Soils	0.80	1.03	1.10
Spodosols	Spodic Soils	4.30	5.51	5.89
Ultisols	Low Activity Clay Soils	1.25	1.60	1.71
Vertisols	High Activity Clay Soils	1.85	2.37	2.53
Histosol	N/A	0.00	0.00	0.00

Sources: California Air Resources Board. 2020. Benefits Calculator Tool, Agricultural Land Conservation, California Climate Investments. Available: https://ww2.arb.ca.gov/resources/documents/cci-quantification-benefits-and-reporting-materials. Accessed: March 2021.

MT = metric tons; C = carbon; ha = hectare; IPCC = Intergovernmental Panel on Climate Change; yr = year

[1]Assumes a soil carbon accumulation period of 20 years.

[2] Based on a carbon stock change factor of 1 for cropland, 1.28 for grazing land, and 1.37 for forest (California Air Resources Board 2020).

Table C-1-B.1. Average Horsepower for Diesel, Gasoline, and Compressed Natural Gas Equipment

Equipment	HP	Equipment	HP
Aerial Lifts (CNG)	19	Pavers (Diesel)	81
Aerial Lifts (Diesel)	46	Paving Equipment (Diesel)	89
Aerial Lifts (Gasoline)	33	Paving Equipment (Gasoline)	8
Air Compressors (Diesel)	37	Plate Compactors (Diesel)	8
Air Compressors (Gasoline)	6	Plate Compactors (Gasoline)	6
Bore/Drill Rigs (Diesel)	83	Pressure Washers (Diesel)	14
Bore/Drill Rigs (Gasoline)	17	Pressure Washers (Gasoline)	7
Cement and Mortar Mixers (Diesel)	10	Pumps (Diesel)	11
Cement and Mortar Mixers (Gasoline)	7	Pumps (Gasoline)	6
Concrete/Industrial Saws (Diesel)	33	Rollers (Diesel)	36
Concrete/Industrial Saws (Gasoline)	10	Rollers (Gasoline)	12
Cranes (Diesel)	367	Rough Terrain Forklifts (Diesel)	96
Cranes (Gasoline)	74	Rough Terrain Forklifts (Gasoline)	85
Crawler Tractors (Diesel)	87	Rubber Tired Dozers (Diesel)	367
Crushing/Proc. Equipment (Gasoline)	12	Rubber Tired Loaders (Diesel)	150
Dumpers/Tenders (Diesel)	16	Rubber Tired Loaders (Gasoline)	72
Dumpers/Tenders (Gasoline)	9	Scrapers (Diesel)	423
Excavators (Diesel)	36	Signal Boards (Diesel)	6
Forklifts (CNG)	70	Signal Boards (Gasoline)	8
Forklifts (Diesel)	82	Skid Steer Loaders (Diesel)	71
Forklifts (Gasoline)	70	Skid Steer Loaders (Gasoline)	19
Generator Sets (CNG)	83	Surfacing Equipment (Diesel)	399
Generator Sets (Diesel)	14	Surfacing Equipment (Gasoline)	8
Generator Sets (Gasoline)	11	Sweepers/Scrubbers (Diesel)	36
Graders (Diesel)	148	Sweepers/Scrubbers (Gasoline)	13
Off-Highway Tractors (Diesel)	38	Tractors/Loaders/Backhoes (Diesel)	84
Off-Highway Trucks (Diesel)	376	Tractors/Loaders/Backhoes (Gasoline)	63
Other Construction Equipment (Diesel)	82	Trenchers (Diesel)	40
Other Construction Equipment (Gasoline)	126	Trenchers (Gasoline)	15
Other General Industrial Equipment (Diesel)	35	Welders (Diesel)	46
Other General Industrial Equipment (Gasoline)	11	Welders (Gasoline)	16
Other Material Handling Equipment (Diesel)	93		
Other Material Handling Equipment (Gasoline)	54		

Source: California Air Resources Board (CARB). 2021. OFFROAD2017 – ORION. Available: https://arb.ca.gov/emfac/emissions-inventory. Database queried by Ramboll and provided electronically to ICF. September 2021.

CNG = compressed natural gas; HP = horsepower

Table C-3.1. Average Home-Based-Work Trip Length by California County

County	Trip Length (mi)	County	Trip Length (mi)
Alameda	11.98	Placer	13.71
Alpine	16.99	Plumas	19.06
Amador	23.12	Riverside	16.91
Butte	10.41	Sacramento	11.08
Calaveras	22.56	San Benito	21.19
Colusa	26.70	San Bernardino	15.29
Contra Costa	14.21	San Diego	11.80
Del Norte	9.05	San Francisco	9.51
El Dorado	16.21	San Joaquin	18.80
Fresno	11.35	San Luis Obispo	10.58
Glenn	19.61	San Mateo	10.89
Humboldt	10.76	Santa Barbara	7.57
Imperial	9.68	Santa Clara	10.14
Inyo	16.01	Santa Cruz	12.98
Kern	12.05	Shasta	9.63
Kings	14.18	Sierra	28.04
Lake	15.32	Siskiyou	14.04
Lassen	14.81	Solano	16.15
Los Angeles	12.04	Sonoma	11.58
Madera	16.95	Stanislaus	15.62
Marin	11.98	Sutter	13.24
Mariposa	26.94	Tehama	15.24
Mendocino	11.94	Trinity	29.35
Merced	17.47	Tulare	11.58
Modoc	12.73	Tuolumne	14.50
Mono	16.03	Ventura	13.56
Monterey	10.41	Yolo	12.41
Napa	12.32	Yuba	17.85
Nevada	14.13	All counties (statewide)	12.64
Orange	11.54		

Source: 2015 California Statewide Travel Demand Model (CSTDM).

mi = miles

Table R-1.1 Global Warming Potentials of Commonly Used Refrigerants

Refrigerant Name	Trade/Common Name (if one exists)	GWP
R-717	Ammonia	0
R-1234ze(E)	Solstice® ze	1
R-1224yd(Z)	AMOLEA™ 1224yd	1
R-744	CO_2	1
R-1234zd(E)	Solstice® zd	1
R-514A	Opteon™ XP30	2
R-290	Propane	4
R-600a	Isobutane	5
R-170	Ethane	6
R-601	Pentane	11
R-161	HFC-161	12
R-123	HCFC-123	77
R-225ca	HCFC-225ca	122
R-152a	HFC-152a	124
R-454B	Opteon™ XL41	466
R-225cb	HCFC-225cb	595
R-450A	Solstice® N13	601
R-124	HCFC-124	609
R-513A	Opteon™ XP10	631
R-32	HFC-32	675
R-452B	Opteon™ XL55	676
R-141b	HCFC-141b	725
R-466A	—	733
R-365mfc	HFC-365mfc	794
R-401C	Suva® MP-52	933
R-245fa	HFC-245fa	1,030
R-416A	FRIGC FR-12	1,085
R-401A	MP39	1,183
R-401B	MP66	1,288
R-414B	Hot Shot™	1,362
R-448A	Solstice® N40	1,387
R-449A	Opteon™ XP40	1,397
R-134a	HFC-134a	1,430
R-414A	GHX4	1,478
R-426A	RS-24	1,508
R-420A	Choice® Refrigerant	1,536
Free Zone	—	1,569
R-409A	FX-56	1,585
R-411A	—	1,597
Freeze 12	—	1,606
R-407D	—	1,627

Table R-1.1 Global Warming Potentials of Commonly Used Refrigerants (cont.)

Refrigerant Name	Trade/Common Name (if one exists)	GWP
R-4310mee	HFC-43-10mee, HFC-4310mee, R-43-10mee	1,640
R-411B	—	1,705
G2018C	—	1,731
R-453A	RS-70, RS-44b	1,765
R-407C	—	1,774
R-437A	MO49 Plus	1,805
R-417C	Hot Shot™ 2	1,809
R-22	HCFC-22, Freon	1,810
R-407F	—	1,825
R-442AF	RS-50	1,888
GHG-HP	—	1,893
R-406A	—	1,938
R-413A	MO49	2,053
R-434A	RS-45	2,070
R-410A	Puron®, AZ-20	2,088
R-407A	KLEA® 60	2,107
R-427A	—	2,138
R-452A	Opteon™ XP44	2,141
R-410B	AC9100	2,229
R-438A	MO99	2,265
R-423A	39TC	2,280
R-142b	HCFC-142b	2,310
R-417A	MO59, NU22	2,346
NARM-502	—	2,375
GHG-X5	—	2,377
R-402B	HP-81	2,416
R-424A	RS-44	2,440
R-422B	NU-22B	2,526
R-421A	—	2,631
R-422D	MO29	2,730
R-402A	HP-80	2,788
R-407B	—	2,804
R-422C	One Shot™	3,085
R-422A	—	3,143
R-421B	Choice® 421B	3,190
R-227ea	HFC-227ea	3,220
R-408A	FX-10	3,432
R-125	HFC-125	3,500
R-428A	RS-52	3,607
Isceon® MO89	—	3,805
R-404A	HP-62	3,900

Table R-1.1 Global Warming Potentials of Commonly Used Refrigerants (cont.)

Refrigerant Name	Trade/Common Name (if one exists)	GWP
R-507	AZ-50	3,985
R-403B	—	4,458
R-143a	HFC-143a	4,470
R-502	—	4,657
R-11	CFC-11	4,750
R-113	CFC-113	6,130
EP-88	—	6,427
R-13b1	Halon 1301	7,140
R-115	CFC-115	7,370
R-14	PFC-14, CF4	7,390
R-500	—	8,077
R-218	PFC-218	8,830
R-236fa	HFC-236fa	9,810
R-114	CFC-114	10,000
R-12	CFC-12	10,900
R-116	PFC-116	12,200
R-508B	—	13,396
R-13	CFC-13	14,400
R-503	—	14,560
R-23	HFC-23	14,800

Sources: California Air Resource Board (CARB). 2020. Refrigerant Management Program: Service Technicians & Contractors. Available: https://ww2.arb.ca.gov/our-work/programs/refrigerant-management-program/rmp-service-technicians-contractors. Accessed: January 2021.

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— = no common name; R= refrigerant; HFC = hydrofluorocarbon; PFC = perfluorocarbon; CFC = Chlorofluorocarbons; GHG = greenhouse gas; GWP = global warming potential

Table R-1.2. Charge Size, Service Rate, and Leak Rate for Various Equipment Types by Land Use Type

Land Use Type	Equipment Type	Refrigerant Charge (kg)	Leak Rate	Service Rate	Total Leak Rate[1]
Single Family Housing	Household refrigerators and/or freezers	0.15	0.6%	0.0%	0.6%
Apartments Low Rise	Household refrigerators and/or freezers	0.15	0.6%	0.0%	0.6%
Apartments Mid Rise	Household refrigerators and/or freezers	0.15	0.6%	0.0%	0.6%
Apartments High Rise	Household refrigerators and/or freezers	0.15	0.6%	0.0%	0.6%
Condo/Townhouse	Household refrigerators and/or freezers	0.15	0.6%	0.0%	0.6%
Condo/Townhouse High Rise	Household refrigerators and/or freezers	0.15	0.6%	0.0%	0.6%
Mobile Home Park	Household refrigerators and/or freezers	0.15	0.6%	0.0%	0.6%
Retirement Community	Household refrigerators and/or freezers	0.04	0.6%	0.0%	0.6%
Congregate Care	Household refrigerators and/or freezers	0.04	0.6%	0.0%	0.6%
User Defined Residential	Household refrigerators and/or freezers	0.15	0.6%	0.0%	0.6%
Day-Care Center	Household refrigerators and/or freezers	0.15	0.6%	0.0%	0.6%
Elementary School	Household refrigerators and/or freezers	0.15	0.6%	0.0%	0.6%
Junior High School	Household refrigerators and/or freezers	0.15	0.6%	0.0%	0.6%
High School	Household refrigerators and/or freezers	0.15	0.6%	0.0%	0.6%
Junior College (2yr)	Household refrigerators and/or freezers	0.15	0.6%	0.0%	0.6%
University/College (4yr)	Household refrigerators and/or freezers	0.15	0.6%	0.0%	0.6%
Library	Household refrigerators and/or freezers	0.15	0.6%	0.0%	0.6%
Place of Worship	Household refrigerators and/or freezers	0.15	0.6%	0.0%	0.6%
User Defined Educational	Household refrigerators and/or freezers	0.15	0.6%	0.0%	0.6%
City Park	Stand-alone retail refrigerators and freezers	0.40	1.0%	0.0%	1.0%
Golf Course	Stand-alone retail refrigerators and freezers	0.40	1.0%	0.0%	1.0%
Recreational Swimming Pool	Stand-alone retail refrigerators and freezers	0.40	1.0%	0.0%	1.0%
Racquet Club	Stand-alone retail refrigerators and freezers	0.40	1.0%	0.0%	1.0%
Health Club	Stand-alone retail refrigerators and freezers	0.40	1.0%	0.0%	1.0%
Movie Theater (No Matinee)	Stand-alone retail refrigerators and freezers	0.40	1.0%	0.0%	1.0%
Arena	Stand-alone retail refrigerators and freezers	0.40	1.0%	0.0%	1.0%
Quality Restaurant	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%

Table R-1.2. Charge Size, Service Rate, and Leak Rate for Various Equipment Types by Land Use Type (cont.)

Land Use Type	Equipment Type	Refrigerant Charge (kg)	Leak Rate	Service Rate	Total Leak Rate[1]
High Turnover (Sit Down Restaurant)	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
Fast Food Restaurant with Drive Thru	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
Fast Food Restaurant w/o Drive Thru	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
Hotel	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
Motel	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
User Defined Recreational	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
Free-Standing Discount store	Stand-alone retail refrigerators and freezers	0.40	1.0%	0.0%	1.0%
Free-Standing Discount Superstore	Stand-alone retail refrigerators and freezers	0.40	1.0%	0.0%	1.0%
Discount Club	Stand-alone retail refrigerators and freezers	0.40	1.0%	0.0%	1.0%
Regional Shopping Center	Stand-alone retail refrigerators and freezers	0.40	1.0%	0.0%	1.0%
Electronic Superstore	Stand-alone retail refrigerators and freezers	0.40	1.0%	0.0%	1.0%
Home Improvement Superstore	Stand-alone retail refrigerators and freezers	0.40	1.0%	0.0%	1.0%
Strip Mall	Stand-alone retail refrigerators and freezers	0.40	1.0%	0.0%	1.0%
Hardware/Paint Store	Stand-alone retail refrigerators and freezers	0.40	1.0%	0.0%	1.0%
Supermarket	Supermarket refrigeration and condensing units	1,360.0	16.5%	16.5%	33.0%
Convenience Market (24 hour)	Supermarket refrigeration and condensing units	1,360.0	16.5%	16.5%	33.0%
Convenience Market with Gas Pumps	Supermarket refrigeration and condensing units	1,360.0	16.5%	16.5%	33.0%
Automobile Care Center	Supermarket refrigeration and condensing units	1,360.0	16.5%	16.5%	33.0%
Gasoline/Service Station	Supermarket refrigeration and condensing units	1,360.0	16.5%	16.5%	33.0%
User Defined Retail	Supermarket refrigeration and condensing units	1,360.0	16.5%	16.5%	33.0%
Bank (with Drive-Through)	Household refrigerators and/or freezers	0.15	0.6%	0.0%	0.6%
General Office Building	Household refrigerators and/or freezers	0.15	0.6%	0.0%	0.6%
Office Park	Household refrigerators and/or freezers	0.15	0.6%	0.0%	0.6%
Research & Development	Household refrigerators and/or freezers	0.15	0.6%	0.0%	0.6%
Government Office Building	Household refrigerators and/or freezers	0.15	0.6%	0.0%	0.6%
Government (Civic Center)	Household refrigerators and/or freezers	0.15	0.6%	0.0%	0.6%
Pharmacy/Drugstore with Drive Thru	Household refrigerators and/or freezers	0.15	0.6%	0.0%	0.6%
Pharmacy/Drugstore w/o Drive Thru	Household refrigerators and/or freezers	0.15	0.6%	0.0%	0.6%

Table R-1.2. Charge Size, Service Rate, and Leak Rate for Various Equipment Types by Land Use Type (cont.)

Land Use Type	Equipment Type	Refrigerant Charge (kg)	Leak Rate	Service Rate	Total Leak Rate[1]
Medical Office Building	Household refrigerators and/or freezers	0.15	0.6%	0.0%	0.6%
Hospital	Household refrigerators and/or freezers	0.15	0.6%	0.0%	0.6%
User Defined Commercial	Other commercial A/C and heat pumps	13.0	4.0%	4.0%	8.0%
Unrefrigerated Warehouse-No Rail	Cold storage	565.0	7.5%	7.5%	15.0%
Unrefrigerated Warehouse-Rail	Cold storage	565.0	7.5%	7.5%	15.0%
Refrigerated Warehouse-No Rail	Cold storage	565.0	7.5%	7.5%	15.0%
Refrigerated Warehouse-Rail	Cold storage	565.0	7.5%	7.5%	15.0%
General Light Industry	Other commercial A/C and heat pumps	13.0	4.0%	4.0%	8.0%
General Heavy Industry	Other commercial A/C and heat pumps	13.0	4.0%	4.0%	8.0%
Industrial Park	Other commercial A/C and heat pumps	13.0	4.0%	4.0%	8.0%
Manufacturing	Other commercial A/C and heat pumps	13.0	4.0%	4.0%	8.0%
User Defined Industrial	Other commercial A/C and heat pumps	13.0	4.0%	4.0%	8.0%

Source: U.S. Environmental Protection Agency. 2016. Accounting Tool to Support Federal Reporting of Hydrofluorocarbon Emissions: Supporting Documentation. October 2016. Available: https://www.epa.gov/sites/production/files/2015-09/documents/hfc_emissions_accounting_tool_supporting_documentation.pdf. Accessed: January 2021.

A/C = air conditioning; yr = year

[1] Total leak rate is the sum of the operational leak rate and the service leak rate. This total value would only occur in those years in which servicing is required, which may not be every year of the equipment life.

Table R-1.3. Charge Size, Service Rate, and Leak Rate for Various Equipment Types by Land Use Type

Land Use Type	Equipment Type	Refrigerant Charge (kg)	Leak Rate	Service Rate	Total Leak Rate[1]
Single Family Housing	Average room A/C & Other residential A/C and heat pumps	2.75	2.5%	2.5%	5.0%
Apartments Low Rise	Average room A/C & Other residential A/C and heat pumps	2.75	2.5%	2.5%	5.0%
Apartments Mid Rise	Average room A/C & Other residential A/C and heat pumps	2.75	2.5%	2.5%	5.0%
Apartments High Rise	Average room A/C & Other residential A/C and heat pumps	2.75	2.5%	2.5%	5.0%
Condo/Townhouse	Average room A/C & Other residential A/C and heat pumps	2.75	2.5%	2.5%	5.0%
Condo/Townhouse High Rise	Average room A/C & Other residential A/C and heat pumps	2.75	2.5%	2.5%	5.0%
Mobile Home Park	Average room A/C & Other residential A/C and heat pumps	2.75	2.5%	2.5%	5.0%

Table R-1.3. Charge Size, Service Rate, and Leak Rate for Various Equipment Types by Land Use Type (cont.)

Land Use Type	Equipment Type	Refrigerant Charge (kg)	Leak Rate	Service Rate	Total Leak Rate[1]
Retirement Community	Average room A/C & Other residential A/C and heat pumps	2.75	2.5%	2.5%	5.0%
Congregate Care	Average room A/C & Other residential A/C and heat pumps	2.75	2.5%	2.5%	5.0%
User Defined Residential	Average room A/C & Other residential A/C and heat pumps	2.75	2.5%	2.5%	5.0%
Day-Care Center	Stand-alone retail refrigerators and freezers	0.40	1.0%	0.0%	1.0%
Elementary School	Stand-alone retail refrigerators and freezers	0.40	1.0%	0.0%	1.0%
Junior High School	Stand-alone retail refrigerators and freezers	0.40	1.0%	0.0%	1.0%
High School	Stand-alone retail refrigerators and freezers	0.40	1.0%	0.0%	1.0%
Junior College (2yr)	Stand-alone retail refrigerators and freezers	0.40	1.0%	0.0%	1.0%
University/College (4yr)	Stand-alone retail refrigerators and freezers	0.40	1.0%	0.0%	1.0%
Library	Stand-alone retail refrigerators and freezers	0.40	1.0%	0.0%	1.0%
Place of Worship	Stand-alone retail refrigerators and freezers	0.40	1.0%	0.0%	1.0%
User Defined Educational	Stand-alone retail refrigerators and freezers	0.40	1.0%	0.0%	1.0%
City Park	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
Golf Course	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
Recreational Swimming Pool	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
Racquet Club	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
Health Club	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
Movie Theater (No Matinee)	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
Arena	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
Quality Restaurant	Walk-in refrigerators and freezers	10.00	7.5%	7.5%	15.0%
High Turnover (Sit Down Restaurant)	Walk-in refrigerators and freezers	10.00	7.5%	7.5%	15.0%
Fast Food Restaurant with Drive Thru	Walk-in refrigerators and freezers	10.00	7.5%	7.5%	15.0%
Fast Food Restaurant w/o Drive Thru	Walk-in refrigerators and freezers	10.00	7.5%	7.5%	15.0%
Hotel	Walk-in refrigerators and freezers	10.00	7.5%	7.5%	15.0%
Motel	Walk-in refrigerators and freezers	10.00	7.5%	7.5%	15.0%
User Defined Recreational	Walk-in refrigerators and freezers	10.00	7.5%	7.5%	15.0%

Table R-1.3. Charge Size, Service Rate, and Leak Rate for Various Equipment Types by Land Use Type (cont.)

Land Use Type	Equipment Type	Refrigerant Charge (kg)	Leak Rate	Service Rate	Total Leak Rate[1]
Free-Standing Discount store	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
Free-Standing Discount Superstore	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
Discount Club	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
Regional Shopping Center	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
Electronic Superstore	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
Home Improvement Superstore	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
Strip Mall	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
Hardware/Paint Store	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
Supermarket	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
Convenience Market (24 hour)	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
Convenience Market with Gas Pumps	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
Automobile Care Center	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
Gasoline/Service Station	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
User Defined Retail	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
Bank (with Drive-Through)	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
General Office Building	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
Office Park	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
Research & Development	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
Government Office Building	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
Government (Civic Center)	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
Pharmacy/Drugstore with Drive Thru	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
Pharmacy/Drugstore w/o Drive Thru	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
Medical Office Building	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
Hospital	Stand-alone retail refrigerators and freezers	0.40	1.0%	0.0%	1.0%

Source: U.S. Environmental Protection Agency. 2016. Accounting Tool to Support Federal Reporting of Hydrofluorocarbon Emissions: Supporting Documentation. October 2016. Available: https://www.epa.gov/sites/production/files/2015-09/documents/hfc_emissions_accounting_tool_supporting_documentation.pdf. Accessed: January 2021.

A/C = air conditioning; yr = year

[1] Total leak rate is the sum of the operational leak rate and the service leak rate. This total value would only occur in those years in which servicing is required, which may not be every year of the equipment life.

Table R-1.4. Charge Size, Service Rate, and Leak Rate for Various Equipment Types by Land Use Type

Land Use Type	Equipment Type	Refrigerant Charge (kg)	Leak Rate	Service Rate	Total Leak Rate[1]
Day-Care Center	Walk-in refrigerators and freezers	10.00	7.5%	7.5%	15.0%
Elementary School	Walk-in refrigerators and freezers	10.00	7.5%	7.5%	15.0%
Junior High School	Walk-in refrigerators and freezers	10.00	7.5%	7.5%	15.0%
High School	Walk-in refrigerators and freezers	10.00	7.5%	7.5%	15.0%
Junior College (2yr)	Walk-in refrigerators and freezers	10.00	7.5%	7.5%	15.0%
University/College (4yr)	Walk-in refrigerators and freezers	10.00	7.5%	7.5%	15.0%
Library	Walk-in refrigerators and freezers	10.00	7.5%	7.5%	15.0%
Place of Worship	Walk-in refrigerators and freezers	10.00	7.5%	7.5%	15.0%
User Defined Educational	Walk-in refrigerators and freezers	10.00	7.5%	7.5%	15.0%
Movie Theater (No Matinee)	Walk-in refrigerators and freezers	10.00	7.5%	7.5%	15.0%
Arena	Walk-in refrigerators and freezers	10.00	7.5%	7.5%	15.0%
Quality Restaurant	Household refrigerators and/or freezers	0.00	0.6%	0.0%	0.6%
High Turnover (Sit Down Restaurant)	Household refrigerators and/or freezers	0.00	0.6%	0.0%	0.6%
Fast Food Restaurant with Drive Thru	Household refrigerators and/or freezers	0.00	0.6%	0.0%	0.6%
Fast Food Restaurant w/o Drive Thru	Household refrigerators and/or freezers	0.00	0.6%	0.0%	0.6%
Hotel	Household refrigerators and/or freezers	0.00	0.6%	0.0%	0.6%
Motel	Household refrigerators and/or freezers	0.00	0.6%	0.0%	0.6%
User Defined Recreational	Household refrigerators and/or freezers	0.00	0.6%	0.0%	0.6%
Free-Standing Discount Superstore	Walk-in refrigerators and freezers	10.00	7.5%	7.5%	15.0%
Strip Mall	Walk-in refrigerators and freezers	10.00	7.5%	7.5%	15.0%
Hospital	Walk-in refrigerators and freezers	10.00	7.5%	7.5%	15.0%

Source: U.S. Environmental Protection Agency. 2016. Accounting Tool to Support Federal Reporting of Hydrofluorocarbon Emissions: Supporting Documentation. October 2016. Available: https://www.epa.gov/sites/production/files/2015-09/documents/hfc_emissions_accounting_tool_supporting_documentation.pdf. Accessed: January 2021.

A/C = air conditioning; yr = year

[1] Total leak rate is the sum of the operational leak rate and the service leak rate. This total value would only occur in those years in which servicing is required, which may not be every year of the equipment life.

Table R-1.5. Charge Size, Service Rate, and Leak Rate for Various Equipment Types by Land Use Type

Land Use Type	Equipment Type	Refrigerant Charge (kg)	Leak Rate	Service Rate	Total Leak Rate[1]
Day-Care Center	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
Elementary School	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
Junior High School	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
High School	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
Junior College (2yr)	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
University/College (4yr)	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
Library	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
Place of Worship	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
User Defined Educational	Other commercial A/C and heat pumps	13.00	4.0%	4.0%	8.0%
Hospital	Chillers	500.00	2.0%	2.0%	4.0%

Source: U.S. Environmental Protection Agency. 2016. Accounting Tool to Support Federal Reporting of Hydrofluorocarbon Emissions: Supporting Documentation. October 2016. Available: https://www.epa.gov/sites/production/files/2015-09/documents/hfc_emissions_accounting_tool_supporting_documentation.pdf. Accessed: January 2021.

A/C = air conditioning; yr = year

[1] Total leak rate is the sum of the operational leak rate and the service leak rate. This total value would only occur in those years in which servicing is required, which may not be every year of the equipment life.

Climate Vulnerability Worksheets

APPENDIX D

This appendix contains worksheets that planners can use to assess climate vulnerability.

STEP 1 Identify the Extent to which the Measure Reduces Potential Impacts

Exposure

How does the measure remove exposure?

How much does the project design reduce future exposure?

How much does the post-construction operations and management reduce future exposure?

Sensitivity

How much does the measure mitigate the hazard's effect on fragile or critical components of the project?

Does the measure lower the hazard's effect on individuals, particularly members of vulnerable populations?

Does the measure lower the impact to an operational component impacted by the climate hazard?

Potential Impacts: Exposure + Sensitivity

What is the net effect of the measure on reducing exposure and sensitivity?

Impacts Reduction Rating Scale:

0. No Effect 1. Low 2. Medium 3. High 4. Very High

Notes on Rating:

STEP 2 Quantify the Extent to which the Measure Bolsters Adaptive Capacity

Does the measure incorporate policies or standards that account for climate change?

How does the measure improve the project's management of climate hazards?

Does the measure reduce how exposed individuals, and specifically vulnerable populations are exposed to the hazard?

Adaptive Capacity Gains Rating Scale: 0. No Effect 1. Low 2. Medium 3. High 4. Very High

Notes on Rating:

STEP 3 Estimate the Impact on Vulnerability Reduction

How much does the reduction in potential impacts and adaptive capacity lower your overall vulnerability score?

- Identify original vulnerability score
- Subtract potential impacts benefit from existing score
- Add adaptive capacity benefit from existing score
- Update vulnerability score

Potential Impacts					
5	5	5	4	3	2
4	5	4	3	2	1
3	4	3	2	2	1
2	3	2	2	1	1
1	2	1	1	1	1
	Low	Low-Med	Med	Mid-High	High
	Adaptive Capacity				

Note: Color coding indicates severity of the score, with green cells showing the lowest (least vulnerable) scores and dark red showing the highest (most vulnerable)

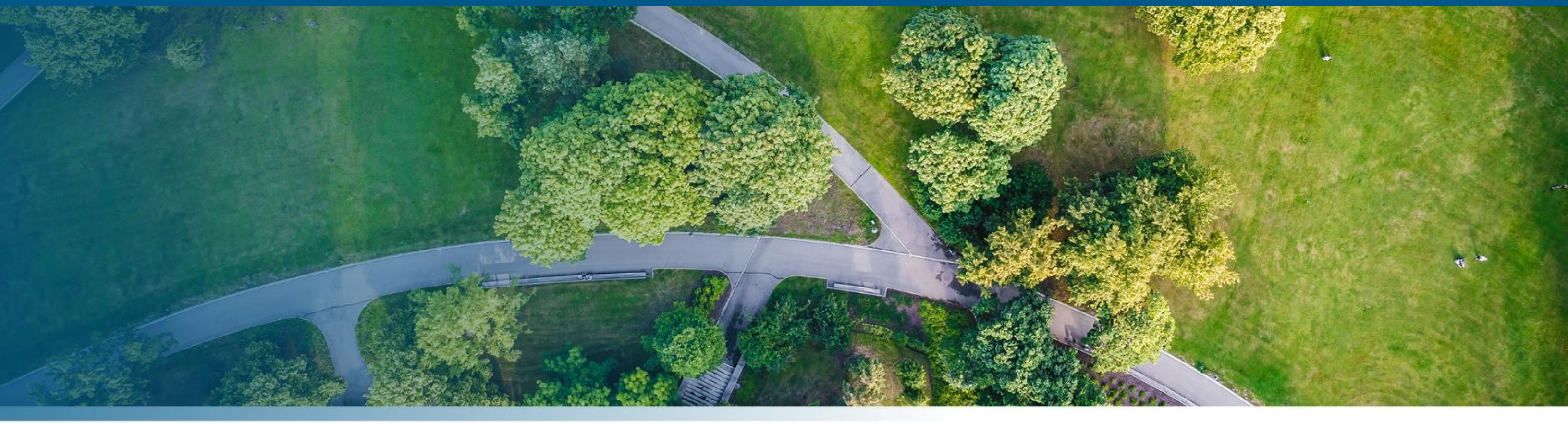
STEP 4 Consider Co-benefits

Consult the co-benefits listed under each measure in Table 4-7 in Chapter 4, *Assessing Climate Exposures and Measures to Reduce Vulnerabilities*. Some measures' co-benefits can be more quantitatively estimated as explained in the Chapter 3, *Measures to Reduce GHG Emissions*.

Improved Air Quality	Energy and Fuel Savings	VMT Reductions	Water Conservation	Enhanced Pedestrian or Traffic Safety
Improved Public Health	Improved Ecosystem Health	Enhanced Energy Security	Enhanced Food Security	Social Equity

Measure Index

APPENDIX E



This appendix provides a roadmap for all measures in the Handbook—emissions reduction, climate risk reduction, and health and equity—by topic or focus area. While not a true index, it aims to assist users to find measures based on concepts, themes, and topics across all chapters in the Handbook. A user primarily interested in addressing tree canopy, for example, can find all relevant measures quickly using the index, regardless of chapter.

The index organizes measures by the following concepts, themes, and topics.

Active transportation: Measures that facilitate or increase human-powered transportation, such as walking, bicycling, rollerskating, or skateboarding.

Affordable housing: Measures that support increased access to affordable housing.

Air quality exposure reduction: Measures that reduce people's direct exposure to air pollution.

Climate resilience: Measures that support an individual, project, community, or jurisdiction's ability and capacity to withstand, respond to, and recover from climate change-related impact and disruptions.

Community ownership and self-determination: Measures that increase a community's capacity to meaningfully participate in and have ownership over the decision making, planning, and outcomes that affect their community.

Economic resilience: Measures that enhance the local economy's capacity to withstand, respond to, and recover from disruptions, both natural and human-caused.

Energy and grid resilience: Measures that increase individual and community energy savings, support renewable energy generation, and enhance grid resilience.

Food justice and access: Measures that increase food access for all and address structural barriers to food access.

Green infrastructure and low-impact development (LID): Measures that support systems and practices to manage stormwater using natural processes—through infiltration, evapotranspiration, or storage and use—to protect water quality and water resources, reduce flood risk, recharge groundwater, and protect habitat. LID and green infrastructure generally seek to protect, restore, or create green spaces (U.S. EPA n.d.).

Job development: Measures that generate jobs, support emerging industries, and increase employment.

Nature-based solutions: Measures that enlist natural processes, habitats, and ecosystems to help address environmental or socioeconomic challenges while simultaneously benefiting the environment.

Passive survivability: Measures that support a building's ability to maintain livable conditions when facing extreme heat and weather, particularly when disconnected from utilities.

Poverty: Measures that help to address poverty and socio-economic deprivation.

Racial equity: Measures that advance racial justice, address historical racial inequities, and support conditions in which racial identity no longer predicts one's socioeconomic outcomes, health, and wellbeing.

Social inclusion: Measures that support the just and fair inclusion of all individuals into society in which all can participate, prosper, and reach their full potential (PolicyLink n.d.).

Social resilience: Measures that support the ability of people and communities to respond to and recover collectively from traumas, disruptions, and stresses. While social resilience is intangible and a reflection of the strength of community bonds, it can be fostered by the built environment through the creation of social spaces that facilitate relationship-building.

Tree canopy: Measures that support tree planting as well as care and maintenance of existing trees in developed areas.

Urban heat island (UHI) reduction: Measures that reduce the urban heat island effect and extreme heat in developed areas through the use of passive cooling strategies and design features.

Active Transportation

Chapter 3

T-3. Provide Transit-Oriented Development

T-6. Implement Commute Trip Reduction Program (Mandatory Implementation and Monitoring)

T-9. Implement Subsidized or Discounted Transit Program

T-10. Provide End-of-Trip Bicycle Facilities

T-17. Improve Street Connectivity

T-18. Provide Pedestrian Network Improvement

T-19-A. Construct or Improve Bike Facility

T-19-B. Construct or Improve Bike Boulevard

T-20. Expand Bikeway Network

T-22-A. Implement Pedal (Non-Electric) Bikeshare Program

T-22-B. Implement Electric Bikeshare Program

T-22-D. Transition Conventional to Electric Bikeshare

T-25. Extend Transit Network Coverage or Hours

T-26. Increase Transit Service Frequency

T-28. Provide Bus Rapid Transit

T-29. Reduce Transit Fares

T-31-A. Locate Project in Area with High Destination Accessibility

T-31-B. Improve Destination Accessibility in Underserved Areas

T-32. Orient Project Toward Transit, Bicycle, or Pedestrian Facility

T-33. Locate Project near Bike Path/ Bike Lane

T-34. Provide Bike Parking

T-35. Provide Traffic Calming Measures

T-36. Create Urban Non-Motorized Zones

T-37. Dedicate Land for Bike Trails

T-46. Provide Transit Shelters

T-47. Provide Bike Parking Near Transit

T-56. Active Modes of Transportation for Youth

Chapter 4

MH-14. Maintain Trails and Parks

MH-16. Identify At-Risk Transportation Corridors

MH-17. Identify Alternative Routes for Transit Service

EH-2. Provide Heat Mitigation for Public Walkways and Transit Stops

Chapter 5

CE-1. Create a Construction Plan with Community Input

CE-2. Ensure Active Modes Access During Construction

PH-2. Increase Urban Tree Canopy and Green Spaces

IC-2. Adopt Design Standards

IC-3. Promotes Accessibility

IC-8. Enhanced Access to Community Resources

AH-2. Promote Affordable Housing in Transit-Rich Areas

Affordable Housing

Chapter 3

T-1. Increase Residential Density

T-3. Provide Transit-Oriented Development

T-4. Integrate Affordable and Below Market Rate Housing

T-16. Unbundle Residential Parking Costs from Property Cost

PH-1. Establish Vegetative Barriers to Reduce Pollution Exposure

PH-2. Increase Urban Tree Canopy and Green Spaces

PH-3. Highly Rated Air Filtration

PH-4. Create Healthful, Sustainable Indoor Spaces

IC-2. Adopt Design Standards

CR-2. Support the Development and Operations of Community Resilience Centers

Climate Resilience

Chapter 3

T-17. Improve Street Connectivity

T-18. Provide Pedestrian Network Improvement

T-19-A. Construct or Improve Bike Facility

T-19-B. Construct or Improve Bike Boulevard

T-20. Expand Bikeway Network

T-32. Orient Project Toward Transit, Bicycle, or Pedestrian Facility

T-33. Locate Project near Bike Path/Bike Lane

T-56. Active Modes of Transportation for Youth

E-1. Buildings Exceed 2019 Title 24 Building Envelope Energy Efficiency Standards

E-4. Install Cool Roofs and/or Cool Walls in Residential Development

E-5. Install Green Roofs in Place of Dark Roofs

E-6. Encourage Residential Participation in Existing Demand Response Program(s)

E-10-A. Establish Onsite Renewable Energy Systems—Generic

E-10-B. Establish Onsite Renewable Energy Systems—Solar Power

E-10-C. Establish Onsite Renewable Energy Systems—Wind Power

E-16. Require Zero Net Energy Buildings

E-17. Require Renewable-Surplus Buildings

E-20. Install Whole-House Fans

E-21. Install Cool Pavements

E-23. Use Microgrids and Energy Storage

E-24. Provide Battery Storage

E-25. Install Electric Heat Pumps

W-1. Use Reclaimed Non-Potable Water

W-2. Use Grey Water

W-3. Use Locally Sourced Water Supply

W-4. Require Low-Flow Water Fixtures

W-5. Design Water-Efficient Landscapes

W-6. Reduce Turf in Landscapes and Lawns

W-7. Adopt a Water Conservation Strategy

S-3. Require Edible Food Recovery Program Partnerships with Food Generators

S-5. Source Wood Materials from Urban Wood Re-Use Program

N-1. Create New Vegetated Open Space

N-2. Expand Urban Tree Planting

N-3. Implement Management Practices to Improve the Health and Function of Natural and Working Lands

N-5. Establish a Local Farmer's Market

N-6. Establish Community Gardens

C-4. Use Local and Sustainable Building Materials

Chapter 4

All measures in the chapter.

Chapter 5

CCD-4. Conduct Community Asset Mapping

IE-1. Prioritize Outreach to Communities of Color and Underserved Groups

IE-3. Elevate Voices of Underrepresented Groups in Project Direction and Outreach

IE-4. Inclusive Community Meetings

PH-1. Establish Vegetative Barriers to Reduce Pollution Exposure

PH-2. Increase Urban Tree Canopy and Green Spaces

PH-3. Highly Rated Air Filtration

PH-5. Provide Equitable Food Access and Food Justice

IC-2. Adopt Design Standards

IC-4. Enhanced Open and Green Spaces

IC-5. Designated Space for Community-Based Organizations, Disadvantaged Businesses, and Community Assets

IC-8. Enhanced Access to Community Resources

AH-1. Support Community Land Trusts

CR-1. Adapt and Re-use Vacant Lots for Green Infrastructure

CR-2. Support the Development and Operations of Community Resilience Centers

CR-3. Passive Survivability

Community Ownership and Self-Determination

Chapter 3

T-31-B. Improve Destination Accessibility in Underserved Areas

N-6. Establish Community Gardens

Chapter 4

MH-11. Encourage/Actively Engage Community in Local Planning

MH-12. Enhance Community Network Support

MH-13. Support Local Food Systems

MH-35. Increase Parks in Underserved Communities

MH-36. Decentralize and Localize Energy Production and Storage

MH-37. Develop Climate Hazard Notification System

Chapter 5

CCD-1. Consult Pre-existing Community Knowledge/Priorities

CCD-2. Conduct a Stakeholder Analysis and Develop a Community-Centered Outreach Plan

CCD-3. Conduct a Community Needs Assessment

CCD-4. Conduct Community Asset Mapping

CCD-5. Establish a Community Benefits Agreement

IE-2. Establish or Join a Community Project Steering Committee

IE-3. Elevate Voices of Underrepresented Groups in Project Direction and Outreach

IE-6. Conduct an Equity Assessment with Community Project Steering Committee

A-1. Use Participatory Budgeting

A-2. Establish Incentive and Penalty Provisions for Community Priorities

A-3. Evaluate Project Performance with Community Project Steering Committee/CBO

A-5. Public Disclosure of Project Commitments

PH-2. Increase Urban Tree Canopy and Green Spaces

IC-1. Invests in Local Arts and Culture to Affirm Community Identity

IC-5. Designated Space for Community-Based Organizations, Disadvantaged Businesses, and Community Assets

IC-8. Enhanced Access to Community Resources

AH-1. Support Community Land Trusts

Economic Resilience

Chapter 3

Chapter 4

EP-4. Waterproof Operational Equipment

EP-5. Upgrade Wastewater Systems

EP-6. Site Outside Floodplain

EP-7. Maintain Stormwater Infrastructure on Key Routes

WF-1. Implement Fire-Safe Landscaping

WF-2. Install Fire Suppression Systems and Improve Structural Strength

WF-3. Strengthen Vulnerable Assets in High Wildfire Risk Areas

WF-4. Educate on Wildfire Resistant Landscaping

WF-5. Site Outside WUI

WF-6. Designate and Strengthen Wildfire Emergency Routes

WF-7. Develop Fire Risk Assessment for New Development

WF-8. Implement Fuel Management

WF-10. Adopt WUI Building Standards

EH-4. Enhance Building Envelope Efficiency

EH-5. Upgrade to Efficient Equipment/Infrastructure

EH-7. Install Equipment Cooling System

D-6. Build Alternatives Forms of Water Recreation

D-7. Diversify Water Supply Sources

D-8. Develop Groundwater Sustainability Plan

Chapter 5

CCD-5. Establish a Community Benefits Agreement

CE-6. Provide Funds to Businesses Impacted by Construction Activities

PH-5. Provide Equitable Food Access and Food Justice

IEP-1. Local Labor and Apprenticeships (Construction)

IEP-2. Local Labor and Apprenticeships (Operations)

IEP-3. Contract with Diverse Suppliers

IEP-4. Use of Locally/Regionally Manufactured Products and Materials

IEP-5. Higher Wage and Working Condition Standards

IC-5. Designated Space for Community-Based Organizations, Disadvantaged Businesses, and Community Assets

IC-6. Create Non-Standard Commercial or Retail Spaces

IC-8. Enhanced Access to Community Resources

AH-3. Protection for Existing Tenants of Redevelopment Projects

AH-4. Incorporates Permanent Supportive Housing

Energy and Grid Resilience

Chapter 3

T-53. Electrify Loading Docks

T-54. Install Hydrogen Fueling Infrastructure

Energy section – all measures except E-14

E-26. Biomass Energy

Water section – all measures

LL-1. Replace Gas Powered Landscape Equipment with Zero-Emission Landscape Equipment

C-1-A. Use Electric or Hybrid Powered Equipment

C-1-B. Use Cleaner-Fuel Equipment

N-8. Agricultural Equipment Efficiency

M-6 Off-Road Equipment Efficiency

Chapter 4

MH-1. Strengthen Energy Infrastructure

MH-28. Transition to Climate-Smart Energy

Food Justice and Access

Chapter 3

Chapter 4

Chapter 5

Green Infrastructure and Low-Impact Development (LID)

Chapter 3

Chapter 4

Chapter 5

PH-2. Increase Urban Tree Canopy and Green Spaces

IC-4. Enhanced Open and Green Spaces

CR-1. Adapt and Re-use Vacant Lots for Green Infrastructure

Job Development

Chapter 3

T-2. Increase Job Density

T-3. Provide Transit-Oriented Development

T-25. Extend Transit Network Coverage or Hours

T-26. Increase Transit Service Frequency

T-31-B. Improve Destination Accessibility in Underserved Areas

T-40. Establish a School Bus Program

E-22. Obtain Third-party HVAC Commissioning and Verification of Energy Savings

S-1. Institute or Extend Recycling Services

S-5. Source Wood Materials from Urban Wood Re-Use Program

N-4. Require Best Management Practices for Manure Management

N-5. Establish a Local Farmer's Market

C-3. Use Local Construction Contractors

C-4. Use Local and Sustainable Building Materials

R-1. Use Alternative Refrigerants Instead of High-GWP Refrigerants

R-2. Install Secondary Loop and/or Cascade Supermarket Systems in Place of Direct Expansion Systems

R-3. Install Transcritical CO2 Supermarket Systems in Place of High-GWP Systems

R-4. Install Microchannel Heat Exchangers in A/C Equipment in Place of Conventional Heat Exchanger

Chapter 4

MH-13. Support Local Food Systems

MH-24. Develop Climate Emergency/Business Resilience Plan

MH-36. Decentralize and Localize Energy Production and Storage

MH-40. Address Energy/Water Efficiency Funding Barriers

MH-41. Expand Urban Greening/Agriculture

WF-8. Implement Fuel Management

D-6. Build Alternatives Forms of Water Recreation

Chapter 5

CCD-5. Establish a Community Benefits Agreement

IEP-1. Local Labor and Apprenticeships (Construction)

IEP-2. Local Labor and Apprenticeships (Operations)

IEP-3. Contract with Diverse Suppliers

IEP-4. Use of Locally/Regionally Manufactured Products and Materials

IEP-5. Higher Wage and Working Condition Standards

IC-1. Invests in Local Arts and Culture to Affirm Community Identity

IC-5. Designated Space for Community-Based Organizations, Disadvantaged Businesses, and Community Assets

IC-6. Create Non-Standard Commercial or Retail Spaces

Nature-Based Solutions

All measures listed for *Green Infrastructure and Low-Impact Development (LID)*.

S-5. Source Wood Materials from Urban Wood Re-Use Program

N-7. Wildfire Resilience and Management

Passive Survivability

Chapter 3

Chapter 4

WF-4. Educate on Wildfire Resistant Landscaping

WF-5. Site Outside WUI

WF-6. Designate and Strengthen Wildfire Emergency Routes

WF-9. Install Air Filters

WF-10. Adopt WUI Building Standards

EH-1. Install Green Infrastructure

EH-3. Install Heat-Reducing Roof

EH-4. Enhance Building Envelope Efficiency

EH-5. Upgrade to Efficient Equipment/Infrastructure

EH-12. Provide Backup Power for Cooling Centers

EH-14. Develop Low-Income Energy Programs

EH-15. Provide Low-Income Air Conditioning

D-1. Install Water Efficient Appliances

D-2. Install Water Reuse Infrastructure

Chapter 5

PH-3. Highly Rated Air Filtration

PH-4. Create Healthful, Sustainable Indoor Spaces

PH-5. Provide Equitable Food Access and Food Justice

IC-2. Adopt Design Standards

IC-3. Promotes Accessibility

CR-1. Adapt and Re-use Vacant Lots for Green Infrastructure

CR-3. Passive Survivability

Poverty

Chapter 3

T-3. Provide Transit-Oriented Development

T-4. Integrate Affordable and Below Market Rate Housing

T-9. Implement Subsidized or Discounted Transit Program

T-11. Provide Employer-Sponsored Vanpool

T-16. Unbundle Residential Parking Costs from Property Cost

T-23. Community-Based Travel Planning

T-25. Extend Transit Network Coverage or Hours

T-26. Increase Transit Service Frequency

T-29. Reduce Transit Fares

T-31-B. Improve Destination Accessibility in Underserved Areas

T-55. Infill Development

T-56. Active Modes of Transportation for Youth

E-4. Install Cool Roofs and/or Cool Walls in Residential Development

E-16. Require Zero Net Energy Buildings

E-17. Require Renewable-Surplus Buildings

E-25. Install Electric Heat Pumps

S-3. Require Edible Food Recovery Program Partnerships with Food Generators

N-6. Establish Community Gardens

Chapter 4

MH-12. Enhance Community Network Support

MH-13. Support Local Food Systems

MH-21. Ensure Homeless Services' Availability in Hazardous Conditions

MH-27. Provide Greater Affordable Housing Options

MH-30. Establish Community Resilience Hubs

MH-35. Increase Parks in Underserved Communities

MH-36. Decentralize and Localize Energy Production and Storage

EH-14. Develop Low-Income Energy Programs

EH-15. Provide Low-Income Air Conditioning

EH-16. Establish a Shuttle System to Cooling Centers

Chapter 5

CCD-5. Establish a Community Benefits Agreement

PH-5. Provide Equitable Food Access and Food Justice

IEP-1. Local Labor and Apprenticeships (Construction)

IEP-2. Local Labor and Apprenticeships (Operations)

IEP-3. Contract with Diverse Suppliers

IEP-5. Higher Wage and Working Condition Standards

IC-5. Designated Space for Community-Based Organizations, Disadvantaged Businesses, and Community Assets

IC-8. Enhanced Access to Community Resources

AH-2. Promote Affordable Housing in Transit-Rich Areas

AH-3. Protection for Existing Tenants of Redevelopment Projects

AH-4. Incorporates Permanent Supportive Housing

AH-5. Make Housing Units Permanently Affordable

AH-6. Support the Formation of Collective Ownership Models: Limited-Equity Housing Cooperatives or Mutual Housing Associations

AH-7. No Net Loss of Affordable Housing Units/One-For-One Affordable Housing Policies

Racial Equity

Chapter 4

MH-11. Encourage/Actively Engage Community in Local Planning

MH-12. Enhance Community Network Support

MH-35. Increase Parks in Underserved Communities

Chapter 5

CCD-1. Consult Pre-existing Community Knowledge/Priorities

CCD-2. Conduct a Stakeholder Analysis and Develop a Community-Centered Outreach Plan

CCD-3. Conduct a Community Needs Assessment

CCD-5. Establish a Community Benefits Agreement

IE-1. Prioritize Outreach to Communities of Color and Underserved Groups

IE-2. Establish or Join a Community Project Steering Committee

IE-3. Elevate Voices of Underrepresented Groups in Project Direction and Outreach

IE-4. Inclusive Community Meetings

IE-5. Provide Education on Essential Topics Related to Project

IE-6. Conduct an Equity Assessment with Community Project Steering Committee

A-1. Use Participatory Budgeting

A-3. Evaluate Project Performance with Community Project Steering Committee/CBO

PH-2. Increase Urban Tree Canopy and Green Spaces

PH-5. Provide Equitable Food Access and Food Justice

IEP-1. Local Labor and Apprenticeships (Construction)

IEP-2. Local Labor and Apprenticeships (Operations)

IEP-3. Contract with Diverse Suppliers

IEP-5. Higher Wage and Working Condition Standards

IC-1. Invests in Local Arts and Culture to Affirm Community Identity

IC-5. Designated Space for Community-Based Organizations, Disadvantaged Businesses, and Community Assets

Social Inclusion

Chapter 3

T-4. Integrate Affordable and Below Market Rate Housing

T-31-B. Improve Destination Accessibility in Underserved Areas

T-46. Provide Transit Shelters

E-4. Install Cool Roofs and/or Cool Walls in Residential Development

E-5. Install Green Roofs in Place of Dark Roofs

E-16. Require Zero Net Energy Buildings

E-17. Require Renewable-Surplus Buildings

E-25. Install Electric Heat Pumps

S-3. Require Edible Food Recovery Program Partnerships with Food Generators

N-2. Expand Urban Tree Planting

Chapter 4

MH-10. Implement Community-wide Climate Change Outreach Program

MH-11. Encourage/Actively Engage Community in Local Planning

MH-12. Enhance Community Network Support

MH-21. Ensure Homeless Services' Availability in Hazardous Conditions

MH-27. Provide Greater Affordable Housing Options

MH-30. Establish Community Resilience Hubs

MH-32. Establish Urban Tree Management Plan

MH-35. Increase Parks in Underserved Communities

MH-36. Decentralize and Localize Energy Production and Storage

MH-38. Integrate Climate into Health Programs

EH-11. Work with Schools to Reduce Heat Exposure

EH-12. Provide Backup Power for Cooling Centers

EH-14. Develop Low-Income Energy Programs

EH-15. Provide Low-Income Air Conditioning

EH-16. Establish a Shuttle System to Cooling Centers

Chapter 5

All measures in the chapter.

Social Resilience

Chapter 3

T-4. Integrate Affordable and Below Market Rate Housing

T-17. Improve Street Connectivity

T-31-A. Locate Project in Area with High Destination Accessibility

T-31-B. Improve Destination Accessibility in Underserved Areas

T-41. Implement a School Pool Program

N-1. Create New Vegetated Open Space

N-2. Expand Urban Tree Planting

N-5. Establish a Local Farmer's Market

N-6. Establish Community Gardens

N-7. Wildfire Resilience and Management

Chapter 4

MH-11. Encourage/Actively Engage Community in Local Planning

MH-12. Enhance Community Network Support

MH-30. Establish Community Resilience Hubs

MH-32. Establish Urban Tree Management Plan

MH-35. Increase Parks in Underserved Communities

MH-41. Expand Urban Greening/Agriculture

EH-1. Install Green Infrastructure

EH-2. Provide Heat Mitigation for Public Walkways and Transit Stops

EH-9. Expand Urban Tree Canopy

EH-11. Work with Schools to Reduce Heat Exposure

Chapter 5

CCD-4. Conduct Community Asset Mapping

CCD-5. Establish a Community Benefits Agreement

PH-2. Increase Urban Tree Canopy and Green Spaces

PH-5. Provide Equitable Food Access and Food Justice

IEP-1. Local Labor and Apprenticeships (Construction)

IEP-2. Local Labor and Apprenticeships (Operations)

IEP-3. Contract with Diverse Suppliers

IC-1. Invests in Local Arts and Culture to Affirm Community Identity

IC-2. Adopt Design Standards

IC-3. Promotes Accessibility

IC-4. Enhanced Open and Green Spaces

IC-5. Designated Space for Community-Based Organizations, Disadvantaged Businesses, and Community Assets

IC-8. Enhanced Access to Community Resources

AH-1. Support Community Land Trusts

AH-2. Promote Affordable Housing in Transit-Rich Areas

AH-3. Protection for Existing Tenants of Redevelopment Projects

AH-4. Incorporates Permanent Supportive Housing

AH-6. Support the Formation of Collective Ownership Models: Limited-Equity Housing Cooperatives or Mutual Housing Associations

CR-1. Adapt and Re-use Vacant Lots for Green Infrastructure

CR-2. Support the Development and Operations of Community Resilience Centers

Tree Canopy

Chapter 3

N-1. Create New Vegetated Open Space

N-2. Expand Urban Tree Planting

Chapter 4

MH-32. Establish Urban Tree Management Plan

MH-35. Increase Parks in Underserved Communities

MH-41. Expand Urban Greening/Agriculture

EH-9. Expand Urban Tree Canopy

Chapter 5

PH-2. Increase Urban Tree Canopy and Green Spaces

IC-4. Enhanced Open and Green Spaces

CR-1. Adapt and Re-use Vacant Lots for Green Infrastructure

Urban Heat Island Reduction

Chapter 3

T-1. Increase Residential Density

T-15. Limit Residential Parking Supply

E-4. Install Cool Roofs and/or Cool Walls in Residential Development

E-5. Install Green Roofs in Place of Dark Roofs

E-21. Install Cool Pavements

N-1. Create New Vegetated Open Space

N-2. Expand Urban Tree Planting

N-3. Implement Management Practices to Improve the Health and Function of Natural and Working Lands

N-6. Establish Community Gardens

Chapter 4

MH-5. Use Green Infrastructure for Stormwater Management

MH-23. Landscape with Climate Considerations

MH-32. Establish Urban Tree Management Plan

MH-33. Implement Park and Natural Resources Protection

MH-35. Increase Parks in Underserved Communities

MH-39. Implement Pervious and Climate-Smart Surfaces

MH-41. Expand Urban Greening/Agriculture

EH-1. Install Green Infrastructure

EH-3. Install Heat-Reducing Roof

EH-8. Use Alternative Pavement Surfaces

EH-9. Expand Urban Tree Canopy

EH-10. Install Covered Parking

Chapter 5

PH-2. Increase Urban Tree Canopy and Green Spaces

IC-4. Enhanced Open and Green Spaces

CR-1. Adapt and Re-use Vacant Lots for Green Infrastructure

References

PolicyLink. n.d. *The Equity Manifesto*. Available: https://www.policylink.org/about-us/equity-manifesto. Accessed: October 2021.

U.S. Environmental Protection Agency (U.S. EPA). n.d. *Urban Runoff: Low Impact Development*. Available: https://www.epa.gov/nps/urban-runoff-low-impact-development. Accessed: October 2021.

Summary of Updates to the Handbook

APPENDIX F

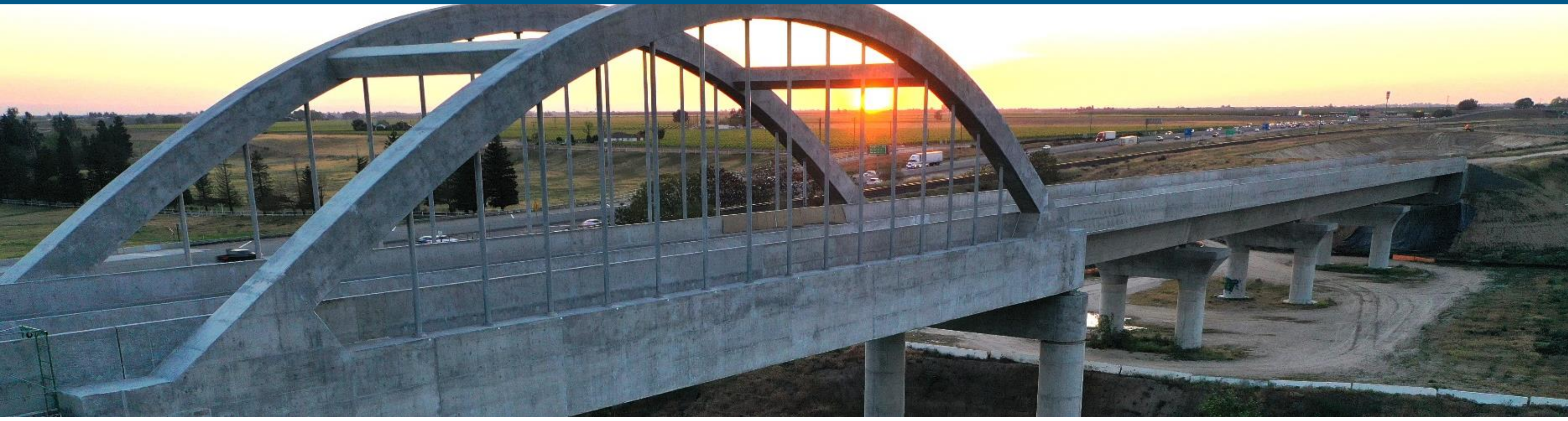


Photo Credit: Justin Chechourka, April 2022

This appendix summarizes the revisions and updates made to the Handbook since the 2021 comprehensive Update. The following table presents a description of the updates by section.

2024 Update

Handbook Section	Description of Update
Title Page 2	Updated the Final Draft date from December 2021 to October 2024. Updated the copyright year from 2021 to 2024. Added the Ramboll Americas Engineering Solutions, Inc. and U.S. Environmental Protection Agency logos.
Acknowledgements	Re-labeled the previous acknowledgements page to *Acknowledgements 2021 Update*. Added a new acknowledgements page for the 2024 Update, including Ramboll Americas Engineering Solutions, Inc.; the Capital Region Priorities Plan Steering Committee; and the CalEEMod focus group.
Acknowledgements: Funding Partners	Added a funding partners description for the 2024 Update, which includes the U.S. Environmental Protection Agency (via the Inflation Reduction Act of 2022 and the Climate Pollution Reduction Grants program) and the Sacramento Metropolitan Air Quality Management District.
An Important Consideration	Added a reference to Appendix F (this appendix) that summarizes the 2024 Updates.
Chapter 1: *Process and Approach for Handbook Development*	Added text to explain that the CAPCOA Board added 11 new quantified measures in 2024.
Chapter 2: *Integrated and Resilient Planning*	In *Exposure to Environmental Burdens*, updated text to reflect the most recent version of CalEnviroScreen (version 4.0) and most recent definition of a disadvantaged community based on CalEPA's update from May 2022. Updated Figure 2-1 to include the most recent designations of disadvantaged and low-income communities from May 2022. In *Clean Air Act and Greenhouse Gases*, added a description of Executive Order 14008 from 2021. In *GHG Reduction Goals and Strategies*, added minor text updates for the 2022 Scoping Plan Update and Assembly Bill 1279. In *Clean Energy and Conservation*, added minor text updates for the 2022 CALGreen standards.

Handbook Section	Description of Update
Chapter 3: *Measures to Reduce GHG Emissions*	In *Categorizing Measures*, updated the sector descriptions to accurately characterize the sectors with the addition of the new measures. In *Categorizing Measures,* updated the sector navigation tree figures to account for the new measures. In *Exclusion of Lifecycle and Biogenic CO_2 Emissions*, added a discussion of the Energy sector because of the new biomass measure (Measure E-26). In *Supporting or Non-Quantified GHG Reduction Measures*, added an explanation of why the numbering scheme for the measures is non-sequential. Also removed from Table 3-1 the non-quantified measures that are quantifiable as of the 2024 Update (Measures T-40, T-46, E-21, and S-3). In *Transportation*, updated the sector navigation tree figure. Under *Combining Measures Across Scales*, updated the measure totals for the Project/Site and Plan/Community scales. Under *Combining Measures within a Subsector*, updated the total number of subsectors from six to seven and added a reference to the new School Programs subsector; updated the number of quantified measures and subsector maximums in the table. In *Transportation*, for Measures T-1, T-2, T-3, and T-4, updated the measures included under *Subsector Maximum* to also include new Measure T-55. For Measures T-19-A, T-19-B, T-20, T-21-A, T-21-B, T-22-A, T-22-B, T-22-C, updated the measures included under *Subsector Maximum* to also include new Measure T-22-D. For Measures T-25, T-26, T-27, T-28, T-29, updated the measures included under *Subsector Maximum* to also include new Measure T-46. In *Transportation*, added five measure factsheets (Measures T-22-D, *Transition Conventional to Electric Bikeshare*; T-40, *Establish a School Bus Program*; T-46, *Provide Transit Shelters*; T-55, *Infill Development*; and T-56, *Active Modes of Transportation for Youth*). In *Energy*, updated the sector navigation tree figure. Also added text to note the lifecycle considerations that are relevant to new Measure E-26, under *Measures to Increase Renewable Energy Generation*. In *Energy*, added two measure factsheets (Measures E-21, *Install Cool Pavement*, and E-26, *Biomass Energy*). In *Solid Waste*, updated the sector introduction discussion to account for the new Solid Waste measure (Measure S-3). Also updated the sector navigation tree figure.

Handbook Section	Description of Update
	In *Solid Waste*, added one measure factsheet (Measure S-3, *Require Edible Food Recovery Program Partnerships with Food Generators*). In *Natural and Working Lands*, updated the sector introduction discussion to account for the new Natural and Working Lands measures (Measures N-7 and N-8). Also updated the sector navigation tree figure. In *Natural and Working Lands*, added two measure factsheets (Measures N-7. *Wildfire Resilience*, and Management and N-8, *Agricultural Equipment Efficiency*). In *Construction*, added text to the measure description for Measure C-1-A, *Use Electric or Hybrid Powered Equipment*, to explain that there are similar measures in other sectors (i.e., new Measures N-8 and M-6). In *Miscellaneous*, updated the sector introduction discussion to account for the new Miscellaneous measure (Measure M-6). Also updated the sector navigation tree figure. In *Miscellaneous*, added one measure factsheet (Measure M-6, *Off-Road Equipment Efficiency*).
Chapter 5: *Measures for Advancing Health and Equity*	In *Statewide Goals and Policies*, updated text to reflect the most recent definition of a disadvantaged community based on CalEPA's update from May 2022.
Appendix A: *Key Terms and Definitions*	To the definition of Disadvantaged Community, updated the text to reflect the most recent definition based on CalEPA's update from May 2022.
Appendix B: *Federal and State Planning Framework*	Added a description of the 2022 *Climate Change Scoping Plan,* Executive Order N-82-20, and AB 1279 (*the Climate Crisis Act*). To *Public Health and Equity*, updated text to reflect the most recent definition of a disadvantaged community based on CalEPA's update from May 2022.
Appendix C: *Emission Factors and Data Tables*	Added the following tables associated with the new measures: Tables T-40.1, T-40.2, E-21.1, E-26.1, E-26.2, S-3.1, and S-3.2.
Appendix E: *Measure Index*	Added the new GHG reduction measures to the appropriate topics and focus areas.