

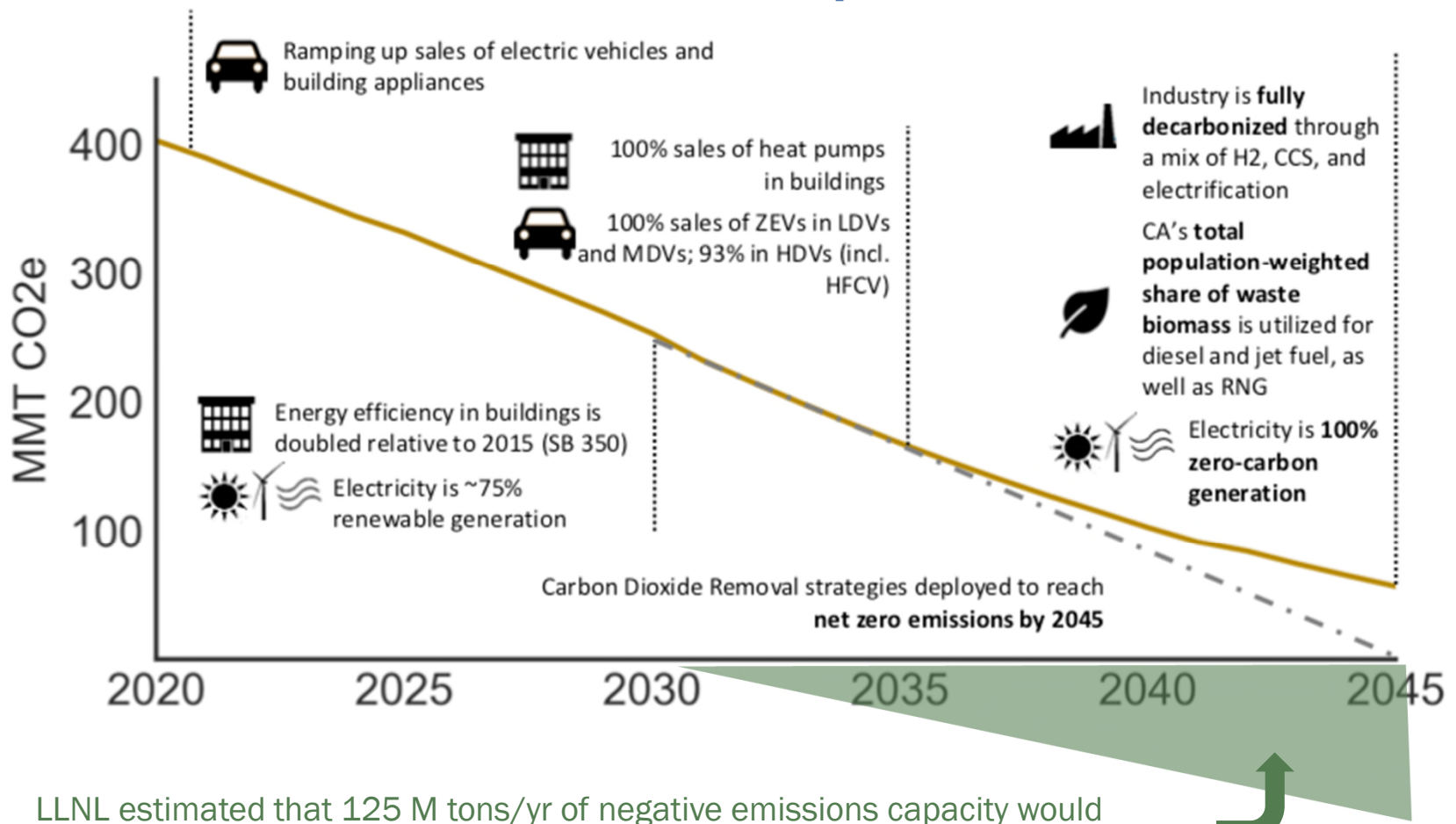


California's quest for carbon neutrality

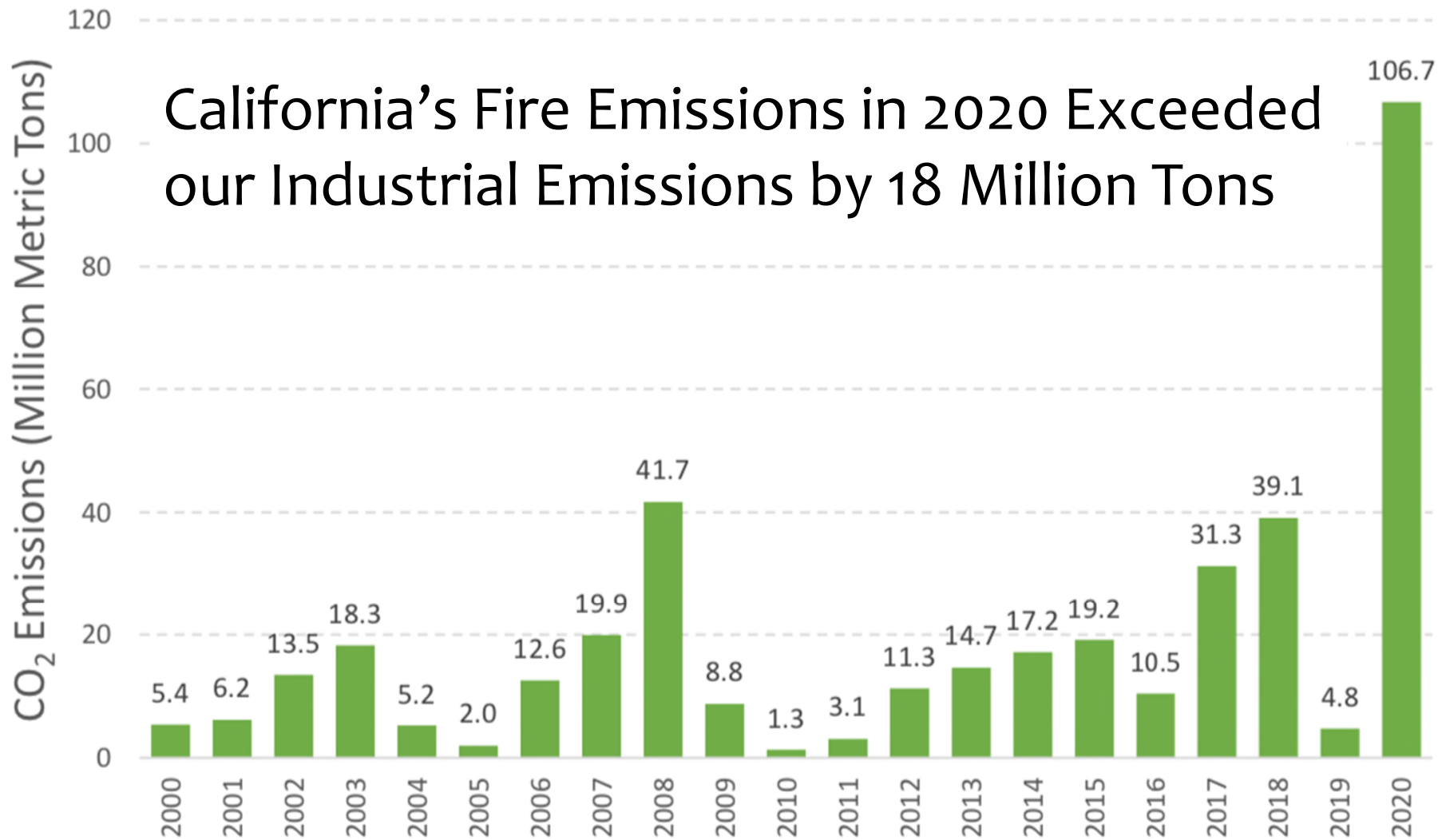
The role of biomass and geologic CO₂ storage

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California's Path to Zero Requires Carbon Removal



LLNL estimated that 125 M tons/yr of negative emissions capacity would comfortably meet the need – especially if some measures are slow



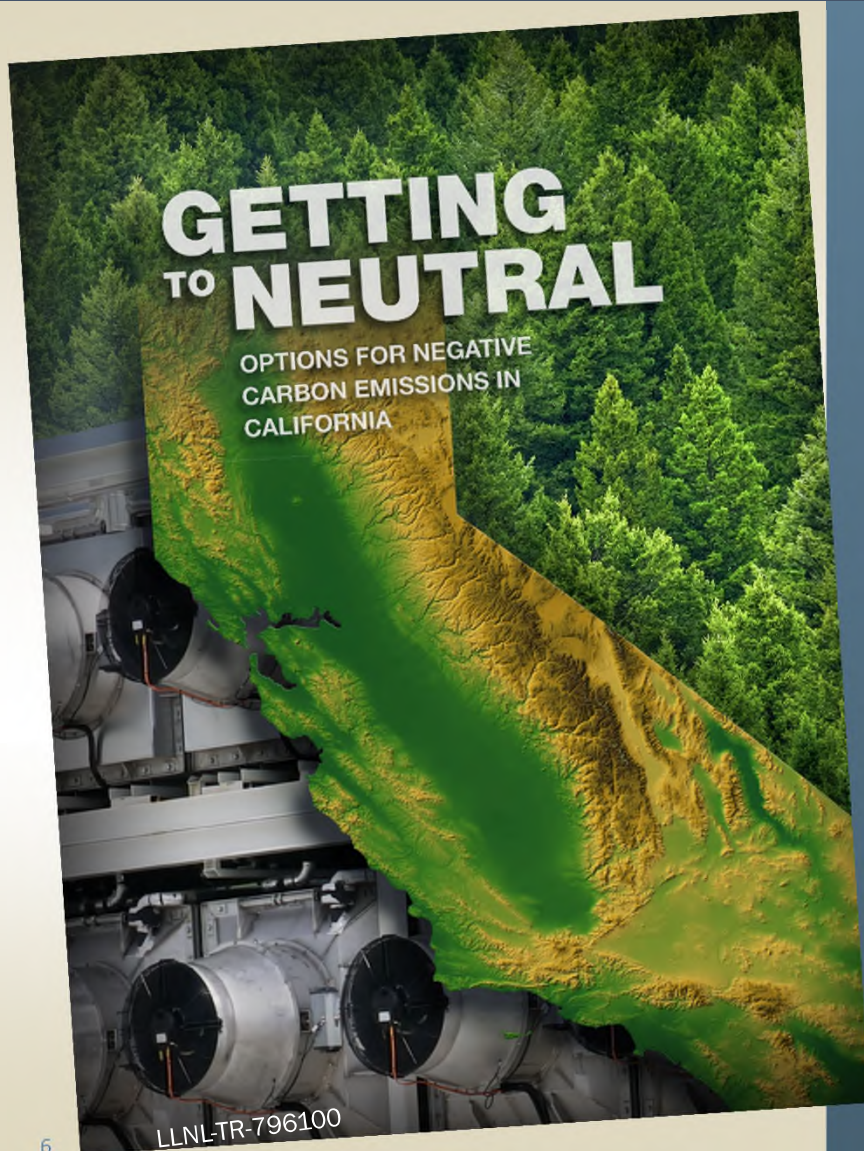
CARB 2022 Scoping Plan

Table 2-3: GHG emissions and removals needed to achieve carbon neutrality and meet the 20 MMTCO₂ removal and capture target in 2030 and the 100 MMTCO₂ removal and capture target in 2045.¹⁶⁴

| | 2030 (MMTCO ₂ e) | 2045 (MMTCO ₂ e) |
|---|--------------------------------|--------------------------------|
| GHG Emissions | 233 | 72 |
| AB 32 GHG Inventory Sector Emissions | 226 | 65 |
| Net NWL GHG Emissions Across All Landscapes (annual average from 2025–2045) | 7 | 7 |
| Carbon Capture and Sequestration (CCS): Avoided GHG Emissions from Industry and Electric Sectors | (13) | (25) |
| Carbon Dioxide Removal (CDR) including natural and working lands carbon sequestration, ¹⁶⁵ Direct Air Capture, and Bioenergy with CCS (BECCS). | (7) | (75) |
| Net Emissions (GHG Emissions + CDR) | 226 | (3) |

How can we remove CO₂ from the air?

1. **Natural Solutions** (trees and soil)
2. **Waste biomass** (permanently store carbon captured by plants)
3. **Direct air capture** (machines and chemical systems to filter CO₂ from the air)



LLNL's report on California's options for carbon removal and storage evaluated the potential in tons per year, and estimated 2045 costs

https://www-gs.llnl.gov/content/assets/docs/energy/Getting_to_Neutral.pdf

We need three main options:

1. Natural and Working Lands



25 MT/year

2. Waste Biomass Conversion to Fuels with CO₂ Storage



83 MT/year

3. Direct Air Capture with CO₂ Storage

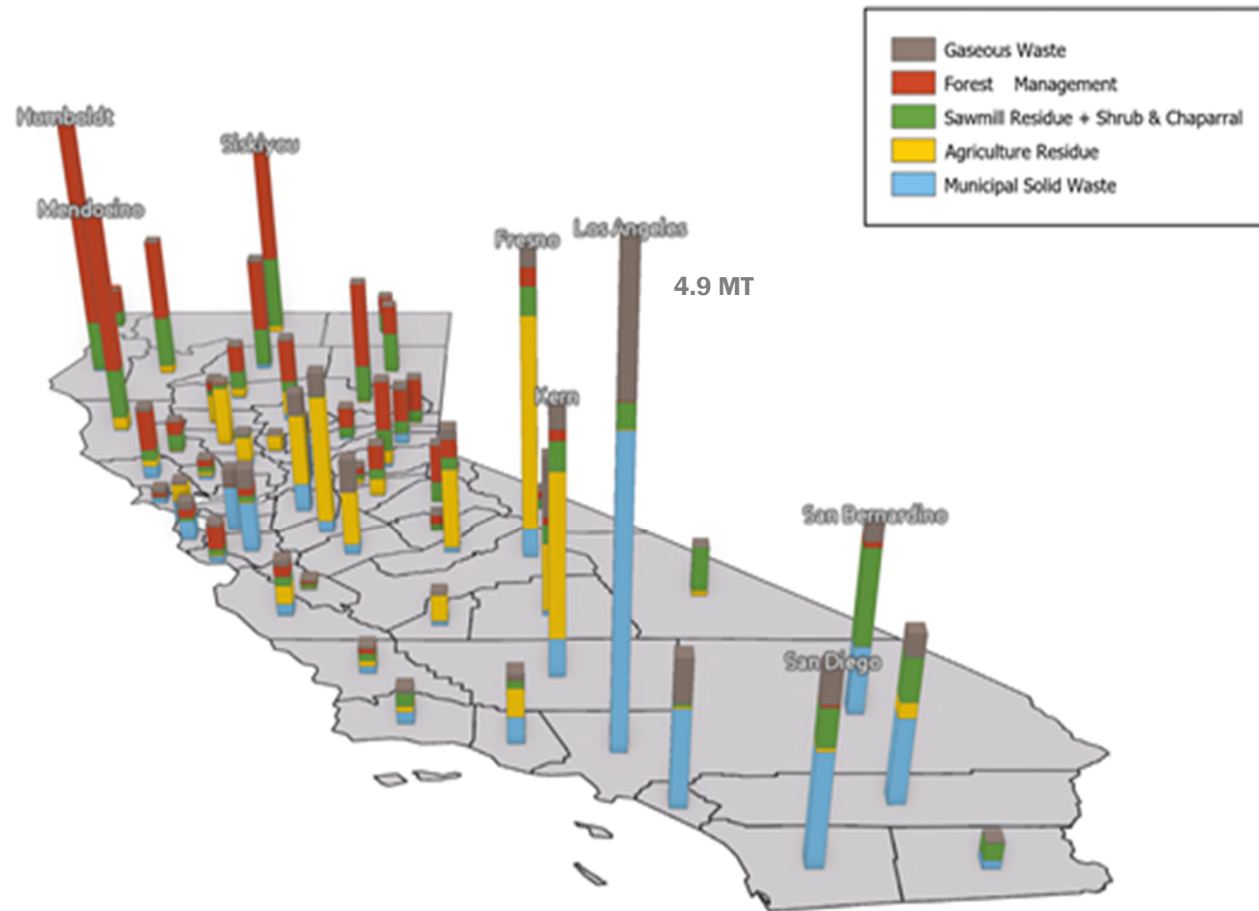


>17 MT/year

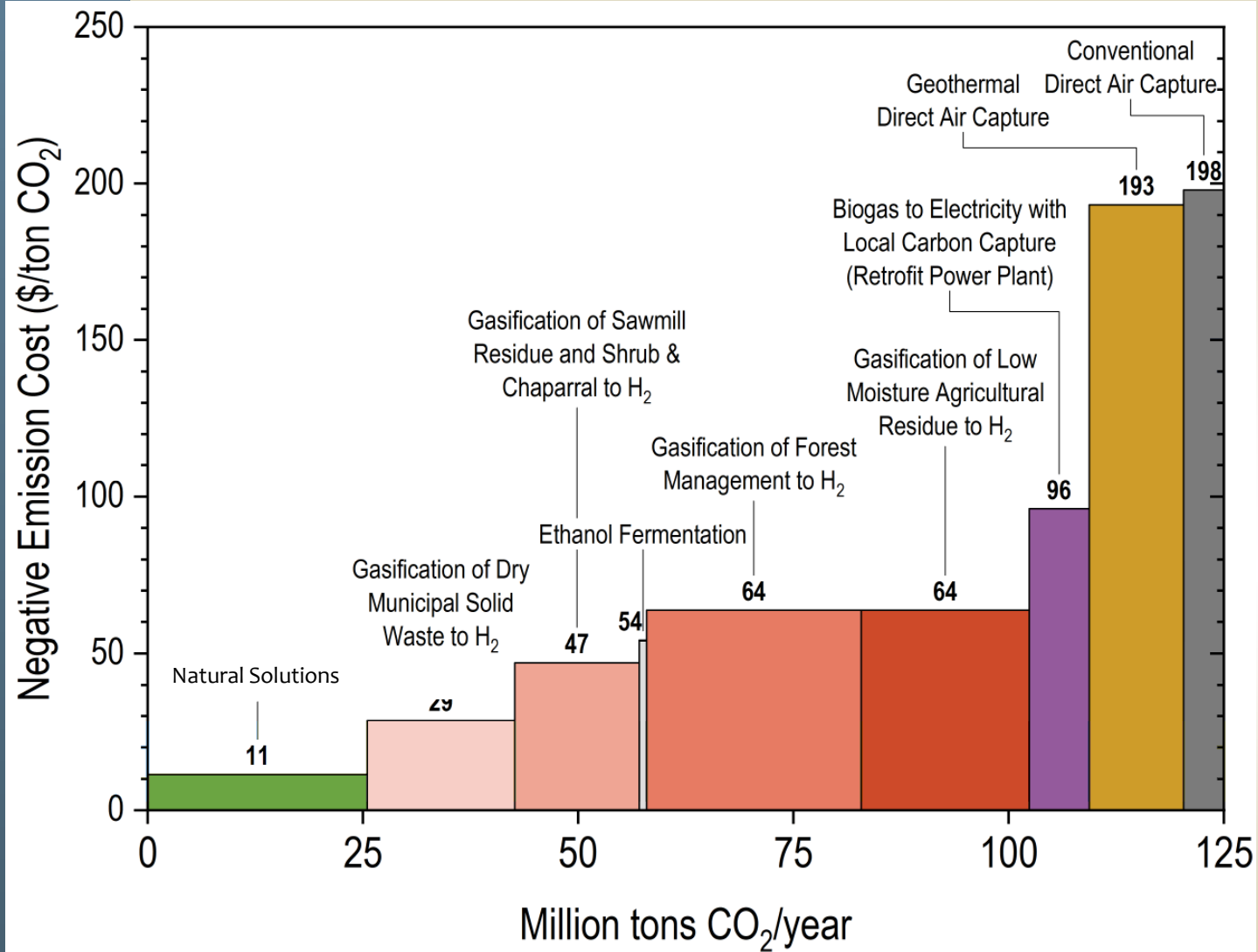
Technological readiness: mid-to-high — no new breakthroughs required

58 million tons of biomass waste is available

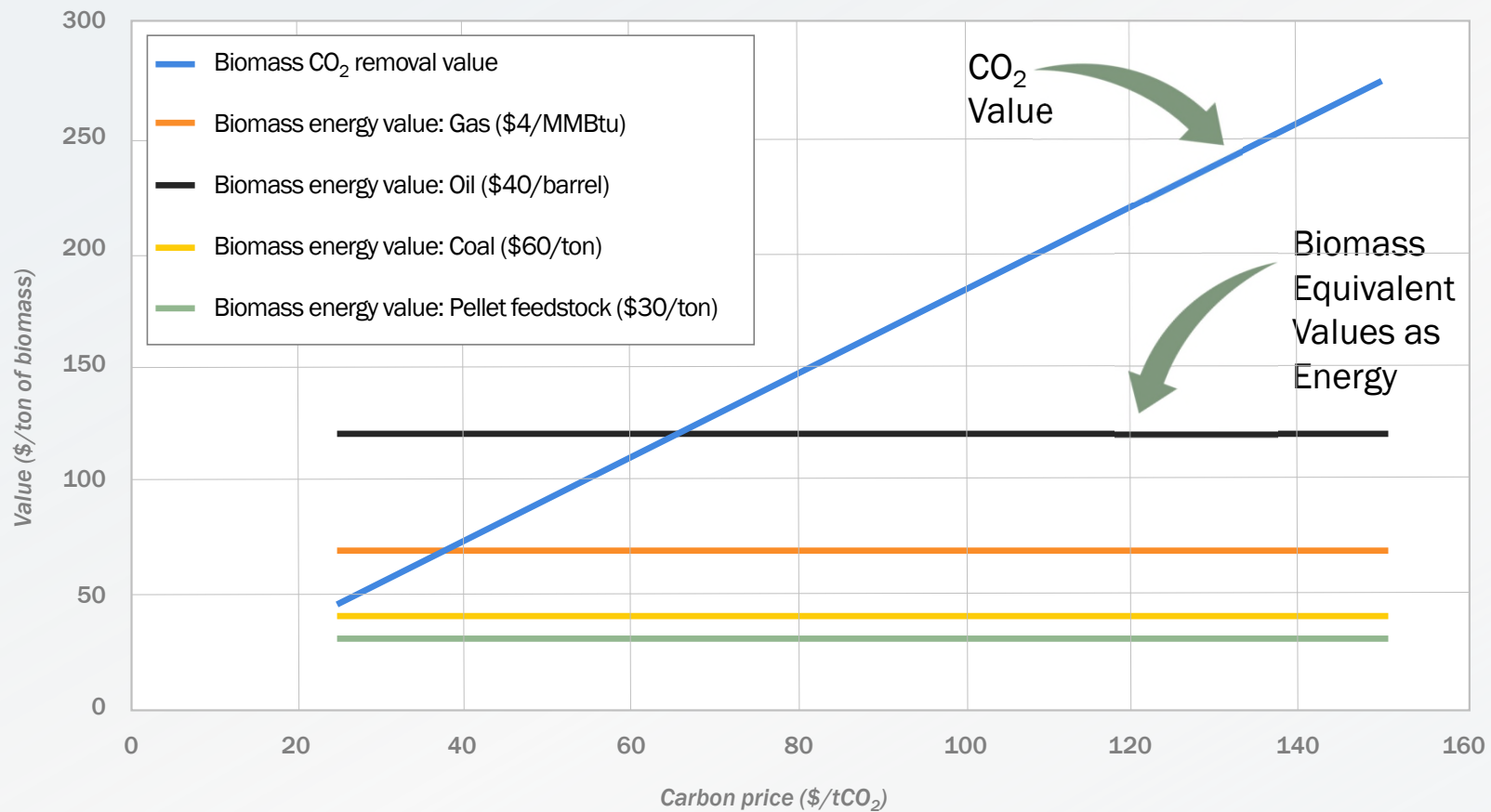
- We estimate that 58 million bone-dry tons will be available from waste sources in 2045
- 100% conversion to CO₂ would yield 106 MT CO₂
- Only waste biomass considered – no energy crops
- Much of this is burned or allowed to decay today



California's least-cost path to 125 MT/year of carbon removal and permanent storage would average about \$65/ton



The carbon removal value of biomass greatly exceeds its energy value at realistic carbon prices



Who will pay? Just like trash removal, we all will.

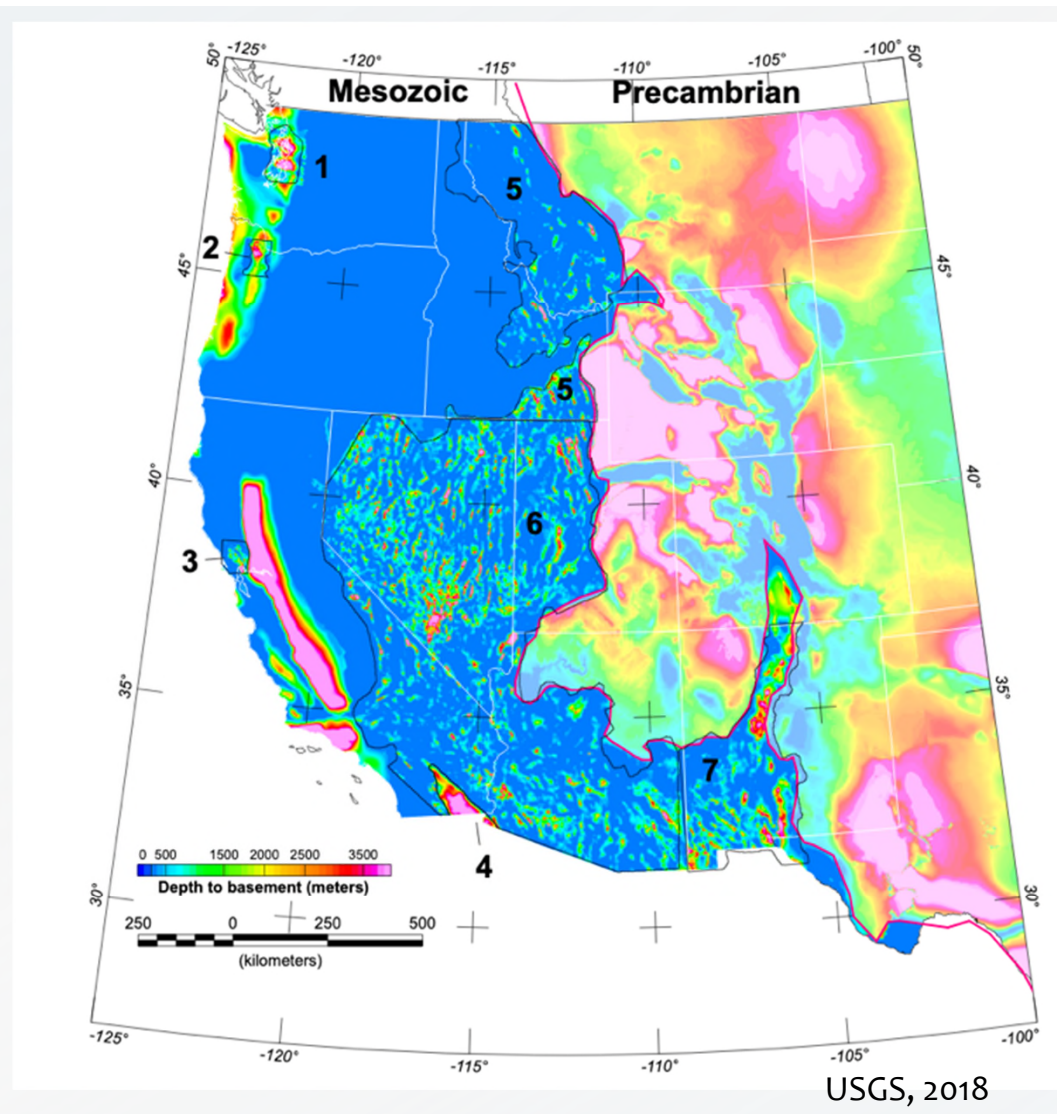
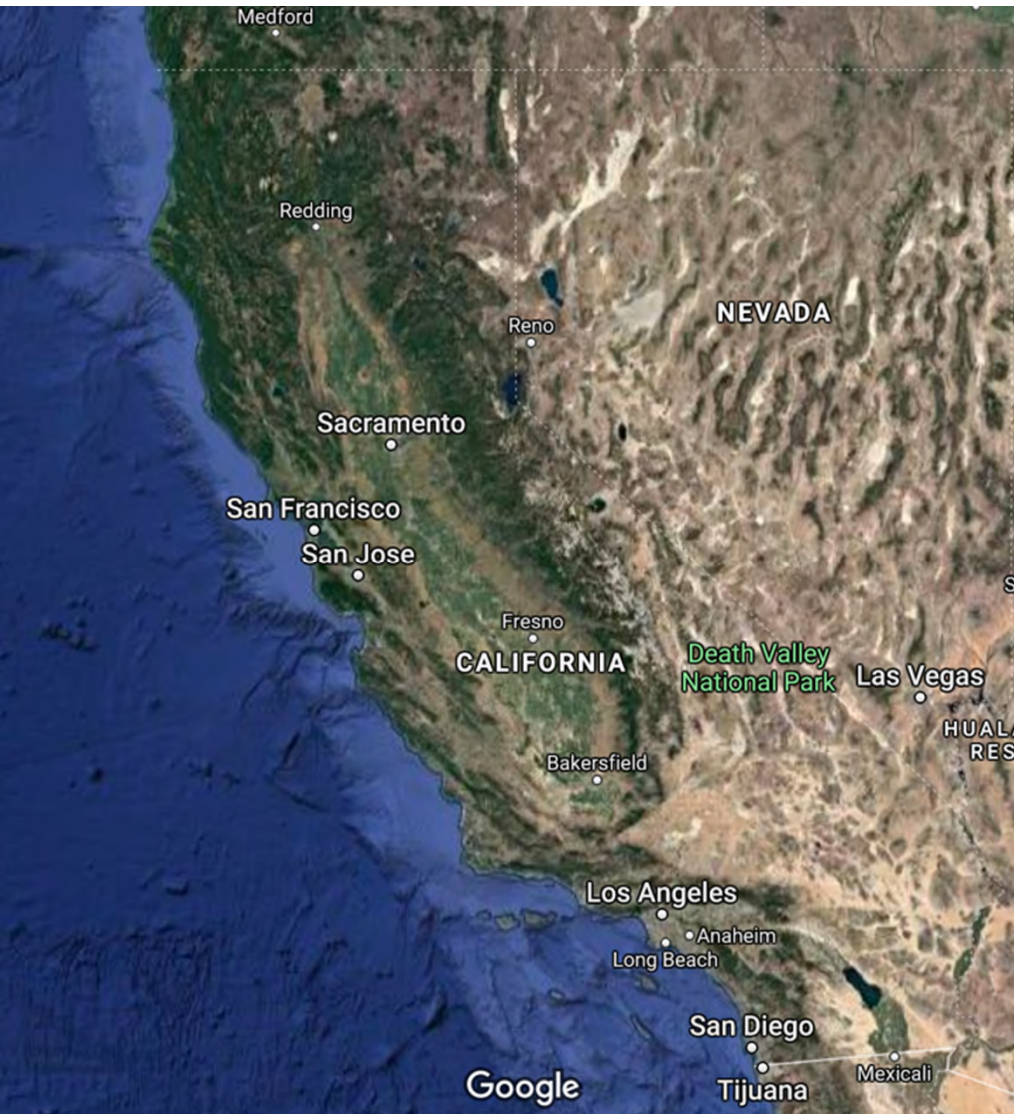


California Negative Emissions:

- 125 MT @ \$65/T = ~\$9B per year
- 0.3% of California GDP

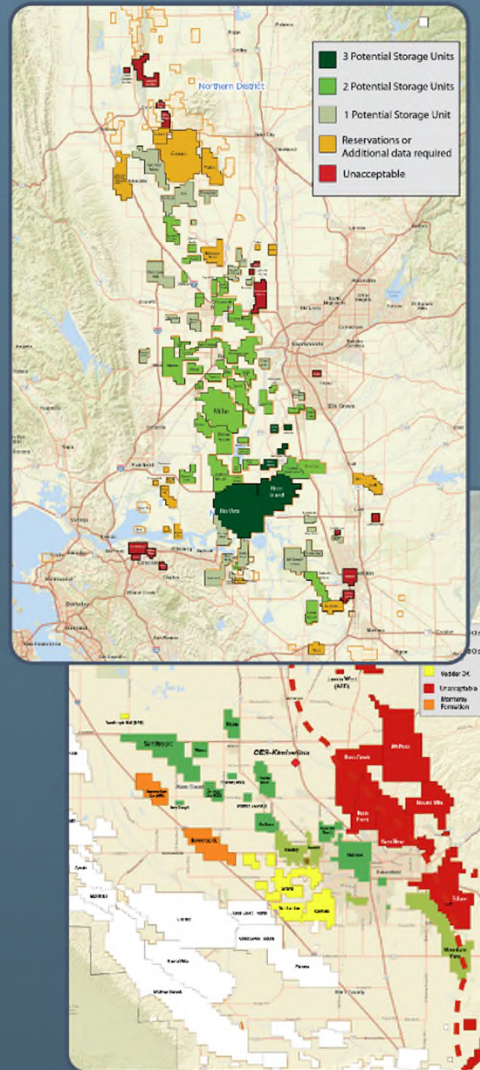
US Trash \$200B Per Year

- 1% of US GDP



There is plenty of safe space in California to store CO₂ underground—in the same rocks that have held oil and gas for millions of years.

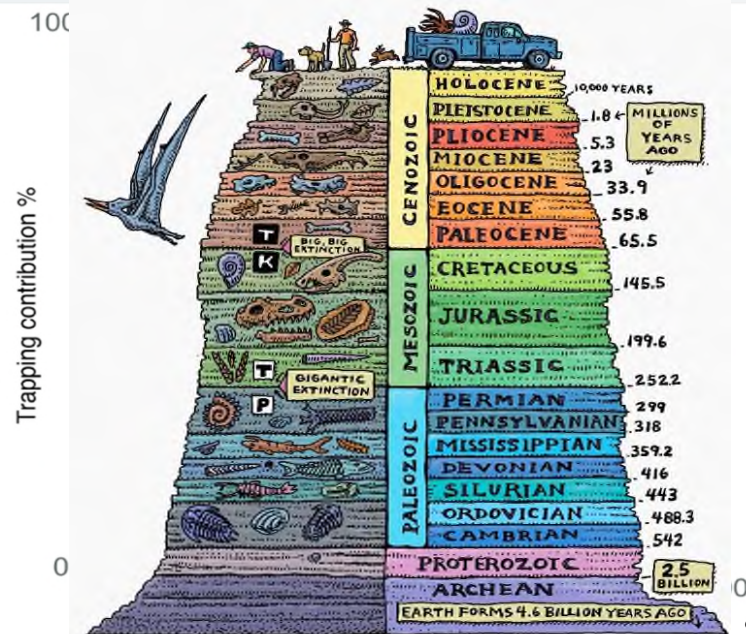
LLNL has identified 17 billion tons of safe storage in just 2 areas of the Central Valley. As much as 200 billion tons may be available.



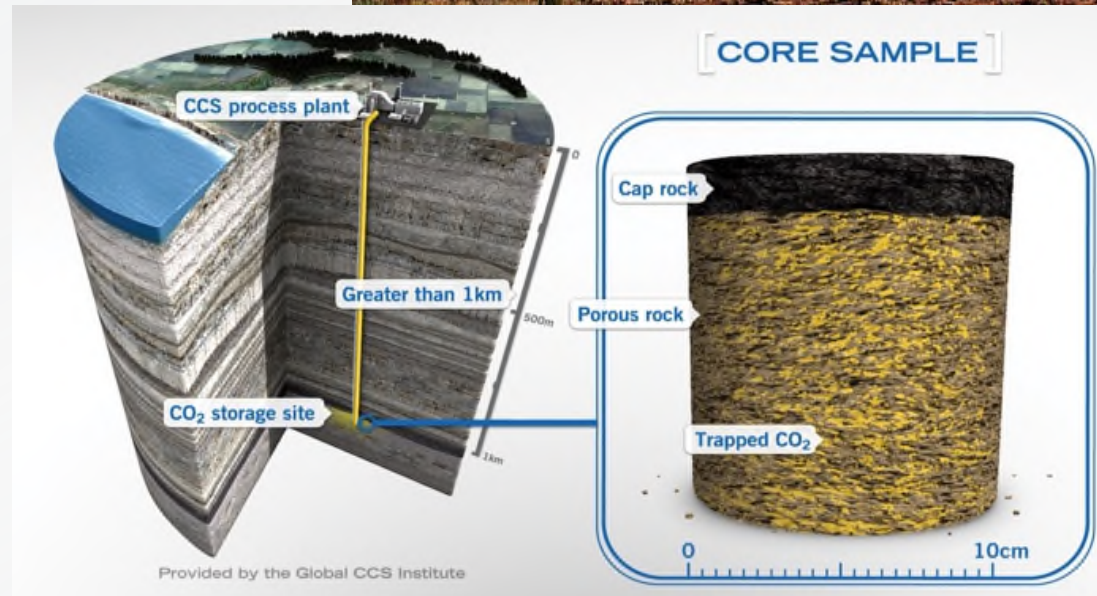
Permanent geologic storage is readily available in CA

Geologic storage

- CO₂ stored in solid but porous rock (e.g. sandstone)
- Far from groundwater, 1000s of feet deep (e.g. 1 mile)
- Multiple mechanisms trap the CO₂
- Mimics natural processes
- Decades of intensive research/10s MtCO₂ stored



Source: IPCC

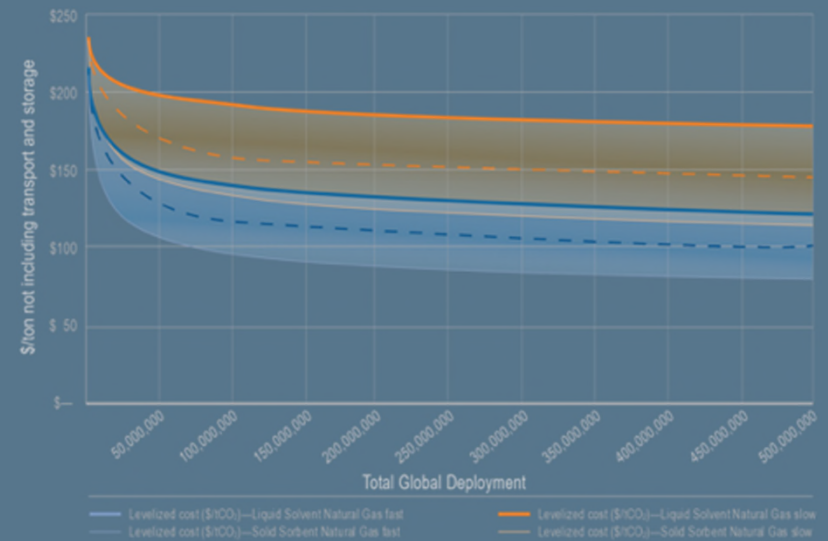


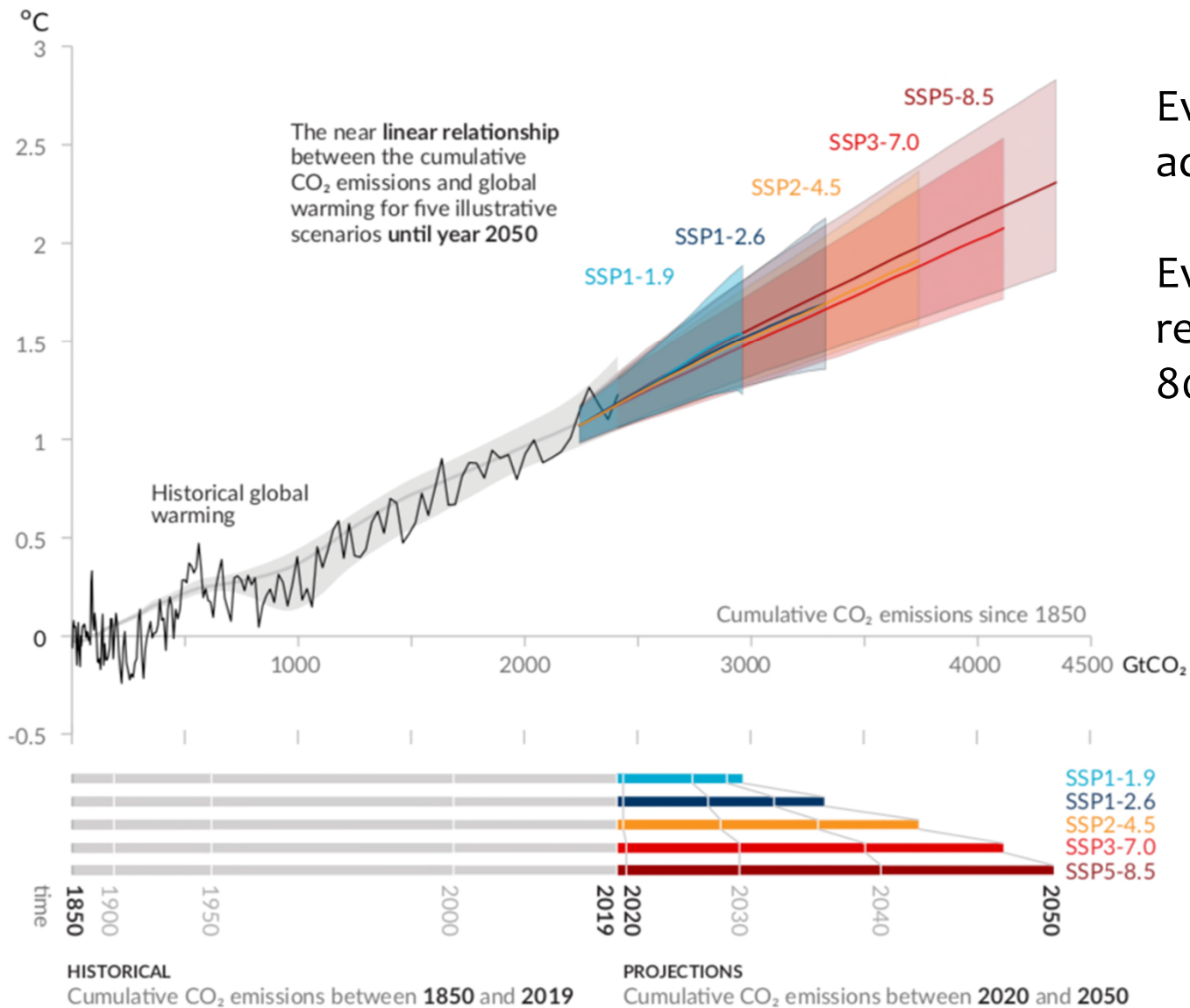
Provided by the Global CCS Institute

Needs & Co-benefits

Support and build Infrastructure:
50-100 new-generation biofuel plants
CO₂ pipeline network
CO₂ storage
Buy down direct air capture costs early

Wildfire prevention and management
Central Valley jobs
Decarbonizing the state's oil industry
Air quality improvements

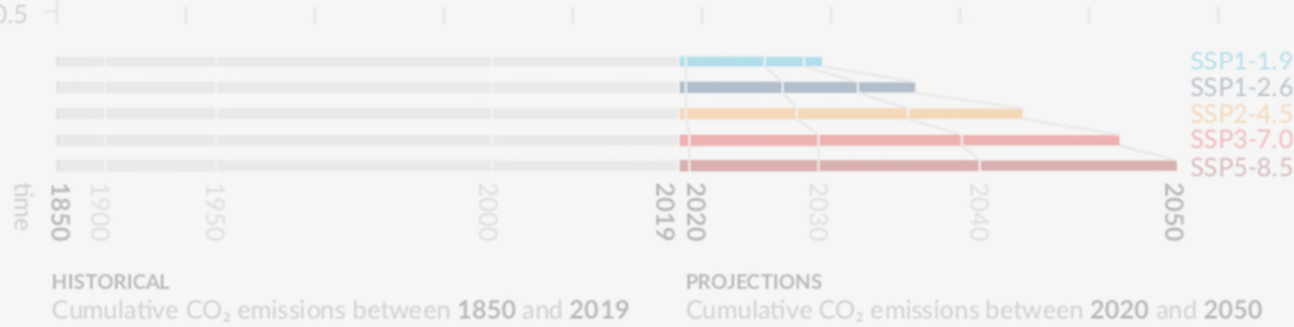
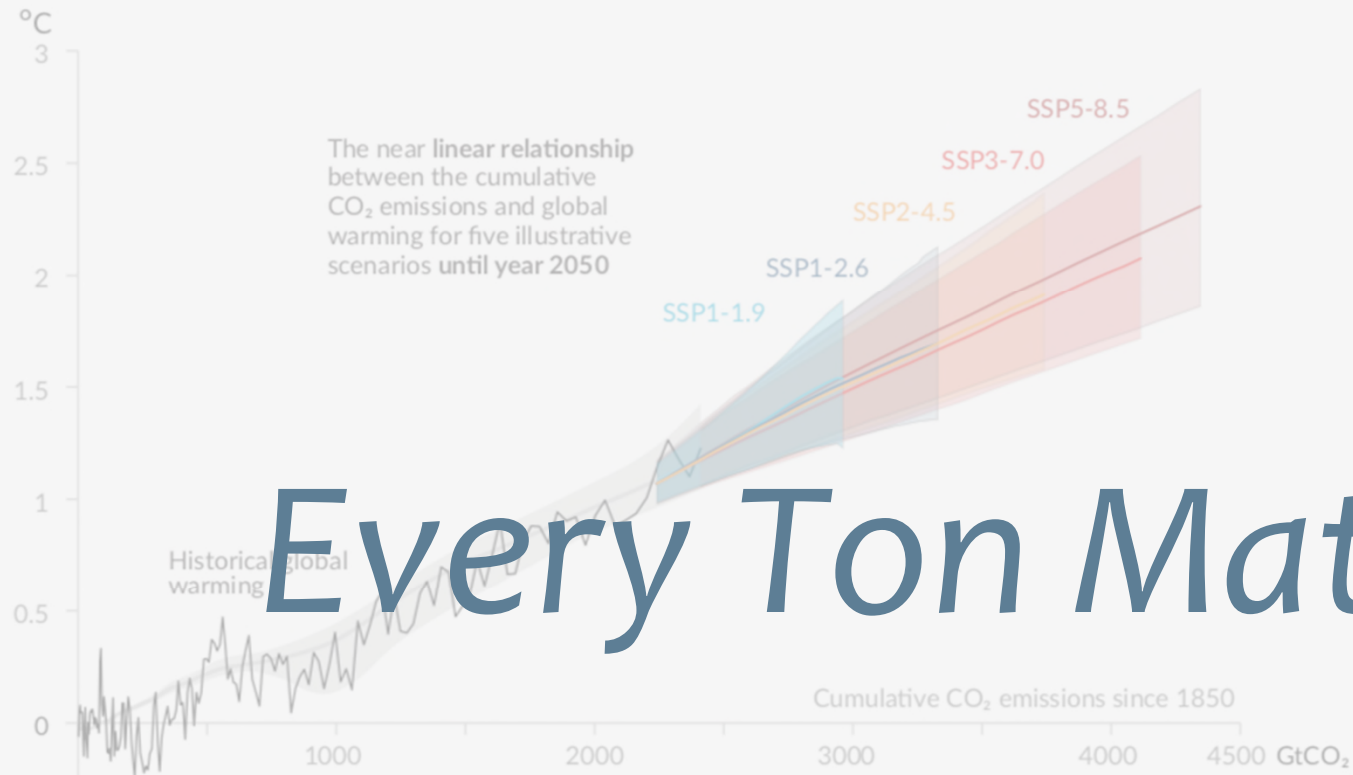




Every ton of CO₂ emissions adds to global warming.

Every ton we remove reverses that by about 80%.

Every Ton Matters



Future cumulative CO₂ emissions differ across scenarios, and determine how much warming we will experience