ACTIVE

CATEGORY Type: **BOILER/HEATER < 5 MMBTU**

BACT Category: MAJOR SOURCE

BACT Determination Number: 327	**BACT Determination Date:** 6/13/2023

Equipment Information

Permit Number: N/A -- Generic BACT Determination

Equipment Description: BOILER

Unit Size/Rating/Capacity: ≥ 75,000 BTU/HR TO < 2.0 MMBTU/HR, FIRED ON NATURAL GAS

Equipment Location:

BACT Determination Information

District Contact: Jeff Quok Phone No.: (279) 207-1145 email: jquok@airquality.org

ROCs	**Standard:**	Good combustion practices
	Technology Description:	
	Basis:	Achieved in Practice
NOx	**Standard:**	See Description
	Technology Description:	Units rated < 0.7 MMBtu/hr: 20 ppmvd at 3% O2 Units rated ≥ 0.7 to < 2.0 MMBtu/hr: 9 ppmvd at 3% O2
	Basis:	Achieved in Practice
SOx	**Standard:**	See Description
	Technology Description:	PUC quality natural gas or produced gas treated using a continuously operating sulfur removal system (≤ 80 ppmv total sulfur & ≤ 4 ppmv H2S)
	Basis:	Achieved in Practice
PM10	**Standard:**	See Description
	Technology Description:	PUC quality natural gas or produced gas treated using a continuously operating sulfur removal system (≤ 80 ppmv total sulfur & ≤ 4 ppmv H2S)
	Basis:	Achieved in Practice
PM2.5	**Standard:**	See Description
	Technology Description:	PUC quality natural gas or produced gas treated using a continuously operating sulfur removal system (≤ 80 ppmv total sulfur & ≤ 4 ppmv H2S)
	Basis:	Achieved in Practice
CO	**Standard:**	See Description
	Technology Description:	Units rated < 0.4 MMBtu/hr: 50 ppmvd at 3% O2 Units rated ≥ 0.4 to < 2.0 MMBtu/hr: 100 ppmvd at 3% O2
	Basis:	Achieved in Practice
LEAD	**Standard:**	
	Technology Description:	
	Basis:	

Comments: This is a generic BACT determination based on BACT determinations made, and published, by other air agencies in California and/or other States.

ACTIVE

CATEGORY Type: **BOILER/HEATER < 5 MMBTU**

BACT Category: Greater or equal to 75,000 BTU/hr to les

BACT Determination Number: 328	**BACT Determination Date:** **6/13/2023**

Equipment Information

Permit Number: N/A -- Generic BACT Determination
Equipment Description: BOILER
Unit Size/Rating/Capacity: Major Source
Equipment Location:

BACT Determination Information

District Contact: Jeff Quok Phone No.: (279) 207-1145 email: jquok@airquality.org

ROCs	**Standard:**	Good combustion practices
	Technology Description:	
	Basis:	Achieved in Practice
NOx	**Standard:**	See Description
	Technology Description:	Units rated < 0.7 MMBtu/hr: 20 ppmvd @ 3% O2 Units rated ≥ 0.7 MMBtu/hr to < 2.0 MMBtu/hr: 12 ppmvd @ 3% O2
	Basis:	Achieved in Practice
SOx	**Standard:**	Good combustion practices
	Technology Description:	
	Basis:	Achieved in Practice
PM10	**Standard:**	Good combustion practices
	Technology Description:	
	Basis:	Achieved in Practice
PM2.5	**Standard:**	Good combustion practices
	Technology Description:	
	Basis:	Achieved in Practice
CO	**Standard:**	See Description
	Technology Description:	Units rated < 0.4 MMBTU/hr: Good combustion practices Units rated ≥ 0.4 MMBTU/hr to < 2.0 MMBtu/hr: 400 ppmvd @ 3% O2
	Basis:	Achieved in Practice
LEAD	**Standard:**	
	Technology Description:	
	Basis:	

Comments: This is a generic BACT determination based on BACT determinations made, and published, by other air agencies in California and/or other States.

777 12th Street, Ste. 300

SACRAMENTO METROPOLITAN AIR QUALITY MANAGEMENT DISTRICT

Sacramento, CA 95814

BEST AVAILABLE CONTROL TECHNOLOGY DETERMINATION

DETERMINATION NOS.: 327 & 328

DATE: 06/13/2023

ENGINEER: Jeffrey Quok

Category/General Equip Description:	Boiler/Heater – Natural gas or LPG
Equipment Specific Description:	#327 – Boiler/heater greater or equal to 75,000 BTU/hr to less than 2.0 MMBTU/hr, fired on natural gas #328 – Boiler/heater greater or equal to 75,000 BTU/hr to less than 2.0 MMBTU/hr, fired on LPG
Equipment Size/Rating:	Major Source
Previous BACT Det. No.:	N/A

This Best Available Control Technology (BACT) determination is for boilers/heaters greater than or equal to 75,000 BTU/hr and less than 2.0 MMBTU/hr, fired on natural gas or LPG at major sources. For purposes of this determination a boiler is any external combustion equipment fired with natural gas or LPG used to produce hot water or steam. Most boilers in this size range are used for providing general hot water to a large commercial or industrial facility or used for space heating.

Process heaters and make-up air heaters as defined below are not applicable to these BACT Determinations.

Make-up Air Heater: Any unit used to heat incoming air in order to maintain the temperature of a spray booth, container, room or other enclosed space to provide breathable air for a person who may be present during operation.

Process Heater: Any unit which transfers heat from combustion gases to process streams, excluding water or steam.

BACT/T-BACT ANALYSIS

A. ACHIEVED IN PRACTICE (Rule 202, §205.1a):

The following control technologies are currently employed as BACT for boilers/heaters ≥ 75,000 BTU/hr and < 2.0 MMBTU/hr by the following agencies and air pollution control districts:

US EPA

BACT
Source: EPA RACT/BACT/LAER Clearinghouse (See Attachment A)

Two determinations were found for units fueled on natural gas in this size range.

RBLC ID # MI-0426: Through contact with the permitting agency it was found that the 1.0 MMBTU/hr boilers in this determination were part of a larger project for a PSD modification of a natural gas compressing station. The boilers proposed by the applicant and the standards included in this determination are based on manufacturer data and not through testing. Because the emission standards were not tested and verified in the field, the District does not consider these emission standards achieved in practice.

RBLC ID # SC-0179: The emission standards in this determination for VOC and PM are in units of pounds per hour, which indicate that the standards are based on the specific input rating of the boiler model evaluated and not general standards for this equipment type and size. The EPA clearinghouse also shows that the emission rates are not based on any specific control technology but on the use of natural gas as a fuel and good combustion practices. Other agencies list natural gas usage and good combustion practices as BACT for VOC and PM and, therefore, this determination will be assumed to be equivalent.

No determinations were found for units fueled on LPG for this size range.

RULE REQUIREMENTS: None

California Air Resource Board (CARB)

BACT
Source: CARB BACT Clearinghouse
CARB BACT Guidelines Search

The only determinations staff found in the CARB BACT Clearinghouse that were not developed by one of the air districts examined later in this determination was SBCAPCD BACT Guidelines 2.1 and 2.2.

Natural Gas or LPG Fired Units ≥ 0.075 and < 2.0 MMBTU/hr			
Pollutant	**Size (MMBtu/hr)**	**Standard/Control Technology**	**Source**
VOC	All	Good combustion practices	SBCAPCD BACT 2.1 (6/14/17) & 2.2 (9/28/21)
NOx	≤ 0.400	20 ppmvd at 3% O_2	SBCAPCD BACT 2.1 (6/14/17)
	> 0.400 & < 1.000	20 ppmvd at 3% O_2	SBCAPCD BACT 2.2 (9/28/21)
	≥ 1.000	12 ppmvd at 3% O_2	SBCAPCD BACT 2.2 (9/28/21)
SOx	All	1. Use PUC quality natural gas (A), or produced gas treated using a continuously operating sulfur removal system (≤ 80 ppmv total sulfur & ≤ 4 ppmv H_2S), and 2. Prepare a Fuel Gas Sulfur Plan (B)	SBCAPCD BACT 2.1 (6/14/17) & 2.2 (9/28/21)
PM10	All	1. Use PUC quality natural gas (A), or produced gas treated using a continuously operating sulfur removal system (≤ 80 ppmv total sulfur & ≤ 4 ppmv H_2S), and 2. Prepare a Fuel Gas Sulfur Plan (B)	SBCAPCD BACT 2.1 (6/14/17) & 2.2 (9/28/21)
PM2.5	All	1. Use PUC quality natural gas (A), or produced gas treated using a continuously operating sulfur removal system (≤ 80 ppmv total sulfur & ≤ 4 ppmv H_2S), and 2. Prepare a Fuel Gas Sulfur Plan (B)	SBCAPCD BACT 2.1 (6/14/17) & 2.2 (9/28/21)
CO	≤ 0.400	50 ppmvd at 3% O_2	SBCAPCD BACT 2.1 (6/14/17)
	> 0.400	100 ppmvd at 3% O_2	SBCAPCD BACT 2.2 (6/14/17)

(A) PUC natural gas stands for California Public Utility Commission Quality Natural Gas. California requires that PUC Gas contain no more than 0.25 grains of hydrogen sulfide and no more than 5 grains of total sulfur per 100 scf of gas.

(B) A Fuel Gas Sulfur Plan is a plan that the owners of the equipment prepare outlining how sulfur will be removed to achieve the required standard. This is not required if the unit is fired on PUC natural gas.

<u>RULE REQUIREMENTS:</u> None

Sacramento Metropolitan AQMD

BACT

Source: SMAQMD BACT #299 – Boilers ≥ 0.075 and < 2 MMBtu/hr fired on Natural Gas (2/23/22)

Natural Gas-Fired Units ≥ 0.075 and < 2.0 MMBTU/hr – Small Emitter Category		
Pollutant	**Unit Size and Type**	**Standard**
VOC	All	Good combustion practices
NOx	Units rated < 1.0 MMBtu/hr	20 ppmvd at 3% O_2
	Units rated ≥ 1.0 MMBtu/hr	12 ppmvd at 3% O_2
SOx	All	PUC quality natural gas or produced gas treated using a continuously operating sulfur removal system (≤ 80 ppmv total sulfur & ≤ 4 ppmv H_2S)
PM10	All	PUC quality natural gas or produced gas treated using a continuously operating sulfur removal system (≤ 80 ppmv total sulfur & ≤ 4 ppmv H_2S) outlined in a Fuel Gas Sulfur Plan.
PM2.5	All	PUC quality natural gas or produced gas treated using a continuously operating sulfur removal system (≤ 80 ppmv total sulfur & ≤ 4 ppmv H_2S) outlined in a Fuel Gas Sulfur Plan.
CO	Units rated < 0.4 MMBtu/hr	50 ppmvd at 3% O_2
	Units rated ≥ 0.4 MMBtu/hr	100 ppmvd at 3% O_2

Source: SMAQMD BACT #300 – Boilers ≥ 0.075 and < 2 MMBtu/hr fired on LPG (2/3/22)

LPG-Fired Units ≥ 0.075 and < 2.0 MMBtu/hr – Small Emitter Category		
Pollutant	**Unit Type**	**Standard**
VOC	All	Good combustion practices
NOx	Units rated < 0.4 MMBtu/hr	77 ppmvd @ 3% O_2
	Units rated ≥ 0.4 MMBtu/hr	30 ppmvd @ 3% O_2
SOx	All	Good combustion practices
PM10	All	Good combustion practices
PM2.5	All	Good combustion practices

LPG-Fired Units ≥ 0.075 and < 2.0 MMBtu/hr – Small Emitter Category		
Pollutant	**Unit Type**	**Standard**
CO	Units rated < 0.4 MMBTU/hr	Good combustion practices
	Units rated ≥ 0.4 MMBTU/hr	400 ppmvd @ 3% O_2

RULE REQIREMENTS:

Rule 414 – Water Heaters, Boilers and Process Heaters Rated Less Than 1,000,000 BTU Per Hour (Amended 10/25/2018)

This rule applies to any person who manufactures, distributes, offers for sale, sells, or installs any type of water heater, boiler or process heater with a rated heat input capacity less than 1.0 MMBTU/hr, fired with gaseous or nongaseous fuels. Units must be certified to meet the emission limits by the SMAQMD or SCAQMD. **LPG-fired units are exempt from this rule.**

No person shall distribute, offer for sale, sell, or install any unit that does not meet the following standards:

Heat Input Range and Type	NOx Limit Nanograms per Joule of Heat Output (ppmv @ 3% O_2)*	CO Limit (ppmv @ 3% O_2)
75,000 to < 400,000 Btu/hr Pool/Spa All others	 40 (55) 14 (20)	 No Limit No Limit
400,000 to 1 million Btu/hr All Types	 14 (20)	 400

* Where limits are shown in units of both nanograms per joule of heat output and ppmv at 3% oxygen, compliance can be demonstrated using either limit.

Rule 411 – NOx from Boilers, Process Heaters and Steam Generators (Amended 8/23/2007)

This rule applies to units fired on gaseous or nongaseous fuels with a rated heat input capacity of 1 million Btu per hour or greater.

No unit shall exceed the following limits:

Unit Size/Description mmBtu/hr Input	NOx Limit ppmvd @ 3% O_2	CO Limit ppmvd @ 3% O_2
Greater than or equal to 1 and less than 5	30	400

South Coast AQMD

BACT
SCAQMD BACT Guidelines do not contain a determination for boilers/heaters rated 2 MMBTU/hr or less, because these units are not required to obtain a written permit, pursuant to SCAQMD Rule 219.

SCAQMD Rule 219 – Equipment Not Requiring a Written Permit Pursuant to Regulation II (Amended 1/7/2022)
Section (b)(2): Boilers, process heaters, or any combustion equipment that has a rated maximum heat input capacity of 2,000,000 Btu per hour (gross) or less and are equipped to be heated exclusively with natural gas, methanol, liquefied petroleum gas, or any combination thereof; or diesel fueled boilers that have a rated maximum heat input capacity of 2,000,000 Btu per hour or less, are fueled exclusively with diesel #2 fuel, and are located more than 4,000 feet above sea level or more than 15 miles offshore from the mainland, and where the maximum NOx emission output of the equipment is less than one pound per day and uses less than 50 gallons of fuel per day, and have been in operation prior to May 3, 2013 provided a filing pursuant to Rule 222 is submitted to the Executive Officer. This exemption does not apply to internal combustion engines or turbines. This exemption does not apply whenever there are emissions other than products of combustion, except for food ovens with a rated maximum heat input capacity of 2,000,000 Btu/hour or less, that are fired exclusively on natural gas and where the process VOC emissions are less than one pound per day and provided a filing pursuant to Rule 222 is submitted to the Executive Officer.

RULE REQUIREMENTS:
Reg XI, Rule 1146.2 – Emissions of Oxides of Nitrogen from Large Water Heaters and Small Boilers and Process Heaters (Amended 12/7/2018)
This rule is applicable to all natural gas-fired units that have a rated heat input capacity less than or equal to 2,000,000 Btu per hour. Units must be certified to meet the emission limits by the SCAQMD.

New units must meet the following standards:

Category	NOx Limit	CO Limit
Units ≤ 0.4 MMBTU/hr (except pool heaters)	14 nanograms per joule of heat output (20 ppmvd @ 3% O_2)	No standard
Pool heaters ≤ 0.4 MMBTU/hr	40 nanograms per joule of heat output (55 ppmvd @ 3% O_2)	No standard
Units > 0.4 and ≤ 2.0 MMBTU/hr	14 nanograms per joule of heat output (20 ppmvd @ 3% O_2)	400 ppmvd @ 3% O_2

San Joaquin Valley Unified APCD

BACT

SJVUAPCD BACT Guidelines do not contain a determination for boilers rated 5 MMBTU/hr or less, because these units are not required to obtain a written permit, pursuant to SJUVAPCD Rule 2020.

SJVUAPCD Rule 2020 – Exemptions (Amended December 18, 2014)

Section 6.1.1: No Authority to Construct or Permit to Operate shall be required for steam generators, steam superheaters, water boilers, steam cleaners, and closed indirect heat transfer systems that have a maximum input heat rating of 5,000,000 Btu per hour (gross) or less and is equipped to be fired exclusively with natural gas, liquefied petroleum gas, or any combination of the two.

RULE REQUIREMENTS:

SJVUAPCD Rule 4308 – Boilers, Steam Generators, and Process Heaters – 0.075 MMBtu/hr to less than 2.0 MMBtu/hr (Amended 11/14/2013)

This rule applies to any person who supplies, sells, offers for sale, installs, or solicits the installation of any boiler, steam generator, process heater or water heater with a rated heat input capacity of greater than or equal to 75,000 British thermal units per hour and less than 2,000,000 British thermal units per hour.

A person shall not supply, sell, offer for sale, install, or solicit the installation of any boiler, process heater or water heater unless it has been certified pursuant to the standards in the table below.

Type and Size of Unit, in MMBtu/hr	NOx Limit lb/MMBtu of heat input (ppmvd @ 3% O_2)	
	PUC Natural Gas*	Non-PUC Natural Gas or Liquid
Units ≥ 0.075 and ≤ 0.4, except as below	0.024 (20)	0.093 (77)
Units > 0.4 and < 2.0, except as below	0.024 (20)	0.036 (30)
Instantaneous water heaters ≥ 0.075 and ≤ 0.4	0.024 (20)	0.093 (77)
Instantaneous water heaters > 0.4 and < 2.0	0.024 (20)	0.093 (77)
Pool heaters ≥ 0.075 and ≤ 0.4	0.068 (55)	0.093 (77)
Pool heaters > 0.4 and < 2.0	0.024 (20)	0.036 (30)

* PUC Natural Gas stands for California Public Utility Commission Quality Natural Gas

Units with a rating of ≥ 0.4 MMBtu/hr and < 2.0 MMBtu/hr must meet a standard of 400 ppmvd @ 3% O_2 for CO.

San Diego County APCD

BACT

SDCAPCD BACT Guidelines do not contain a determination for boilers/heaters rated 2 MMBtu/hr or less fired exclusively with natural gas and/or liquefied petroleum gas, because these units are not required to obtain a written permit, pursuant to SDCAPCD Rule 11.

SDCAPCD Rule 11 – Exemptions from Rule 10 Permit Requirements (Amended 10/13/2022)

Section (d)(2)(iv): Any boiler, process heater, steam generator, or water heater with a manufacturer's maximum gross heat input rating of:

(A) less than 1 million BTU per hour fired with any fuel, or

(B) 2 million BTU per hour or less fired exclusively with natural gas and/or liquefied petroleum gas.

RULE REQUIREMENTS:

Regulation 4, Rule 69.2.1 – Small Boilers, Process Heaters, and Steam Generators (Adopted 7/8/2020)

This rule applies to any person who manufactures, sells, offers for sale or distributes for use within San Diego County, or installs within San Diego County a new unit (boiler, process heater, or steam generator) with a heat input rating from 75,000 Btu per hour to 2 million Btu per hour.

Effective 7/1/2021 no person shall manufacture, distribute, sell, offer for sale, or install within San Diego County any new unit that exceeds the following emission levels:

Fuel	Unit Type & Heat Input Rating BTU/hr	NOx Limit ppmvd @ 3% O_2	CO Limit ppmvd @ 3% O_2
Natural Gas	75,000 to 400,000 Pool Heaters	55	N/A
Natural Gas	75,000 to 400,000 All Other Units	20	N/A
Natural Gas	> 400,000 to 2,000,000 All Units	20	400
Non PUC Gas or Liquid Fuel	75,000 to 400,000 All Units	77	N/A
Non PUC Gas or Liquid Fuel	> 400,000 to 2,000,000 All Units	30	400

Bay Area AQMD

BACT
BAAQMD BACT Guidelines do not contain a determination for boilers/heaters rated 10 MMBTU/hr or less fired exclusively on natural gas or LPG, because units rated less than 10 MMBTU/hr fired exclusively on natural gas or LPG are not required to obtain a permit, pursuant to BAAQMD Rule 2-1.

BAAQMD Regulation 2, Rule 1 – General Requirements (Amended 12/6/2017)
Section 2-1-114: Boilers, heaters, steam generators, duct burners, and similar combustion equipment with less than 10 million BTU per hour rated heat input if fired exclusively with natural gas (including compressed natural gas), liquefied petroleum gas (e.g. propane, butane, isobutene, propylene, butylene, and their mixtures), or any combination thereof are exempt from being required to obtain an Authority to Construct or Permit to Operate.

RULE REQUIREMENTS:
BAAQMD Regulation 9, Rule 6 – Nitrogen Oxides Emissions from Natural Gas-Fired Water Heaters (Amended 11/7/2007)
This rule applies to natural gas-fired boilers and water heaters with a rated heat input capacity less than or equal to 2,000,000 BTU/hr. Units must be certified to meet the emission limits by the BAAQMD or SCAQMD.

Rated Heat Input Capacity Btu/hr	Type of Unit	NOx Limit nanograms per joule of heat output (ppm @ 3% O_2)
≤ 75,000	Mobile Home Water Heaters	40
	Other Storage Tank Water Heaters	10
75,001 to 400,000	Mobile Home Water Heaters	40
	Pool/Spa Heaters	Exempt
	All Other	14
400,001 to 2,000,000	Mobile Home Water Heaters	40
	Pool/Spa Heaters	14 (20)
	All Other	14 (20)

Summary of Achieved in Practice Control Technologies

The following control technologies have been identified as achieved in practice and are ranked based on stringency:

UNIT CONVERSION FOR NOx & CO

Depending on the agency, NOx and CO emission standards were listed in either ppmvd @ 3% O_2 or in nanograms per joule of heat output. For purposes of comparison all nanograms per joule of heat output standards have been converted to ppmvd @ 3% O_2.

NOx AND CO ACHIVED IN PRACTICE STANDARDS

For boilers in the size range covered by this determination, burner design is the predominant method to control NOx emissions. Low-NOx burners typically lower the flame temperature and require greater excess air levels which can cause increases in CO emissions. Therefore, because these pollutants can be dependent on one another, standards will be ranked together. Due to the non-attainment status in Sacramento County, an emphasis will be placed on NOx emissions when ranking emission standards. Previously, the industry standard for units in this range was to obtain SCAQMD certification for compliance with their Rule 1146.2 – Emissions of Oxides of Nitrogen from Large Water Heaters and Small Boilers and Process Heaters. As shown below, the NOx and CO standards in the SBCAPCD BACT Guidelines are more stringent than SCAQMD certification.

SBCAPCD BACT Guidelines 2.1 and 2.2 apply to units fueled by liquid and/or gaseous and/or solid fossil fuels. SBCAPCD Rule 802 requires BACT to be applied to new sources that emit 25 lbs/day or more of any nonattainment pollutant or its precursors (except CO). The rule also has an exemption for sources from offset requirements as long as applicants meet the specified conditions, one of which is to apply BACT to the equipment or process. This rule also sets an offset threshold of 25 tons/year for nonattainment pollutants and precursors (except CO and PM2.5). As of yet, for the size range covered by this determination, the SBCAPCD guidelines have only been applied to units at a single source in order for the source to be exempt from offset requirements. Specifically, the 12 ppmvd NOx standard BACT was applied to three 1.5 MMBtu/hr natural gas-fired boilers in a stacked configuration (manifolded together).

In contrast, the SMAQMD requires BACT to be applied to all new sources that emit over 0 lbs/day (or 0.49 lbs/day due to rounding) of NOx. The SMAQMD permits all units with a maximum heat input of 1.0 MMBtu/hr or greater or multiple units used in the same process whose combined maximum heat input rating is 1.0 MMBtu/hr or greater. Whereas the SBCAPCD exempts external combustion equipment with a maximum heat input rating less than or equal to 2.0 MMBTU/hr. Because of the low permitting and BACT thresholds, if adopted, the 12 ppmvd NOx limit would be applied to many more boilers including small sources where the only permitted unit may be a space heating boiler between 1.0 and 2.0 MMBtu/hr. Because of this discrepancy staff reviewed current new products being offered by major boiler manufactures for natural gas-fired units in this range. Staff found that several manufacturers have natural gas-fired units that span the size range between 1.0 and 2.0 MMBtu/hr that are guaranteed to meet a NOx standard of 12 ppmvd at 3% O_2. Based on this review, the SMAQMD considers units meeting the 12 ppmvd NOx limit in this size range to be readily available and this standard to be achieved in practice.

Even though many of the units that guarantee the 12 ppmvd standard for NOx can be fueled by either natural gas or LPG, the guaranteed NOx standard only applies to the unit when it is fueled by natural gas. Staff has been unable to find any units in this size range fueled by LPG that is guaranteed to meet anything beyond the 30 ppmvd at 3% O_2 standard that was required by BACT determination #219. The BACT Guidelines from SBCAPCD apply to LPG fired unit as well. When asked if the standard had been applied to any LPG-fired units, SBCAPCD responded saying that it had not. They also stated that if an applicant was proposing an LPG-fired unit that was required to meet BACT, they would require the applicant to propose a natural gas-fired unit instead. The SMAQMD currently has active permits with businesses that operate propane/LPG-fired boilers in areas of Sacramento County that are not served by pipeline natural gas. Therefore, the SMAQMD does not consider the SBCAPCD BACT Guidelines 2.1 and 2.2 to be achieved in practice for Propane/LPG-fired units and because natural gas is not available to areas of Sacramento County it is not feasible to require all units to use natural gas as a fuel.

NOx AND CO FOR NATURAL GAS-FIRED UNITS RATED ≥ 75,000 and < 400,000 BTU/HR

Achieved in Practice Standards for NOx & CO for Natural Gas-Fired Units Rated ≥ 75,000 and < 400,000 BTU/hr

Rank	Unit Type	Standard/Control		Source
		NOx (ppmvd @ 3% O_2)	CO (ppmvd @ 3% O_2)	
1	All units	20	50	SBCAPCD BACT 2.1 (2017)
2	Units rated < 1.0 MMBtu/hr (NOx) Units rated < 0.4 MMBtu/hr (CO)	20	50	SMAQMD BACT 299 (2022)
3	Pool heaters	55	No standard	SCAQMD Rule 1146.2 (2018)
	All other units	20	No standard	
4	Units fueled on non-PUC gas	77	No standard	SJVAPCD Rule 4308 (2013) & SDCAPCD Rule 69.2.1 (2020)
	Pool Heaters Fueled on PUC Gas	55	No standard	
	All other units	20	No standard	
5	Mobile home water heaters	55	No standard	BAAQMD Reg. 9 Rule 6 (2007)
	Pool/spa heaters	Exempt	Exempt	
	All other units (A)	20	No standard	

(A) Units with a maximum heat input rating of exactly 75,000 Btu/hr have a lower NOx emission standard of 10 ng/J (15 ppmvd @ 3% O_2).

NOx AND CO FOR NATURAL GAS-FIRED UNITS RATED ≥ 0.4 and < 2.0 MMBTU/HR

Achieved in Practice Standards for NOx & CO for Natural Gas-Fired Units Rated ≥ 400,000 and < 2,000,000 BTU/hr				
Rank	Unit Type	Standard/Control		Source
		NOx (ppmvd @ 3% O_2)	CO (ppmvd @ 3% O_2)	
1	< 1.000 MMBtu/hr (A)	20	100	SMAQMD BACT 299 (2022) & SBCAPCD BACT 2.2 (2017)
	≥ 1.000 MMBtu/hr	12	100	
2	All units	20	400	SCAQMD Rule 1146.2 (2018)
3	All units fueled on non-PUC gas	30	400	SDCAPCD Rule 69.2.1 (2020)
	All units fueled on PUC gas	20	400	
4	Instantaneous water heaters fueled on non-PUC gas	77	400	SJVAPCD Rule 4308 (2013)
	All other units fueled on non-PUC gas	30	400	
	All units fueled on PUC gas	20	400	
5	Mobile home water heaters	55	No standard	BAAQMD Reg. 9 Rule 6 (2007)
	All other units	20	No standard	

(A) Units with a maximum heat input rating of exactly 400,000 Btu/hr has a lower CO standard of 50 ppmvd at 3% O_2 for both SMAQMD and SBAPCD BACTs.

NOx AND CO LPG-FIRED UNITS RATED ≥ 75,000 and < 400,000 BTU/HR

Achieved in Practice Standards for NOx & CO for LPG-Fired Units Rated ≥ 75,000 and < 400,000 BTU/hr				
Rank	Unit Type	Standard/Control		Source
		NOx (ppmvd @ 3% O_2)	CO (ppmvd @ 3% O_2)	
1	All units	77	Good combustion practices	SMAQMD BACT 300 (2022)

Achieved in Practice Standards for NOx & CO for LPG-Fired Units Rated ≥ 75,000 and < 400,000 BTU/hr				
Rank	Unit Type	Standard/Control		Source
		NOx (ppmvd @ 3% O_2)	CO (ppmvd @ 3% O_2)	
2	All units	77	No standard	SJVAPCD Rule 4308 (2013) & SDCAPCD Rule 69.2.1 (2020)
3	All units	No standard	No standard	SCAQMD & BAAQMD

NOx and CO FOR LPG-FIRED UNITS RATED ≥ 0.4 and < 2.0 MMBTU/HR

Achieved in Practice Standards for NOx & CO for LPG-Fired Units Rated ≥ 400,000 and < 2,000,000 BTU/hr				
Rank	Unit Type	Standard/Control		Source
		NOx (ppmvd @ 3% O_2)	CO (ppmvd @ 3% O_2)	
1	All units	30	400	SMAQMD BACT 300 (2022) & SDCAPCD Rule 69.2.1 (2020)
2	Instantaneous water heaters	77	400	SJVAPCD Rule 4308 (2013) & SDCAPCD Rule 69.2.1 (2020)
	All other units	30	400	
3	All units	No standard	No standard	SCAQMD & BAAQMD

VOC FOR NATURAL GAS AND LPG-FIRED UNITS

The only standard set for VOC for this category of equipment is the use of good combustion practices by last SMAQMD BACT Determination, CARB BACT Clearinghouse (SBCAPCD), and EPA BACT Clearinghouse.

SOx AND PM FOR NATURAL GAS-FIRED UNITS

The SBCAPCD BACT Guidelines list the same standard for SOx, PM10 and PM2.5, which relates to burning only low sulfur fuel. Sulfur content in fuels does contribute to particulate emissions through the formation of sulfates. A small portion of sulfates are directly emitted from combustion, but most are formed in the atmosphere as a biproduct of sulfur dioxide emissions. Therefore, a reduction in the sulfur content of the fuel would lead to a reduction in particulate matter and will be considered achieved in practice as a standard for particulate matter. Because the achieved in practice per agency for SOx, PM10, and PM2.5 for natural gas-fired units are equivalent they have been combined into one section for brevity.

Achieved in Practice Standards for SOx for Natural Gas-Fired Units Rated ≥ 75,000 and < 2,000,000 BTU/hr		
Rank	Standard/Control	Source
1	PUC quality natural gas or produced gas treated using a continuously operating sulfur removal system (≤ 80 ppmv total sulfur & ≤ 4 ppmv H_2S) outlined in a Fuel Gas Sulfur Plan.	SMAQMD BACT 299 (2022) & SBCAPCD BACT 2.1 & 2.2 (2017)
2	No standards	SCAQMD, SJVAPCD, SDCAPCD, BAAQMD

(A) PUC Natural Gas stands for California Public Utility Commission Quality Natural Gas. California requires that PUC Gas contain no more than 0.25 grains of hydrogen sulfide and no more than 5 grains of total sulfur per 100 scf of gas.

SOx AND PM FOR LPG-FIRED UNITS

As stated previously the SBCAPCD BACT Guidelines 2.1 and 2.2 are not considered achieved in practice for LPG-fired units and will not be considered in this comparison. Because the achieved in practice per agency for SOx, PM10, and PM2.5 for natural gas-fired units are equivalent they have been combined into one section for brevity.

Achieved in Practice Standards for SOx, PM10, and PM2.5 for LPG-Fired Units Rated ≥ 75,000 and < 2,000,000 BTU/hr		
Rank	Standard/Control	Source
1	Good combustion practices	SMAQMD BACT 299 (2022)
2	No standards	SMAQMD, SJVAPCD, SDCAPCD, BAAQMD

B. TECHNOLOGICALLY FEASIBLE AND COST EFFECTIVE (Rule 202, §205.1.b.):

Technologically Feasible Alternatives:
Any alternative basic equipment, fuel, process, emission control device or technique, singly or in combination, determined to be technologically feasible by the Air Pollution Control Officer.

The table below shows the technologically feasible alternatives identified as capable of reducing emissions beyond the levels determined to be "Achieved in Practice" as per Rule 202, §205.1.a.

Pollutant	**Technologically Feasible Alternatives**
VOC	No other technologically feasible option identified
NOx	1. Selective Catalytic Reduction (5 ppm) 2. Ultra Low NOx Burner (9 ppm for natural gas, 12 ppm for LPG)

Pollutant	Technologically Feasible Alternatives
SOx	No other technologically feasible option identified
PM10	No other technologically feasible option identified
PM2.5	No other technologically feasible option identified
CO	No other technologically feasible option identified

Cost Effective Determination:
After identifying the technologically feasible control options, a cost analysis is performed to take into consideration economic impacts for all technologically feasible controls identified.

Maximum Cost per Ton of Air Pollutants Controlled

1. A control technology is considered to be cost-effective if the cost of controlling one ton of that air pollutant is less than the limits specified below:

Pollutant	Maximum Cost ($/ton)
VOC	23,600
NO_X	32,900
PM10	11,400
SO_X	18,300
CO	300

Cost Effectiveness Analysis Summary

This BACT determination will perform a cost effectiveness analysis in accordance with the updated EPA OAQPS Air Pollution Control Cost Manual. The electricity (11.24 cents/kWh) rate was based on an industrial application as approved by the District. The life of the equipment was based on the EPA cost manual recommendation. The interest rate was based on the previous 6-month average interest rate on United States Treasury Securities (based on the life of the equipment) and addition of two percentage points and rounding up to the next higher integer rate. The labor (Occupation Code 51-8099: Plant and System Operators - Other) and maintenance (Occupation Code 49-2094: electrical and electronics commercial and industrial equipment repairers) rates were based on data from the Bureau of Labor Statistics.

SCR:
As shown in Attachment B, the cost effectiveness for the add on SCR system to control NOx to a 5 ppm level was calculated to be **$612,483/ton** for a 0.075 MMBtu/hr boiler and **$134,154/ton** for a 2 MMBtu/hr boiler. Since BACT for a 2 MMBtu/hr boiler is never triggered for CO (14.2 lbs/day max) even with a boiler meeting Rule 411 limits (400 ppmv CO at 3% O2), the cost for the added CO control was not analyzed. The following basic parameters were used in the analysis.

For a 0.075 MMBtu/hr boiler:

NOx Control Level = 5 ppmv

NOx Baseline Level = 20 ppmv

Boiler Rating = 0.075 MMBtu/hr

Equipment Life = 30 years

Total Capital Investment = $28,627

Direct Annual Cost = $195 per year

Indirect Annual Cost = $3,489 per year

Total Annual Cost = $3,638 per year

NOx Removed = 0.00601 tons per year

Cost of NOx Removal = $612,483 per ton reduced

Therefore, add on SCR system is considered not cost effective and is eliminated. Natural gas costs and LPG costs differences are negligible in determining cost effectiveness due to the extremely high cost per ton reduced results. Therefore, both natural gas and LPG fuel would not be cost effective.

For a 2 MMBtu/hr boiler:

NOx Control Level = 5 ppmv

NOx Baseline Level = 20 ppmv

Boiler Rating = 2 MMBtu/hr

Equipment Life = 30 years

Total Capital Investment = $272,817

Direct Annual Cost = $3,099 per year

Indirect Annual Cost = $23,209 per year

Total Annual Cost = $26,308 per year

NOx Removed = 0.2 tons per year

Cost of NOx Removal = $134,154 per ton reduced

Therefore, add on SCR system is considered not cost effective and is eliminated.

Ultra Low NOx Burner (ULNB):
California Boiler was contacted, and they provide the lowest NOx ppm standard for natural gas and LPG boilers between 0.075-2 MMBtu/hr can meet (See Attachment C). California Boiler explained that for 0.7-2 MMBtu/hr natural gas boilers 9 ppm NOx is the lowest achievable NOx at these levels by using a "NP2" metal mesh element type burner. For 0.7-2 MMBtu/hr LPG boilers, 12 ppm NOx is the lowest achievable NOx at these levels by using a "NP2" metal mesh element type burner. For both natural gas and LPG boilers below 0.7 MMBtu/hr, 20 ppm NOx is the lowest achievable NOx.

Since California Boiler can currently provide boilers in the 0.7-2 MMBtu/hr size range that meet 9 ppm NOx for natural gas and 12 ppm NOx for LPG, the 9 ppm NOx limit for natural gas and 12 ppm NOx for LPG will be considered achieved in practice.

C. SELECTION OF BACT:

Based on the above analysis, BACT for VOC, NOx, SOx, PM10, PM2.5 and CO will be the most stringent standards of what is currently achieved in practice.

BACT DETERMINATION #327 – BOILERS/HEATERS RATED GREATER THAN OR EQUAL TO 75,000 BTU/HR TO LESS THAN 2.0 MMBTU/HR, FIRED ON NATURAL GAS – MAJOR SOURCE CATEGORY		
Pollutant	**Standard**	**Source**
VOC	Good combustion practices	SMAQMD, SBCAPCD
NOx	Units rated < 0.7 MMBtu/hr: 20 ppmvd at 3% O_2 Units rated ≥ 0.7 to < 2.0 MMBtu/hr: 9 ppmvd at 3% O_2	Achieved in Practice per California Boiler
SOx	PUC quality natural gas or produced gas treated using a continuously operating sulfur removal system (≤ 80 ppmv total sulfur & ≤ 4 ppmv H_2S)	SMAQMD, SBCAPCD
PM10	PUC quality natural gas or produced gas treated using a continuously operating sulfur removal system (≤ 80 ppmv total sulfur & ≤ 4 ppmv H_2S) outlined in a Fuel Gas Sulfur Plan.	SMAQMD, SBCAPCD
PM2.5	PUC quality natural gas or produced gas treated using a continuously operating sulfur removal system (≤ 80 ppmv total sulfur & ≤ 4 ppmv H_2S) outlined in a Fuel Gas Sulfur Plan.	SMAQMD, SBCAPCD
CO	Units rated < 0.4 MMBtu/hr: 50 ppmvd at 3% O_2 Units rated ≥ 0.4 to < 2.0 MMBtu/hr: 100 ppmvd at 3% O_2	SMAQMD

BACT DETERMINATION #328 – BOILERS/HEATERS RATED GREATER THAN OR EQUAL TO 75,000 BTU/HR TO LESS THAN 2.0 MMBTU/HR, FIRED ON LPG – MAJOR SOURCE CATEGORY		
Pollutant	**Standard**	**Source**
VOC	Good combustion practices	SMAQMD
NOx	Units rated < 0.7 MMBtu/hr: 20 ppmvd @ 3% O_2 Units rated ≥ 0.7 MMBtu/hr to < 2.0 MMBtu/hr: 12 ppmvd @ 3% O_2	SMAQMD/California Boiler
SOx	Good combustion practices	SMAQMD
PM10	Good combustion practices	SMAQMD
PM2.5	Good combustion practices	SMAQMD
CO	Units rated < 0.4 MMBTU/hr: Good combustion practices Units rated ≥ 0.4 MMBTU/hr to < 2.0 MMBtu/hr: 400 ppmvd @ 3% O_2	SMAQMD

D. <u>SELECTION OF T-BACT</u>:

Toxics are in the form of VOCs and particulate matter. Since toxic emissions from natural gas and LPG-fired boilers in the 75,000 Btu/hr to less than 2.0 MMBtu/hr range are so small and the cancer risk is expected to be well below 1 in a million cases, T-BACT was not evaluated for this determination.

APPROVED BY: Brian F Krebs **DATE:** 06-14-2023

Attachment A

Review of BACT Determinations published by EPA

List of BACT determinations published in EPA's RACT/BACT/LAER Clearinghouse (RBLC) for Commercial/Institutional-Sized Boilers/Furnaces < 100 Million BTU/H - Natural Gas (includes propane & liquefied petroleum gas) (Process Code 13.310):

Boilers/Heaters < 2.0 MMBTU/hr							
RBLC#	Permit Date[(A)]	Rating	Fuel	Pollutant	Standard	Control Technology	Case-By-Case Basis
MI-0426	3/24/2017	1 MMBTU/hr	Natural gas	NOx	9 ppmvd @ 3% O_2	Ultra-low NOx burner and good combustion practices	BACT-PSD
MI-0426	3/24/2017	1 MMBTU/hr	Natural gas	CO	84 lb/MMSCF	Good combustion practices and clean burn fuel (pipeline quality NG)	BACT-PSD
MI-0426	3/24/2017	1 MMBTU/hr	Natural gas	PM10/PM2.5	0.52 lb/MMSCF	Good combustion practices and clean burn fuel (pipeline quality NG)	BACT-PSD
SC-0179	3/18/2015	1.83 MMBTU/hr	Natural gas	PM10	0.01 lb/hr	Use of natural gas and good combustion practices	BACT-PSD
SC-0179	3/18/2015	1.83 MMBTU/hr	Natural gas	PM2.5	0.003 lb/hr	Use of natural gas and good combustion practices	BACT-PSD
SC-0179	3/18/2015	1.83 MMBTU/hr	Natural gas	VOC	0.01 lb/hr	Use of natural gas and good combustion practices	BACT-PSD

(A) Due to the large number of entries only determinations made (based on Permit Date) entered since 01/01/2009 are included in the above table.

[yellow box] = Selected as the most stringent BACT determination achieved in practice.

Attachment B

Cost Effectiveness Determination for SCR

Cost Effectiveness for 0.075 MMBtu/hr Boiler

Data Inputs

Enter the following data for your combustion unit:

Is the combustion unit a utility or industrial boiler? Utility

What type of fuel does the unit burn? Natural Gas

Is the SCR for a new boiler or retrofit of an existing boiler? New Construction

Reset Form

Complete all of the highlighted data fields:

What is the MW rating at full load capacity (Bmw)? 0.0092 MW

What is the higher heating value (HHV) of the fuel? 1,000 Btu/scf

What is the estimated actual annual MWhs output? 81 MWhs

Enter the net plant heat input rate (NPHR) 8.2 MMBtu/MW

If the NPHR is not known, use the default NPHR value:

Fuel Type	Default NPHR
Coal	10 MMBtu/MW
Fuel Oil	11 MMBtu/MW
Natural Gas	8.2 MMBtu/MW

Plant Elevation 1500 Feet above sea level

Not applicable to units burning fuel oil or natural gas

Type of coal burned: Not Applicable

Enter the sulfur content (%S) = percent by weight

Not applicable to units buring fuel oil or natural gas

Note: The table below is pre-populated with default values for HHV and %S. Please enter the actual values for these parameters in the table below. If the actual value for any parameter is not known, you may use the default values provided.

Coal Type	Fraction in Coal Blend	%S	HHV (Btu/lb)
Bituminous	0	1.84	11,841
Sub-Bituminous	0	0.41	8,826
Lignite	0	0.82	6,685

Please click the calculate button to calculate weighted average values based on the data in the table above.

Calculate

For coal-fired boilers, you may use either Method 1 or Method 2 to calculate the catalyst replacement cost. The equations for both methods are shown on rows 85 and 86 on the ***Cost Estimate*** tab. Please select your preferred method:

- ○ Method 1
- ○ Method 2
- ◉ Not applicable

Enter the following design parameters for the proposed SCR:

Number of days the SCR operates (t_{SCR})	365	days
Number of days the boiler operates (t_{plant})	365	days
Inlet NO_x Emissions (NOx_{in}) to SCR	0.0243	lb/MMBtu
Outlet NO_x Emissions (NOx_{out}) from SCR	0.0061	lb/MMBtu
Stoichiometric Ratio Factor (SRF)	1.050	

* The SRF value of 1.05 is a default value. User should enter actual value, if known.

Number of SCR reactor chambers (n_{scr})	1	
Number of catalyst layers (R_{layer})	3	
Number of empty catalyst layers (R_{empty})	1	
Ammonia Slip (Slip) provided by vendor	2	ppm
Volume of the catalyst layers ($Vol_{catalyst}$) (Enter "UNK" if value is not known)	UNK	Cubic feet
Flue gas flow rate ($Q_{fluegas}$) (Enter "UNK" if value is not known)	UNK	acfm

Estimated operating life of the catalyst ($H_{catalyst}$)	24,000	hours
Estimated SCR equipment life	30	Years*

* For utility boilers, the typical equipment life of an SCR is at least 30 years.

Gas temperature at the SCR inlet (T)	650	°F
Base case fuel gas volumetric flow rate factor (Q_{fuel})	484	ft^3/min-MMBtu/hour

Concentration of reagent as stored (C_{stored})	29	percent*
Density of reagent as stored (ρ_{stored})	56	lb/cubic feet*
Number of days reagent is stored ($t_{storage}$)	14	days

*The reagent concentration of 29% and density of 56 lbs/cft are default values for ammonia reagent. User should enter actual values for reagent, if different from the default values provided.

Densities of typical SCR reagents:	
50% urea solution	71 lbs/ft^3
29.4% aqueous NH_3	56 lbs/ft^3

Select the reagent used: Ammonia

Enter the cost data for the proposed SCR:

Desired dollar-year	2022		
CEPCI for 2022	317.299	Enter the CEPCI value for 2022 247.7 2016 CEPCI	CEPCI = Chemical Engineering Plant Cost Index
Annual Interest Rate (i)	7	Percent	
Reagent ($Cost_{reag}$)	0.293	$/gallon for 29% ammonia*	* $0.293/gallon is a default value for 29% ammonia. User should enter actual value, if known.
Electricity ($Cost_{elect}$)	0.1124	$/kWh	
Catalyst cost ($CC_{replace}$)	227.00	$/cubic foot (includes removal and disposal/regeneration of existing catalyst and installation of new catalyst	* $227/cf is a default value for the catalyst cost based on 2016 prices. User should enter actual value, if known.
Operator Labor Rate	27.48	$/hour (including benefits)	
Operator Hours/Day	4.00	hours/day*	* 4 hours/day is a default value for the operator labor. User should enter actual value, if known.

Note: The use of CEPCI in this spreadsheet is not an endorsement of the index, but is there merely to allow for availability of a well-known cost index to spreadsheet users. Use of other well-known cost indexes (e.g., M&S) is acceptable.

Maintenance and Administrative Charges Cost Factors:

Maintenance Cost Factor (MCF) =	0.005
Administrative Charges Factor (ACF) =	0.03

SCR Design Parameters

The following design parameters for the SCR were calculated based on the values entered on the *Data Inputs* tab. These values were used to prepare the costs shown on the *Cost Estimate* tab.

Parameter	Equation	Calculated Value	Units	
Maximum Annual Heat Input Rate (Q_B) =	Bmw x NPHR =	0.075	MMBtu/hour	
Maximum Annual MW Output (Bmw) =	Bmw x 8760 =	81	MWhs	
Estimated Actual Annual MWhs Output (Boutput) =		81	MWhs	
Heat Rate Factor (HRF) =	NPHR/10 =	0.82		
Total System Capacity Factor (CF_{total}) =	(Boutput/Bmw)*(tscr/tplant) =	1.000	fraction	
Total operating time for the SCR (t_{op}) =	CF_{total} x 8760 =	8760	hours	
NOx Removal Efficiency (EF) =	(NOx_{in} - NOx_{out})/NOx_{in} =	74.9	percent	
NOx removed per hour =	NOx_{in} x EF x Q_B =	0.00	lb/hour	
Total NO_x removed per year =	(NOx_{in} x EF x Q_B x t_{op})/2000 =	0.0060138	tons/year	
NO_x removal factor (NRF) =	EF/80 =	0.94		
Volumetric flue gas flow rate ($q_{flue\ gas}$) =	Q_{fuel} x QB x (460 + T)/(460 + 700)n_{scr} =	35	acfm	
Space velocity (V_{space}) =	$q_{flue\ gas}$/$Vol_{catalyst}$ =	137.39	/hour	
Residence Time	1/V_{space}	0.01	hour	
Coal Factor (CoalF) =	1 for oil and natural gas; 1 for bituminous; 1.05 for sub-bituminous; 1.07 for lignite (weighted average is used for coal blends)	1.00		
SO_2 Emission rate =	$(\%S/100)x(64/32)*1x10^6)/HHV$ =			Not applicable; factor applies only to coal-fired boilers
Elevation Factor (ELEVF) =	14.7 psia/P =	1.06		
Atmospheric pressure at sea level (P) =	$2116 \times [(59-(0.00356xh)+459.7)/518.6]^{5.256} \times (1/144)*$ =	13.9	psia	
Retrofit Factor (RF)	New Construction	0.80		

* Equation is from the National Aeronautics and Space Administration (NASA), Earth Atmosphere Model. Available at https://spaceflightsystems.grc.nasa.gov/education/rocket/atmos.html.

Catalyst Data:

Parameter	Equation	Calculated Value	Units
Future worth factor (FWF) =	(interest rate)(1/((1+ interest rate)^{Y} -1) , where Y = $H_{catalyts}/(t_{SCR}$ x 24 hours) rounded to the nearest integer	0.3111	Fraction
Catalyst volume ($Vol_{catalyst}$) =	2.81 x Q_B x EF_{adj} x Slipadj x NOx_{adj} x S_{adj} x (T_{adj}/N_{scr})	0.25	Cubic feet
Cross sectional area of the catalyst ($A_{catalyst}$) =	$q_{flue\ gas}$ /(16ft/sec x 60 sec/min)	0	ft^2
Height of each catalyst layer (H_{layer}) =	($Vol_{catalyst}/(R_{layer}$ x $A_{catalyst}$)) + 1 (rounded to next highest integer)	3	feet

SCR Reactor Data:

Parameter	Equation	Calculated Value	Units
Cross sectional area of the reactor (A_{SCR}) =	1.15 x $A_{catalyst}$	0	ft^2
Reactor length and width dimensions for a square reactor =	$(A_{SCR})^{0.5}$	0.2	feet
Reactor height =	(R_{layer} + R_{empty}) x (7ft + h_{layer}) + 9ft	50	feet

Reagent Data:

Type of reagent used: Ammonia

Molecular Weight of Reagent (MW) = 17.03 g/mole

Density = 56 lb/ft^3

Parameter	Equation	Calculated Value	Units
Reagent consumption rate ($m_{reagent}$) =	(NOx_{in} x Q_B x EF x SRF x MW_R)/MW_{NOx} =	0	lb/hour
Reagent Usage Rate (m_{sol}) =	$m_{reagent}$/Csol =	0	lb/hour
	(m_{sol} x 7.4805)/Reagent Density	0	gal/hour
Estimated tank volume for reagent storage =	(m_{sol} x 7.4805 x $t_{storage}$ x 24)/Reagent Density =	100	gallons (storage needed to store a 14 day reagent supply rounded

Capital Recovery Factor:

Parameter	Equation	Calculated Value
Capital Recovery Factor (CRF) =	$i (1+ i)^n/(1+ i)^n - 1$ = Where n = Equipment Life and i= Interest Rate	0.0806

Other parameters	Equation	Calculated Value	Units
Electricity Usage:			
Electricity Consumption (P) =	A x 1,000 x 0.0056 x $(CoalF \times HRF)^{0.43}$ = where A = Bmw for utility boilers	0.05	kW

Cost Estimate

Total Capital Investment (TCI)

TCI for Oil and Natural Gas Boilers

For Oil and Natural Gas-Fired Utility Boilers between 25MW and 500 MW:

$$TCI = 86,380 \times (200/B_{MW})^{0.35} \times B_{MW} \times ELEVF \times RF$$

For Oil and Natural Gas-Fired Utility Boilers >500 MW:

$$TCI = 62,680 \times B_{MW} \times ELEVF \times RF$$

For Oil-Fired Industrial Boilers between 275 and 5,500 MMBTU/hour :

$$TCI = 7,850 \times (2,200/Q_B)^{0.35} \times Q_B \times ELEVF \times RF$$

For Natural Gas-Fired Industrial Boilers between 205 and 4,100 MMBTU/hour :

$$TCI = 10,530 \times (1,640/Q_B)^{0.35} \times Q_B \times ELEVF \times RF$$

For Oil-Fired Industrial Boilers >5,500 MMBtu/hour:

$$TCI = 5,700 \times Q_B \times ELEVF \times RF$$

For Natural Gas-Fired Industrial Boilers >4,100 MMBtu/hour:

$$TCI = 7,640 \times Q_B \times ELEVF \times RF$$

Total Capital Investment (TCI) =	$28,327	in 2022 dollars

Annual Costs

Total Annual Cost (TAC)

TAC = Direct Annual Costs + Indirect Annual Costs

Direct Annual Costs (DAC) =	$195 in 2022 dollars
Indirect Annual Costs (IDAC) =	$3,489 in 2022 dollars
Total annual costs (TAC) = DAC + IDAC	$3,683 in 2022 dollars

Direct Annual Costs (DAC)

DAC = (Annual Maintenance Cost) + (Annual Reagent Cost) + (Annual Electricity Cost) + (Annual Catalyst Cost)

Annual Maintenance Cost =	0.005 x TCI =	$142 in 2022 dollars
Annual Reagent Cost =	m_{sol} x $Cost_{reag}$ x t_{op} =	$1 in 2022 dollars
Annual Electricity Cost =	P x $Cost_{elect}$ x t_{op} =	$47 in 2022 dollars
Annual Catalyst Replacement Cost =		$6 in 2022 dollars
	n_{scr} x Vol_{cat} x ($CC_{replace}$/R_{layer}) x FWF	
Direct Annual Cost =		$195 in 2022 dollars

Indirect Annual Cost (IDAC)

IDAC = Administrative Charges + Capital Recovery Costs

Administrative Charges (AC) =	0.03 x (Operator Cost + 0.4 x Annual Maintenance Cost) =	$1,205 in 2022 dollars
Capital Recovery Costs (CR)=	CRF x TCI =	$2,283 in 2022 dollars
Indirect Annual Cost (IDAC) =	AC + CR =	$3,489 in 2022 dollars

Cost Effectiveness

Cost Effectiveness = Total Annual Cost/ NOx Removed/year

Total Annual Cost (TAC) =	$3,683	per year in 2022 dollars
NOx Removed =	0.00601	tons/year
Cost Effectiveness =	$612,483	per ton of NOx removed in 2022 dollars

Cost Effectiveness for 2.0 MMBtu/hr Boiler

Data Inputs

Enter the following data for your combustion unit:

Is the combustion unit a utility or industrial boiler? Utility

Is the SCR for a new boiler or retrofit of an existing boiler? New Construction

What type of fuel does the unit burn? Natural Gas

Reset Form

Complete all of the highlighted data fields:

What is the MW rating at full load capacity (Bmw)? 0.3 MW

What is the higher heating value (HHV) of the fuel? 1,000 Btu/scf

What is the estimated actual annual MWhs output? 2,628 MWhs

Enter the net plant heat input rate (NPHR) 8.2 MMBtu/MW

If the NPHR is not known, use the default NPHR value:

Fuel Type	Default NPHR
Coal	10 MMBtu/MW
Fuel Oil	11 MMBtu/MW
Natural Gas	8.2 MMBtu/MW

Plant Elevation 1500 Feet above sea level

Not applicable to units burning fuel oil or natural gas

Type of coal burned: Not Applicable

Enter the sulfur content (%S) = percent by weight

Not applicable to units buring fuel oil or natural gas

Note: The table below is pre-populated with default values for HHV and %S. Please enter the actual values for these parameters in the table below. If the actual value for any parameter is not known, you may use the default values provided.

Coal Type	Fraction in Coal Blend	%S	HHV (Btu/lb)
Bituminous	0	1.84	11,841
Sub-Bituminous	0	0.41	8,826
Lignite	0	0.82	6,685

Please click the calculate button to calculate weighted average values based on the data in the table above.

Calculate

For coal-fired boilers, you may use either Method 1 or Method 2 to calculate the catalyst replacement cost. The equations for both methods are shown on rows 85 and 86 on the ***Cost Estimate*** tab. Please select your preferred method:

- ○ Method 1
- ○ Method 2
- ◉ Not applicable

Enter the following design parameters for the proposed SCR:

Number of days the SCR operates (t_{SCR})	365	days
Number of days the boiler operates (t_{plant})	365	days
Inlet NO_x Emissions (NOx_{in}) to SCR	0.0243	lb/MMBtu
Outlet NO_x Emissions (NOx_{out}) from SCR	0.0061	lb/MMBtu
Stoichiometric Ratio Factor (SRF)	1.050	

* The SRF value of 1.05 is a default value. User should enter actual value, if known.

Number of SCR reactor chambers (n_{scr})	1	
Number of catalyst layers (R_{layer})	3	
Number of empty catalyst layers (R_{empty})	1	
Ammonia Slip (Slip) provided by vendor	2	ppm
Volume of the catalyst layers ($Vol_{catalyst}$) (Enter "UNK" if value is not known)	UNK	Cubic feet
Flue gas flow rate ($Q_{fluegas}$) (Enter "UNK" if value is not known)	UNK	acfm

Estimated operating life of the catalyst ($H_{catalyst}$)	24,000	hours
Estimated SCR equipment life	30	Years*

* For utility boilers, the typical equipment life of an SCR is at least 30 years.

Gas temperature at the SCR inlet (T)	650	°F
Base case fuel gas volumetric flow rate factor (Q_{fuel})	484	ft^3/min-MMBtu/hour

Concentration of reagent as stored (C_{stored})	29	percent*
Density of reagent as stored (ρ_{stored})	56	lb/cubic feet*
Number of days reagent is stored ($t_{storage}$)	14	days

* The reagent concentration of 29% and density of 56 lbs/cft are default values for ammonia reagent. User should enter actual values for reagent, if different from the default values provided.

Densities of typical SCR reagents:

50% urea solution	71 lbs/ft^3
29.4% aqueous NH_3	56 lbs/ft^3

Select the reagent used: Ammonia

Enter the cost data for the proposed SCR:

Desired dollar-year	2022		
CEPCI for 2022	317.299	Enter the CEPCI value for 2022 247.7 2016 CEPCI	CEPCI = Chemical Engineering Plant Cost Index
Annual Interest Rate (i)	7	Percent	
Reagent ($Cost_{reag}$)	0.293	$/gallon for 29% ammonia*	* $0.293/gallon is a default value for 29% ammonia. User should enter actual value, if known.
Electricity ($Cost_{elect}$)	0.1124	$/kWh	
Catalyst cost ($CC_{replace}$)	227.00	$/cubic foot (includes removal and disposal/regeneration of existing catalyst and installation of new catalyst	* $227/cf is a default value for the catalyst cost based on 2016 prices. User should enter actual value, if known.
Operator Labor Rate	27.48	$/hour (including benefits)	
Operator Hours/Day	4.00	hours/day*	* 4 hours/day is a default value for the operator labor. User should enter actual value, if known.

Note: The use of CEPCI in this spreadsheet is not an endorsement of the index, but is there merely to allow for availability of a well-known cost index to spreadsheet users. Use of other well-known cost indexes (e.g., M&S) is acceptable.

Maintenance and Administrative Charges Cost Factors:

Maintenance Cost Factor (MCF) =	0.005
Administrative Charges Factor (ACF) =	0.03

SCR Design Parameters

The following design parameters for the SCR were calculated based on the values entered on the *Data Inputs* tab. These values were used to prepare the costs shown on the *Cost Estimate* tab.

Parameter	Equation	Calculated Value	Units	
Maximum Annual Heat Input Rate (Q_B) =	Bmw x NPHR =	2	MMBtu/hour	
Maximum Annual MW Output (Bmw) =	Bmw x 8760 =	2,628	MWhs	
Estimated Actual Annual MWhs Output (Boutput) =		2,628	MWhs	
Heat Rate Factor (HRF) =	NPHR/10 =	0.82		
Total System Capacity Factor (CF_{total}) =	(Boutput/Bmw)*(tscr/tplant) =	1.000	fraction	
Total operating time for the SCR (t_{op}) =	CF_{total} x 8760 =	8760	hours	
NOx Removal Efficiency (EF) =	$(NOx_{in} - NOx_{out})/NOx_{in}$ =	74.9	percent	
NOx removed per hour =	NOx_{in} x EF x Q_B =	0.04	lb/hour	
Total NO_x removed per year =	(NOx_{in} x EF x Q_B x t_{op})/2000 =	0.20	tons/year	
NO_x removal factor (NRF) =	EF/80 =	0.94		
Volumetric flue gas flow rate ($q_{flue\ gas}$) =	Q_{fuel} x QB x (460 + T)/(460 + 700)n_{scr} =	1,139	acfm	
Space velocity (V_{space}) =	$q_{flue\ gas}/Vol_{catalyst}$ =	137.39	/hour	
Residence Time	$1/V_{space}$	0.01	hour	
Coal Factor (CoalF) =	1 for oil and natural gas; 1 for bituminous; 1.05 for sub-bituminous; 1.07 for lignite (weighted average is used for coal blends)	1.00		
SO_2 Emission rate =	$(\%S/100)x(64/32)*1x10^6)/HHV$ =			Not applicable; factor applies only to coal-fired boilers
Elevation Factor (ELEVF) =	14.7 psia/P =	1.06		
Atmospheric pressure at sea level (P) =	$2116 \times [(59-(0.00356xh)+459.7)/518.6]^{5.256} \times (1/144)*$ =	13.9	psia	
Retrofit Factor (RF)	New Construction	0.80		

Catalyst Data:

Parameter	Equation	Calculated Value	Units
Future worth factor (FWF) =	(interest rate)(1/((1+ interest rate)^Y -1) , where Y = $H_{catalyts}/(t_{SCR}$ x 24 hours) rounded to the nearest integer	0.3111	Fraction
Catalyst volume ($Vol_{catalyst}$) =	2.81 x Q_B x EF $_{adj}$ x Slipadj x NOx_{adj} x S_{adj} x (T_{adj}/N_{scr})	8.29	Cubic feet
Cross sectional area of the catalyst ($A_{catalyst}$) =	$q_{flue\ gas}$ /(16ft/sec x 60 sec/min)	1	ft^2
Height of each catalyst layer (H_{layer}) =	$(Vol_{catalyst}/(R_{layer}$ x $A_{catalyst}))$ + 1 (rounded to next highest integer)	3	feet

SCR Reactor Data:

Parameter	Equation	Calculated Value	Units
Cross sectional area of the reactor (A_{SCR}) =	1.15 x $A_{catalyst}$	1	ft^2
Reactor length and width dimensions for a square reactor =	$(A_{SCR})^{0.5}$	1.2	feet
Reactor height =	$(R_{layer}$ + $R_{empty})$ x (7ft + h_{layer}) + 9ft	50	feet

Reagent Data:

Type of reagent used: Ammonia

Molecular Weight of Reagent (MW) = 17.03 g/mole

Density = 56 lb/ft^3

Parameter	Equation	Calculated Value	Units
Reagent consumption rate ($m_{reagent}$) =	$(NOx_{in}$ x Q_B x EF x SRF x $MW_R)/MW_{NOx}$ =	0	lb/hour
Reagent Usage Rate (m_{sol}) =	$m_{reagent}$/Csol =	0	lb/hour
	(m_{sol} x 7.4805)/Reagent Density	0	gal/hour
Estimated tank volume for reagent storage =	(m_{sol} x 7.4805 x $t_{storage}$ x 24)/Reagent Density =	100	gallons (storage needed to store a 14 day reagent supply rounded

Capital Recovery Factor:

Parameter	Equation	Calculated Value
Capital Recovery Factor (CRF) =	$i (1+ i)^n/(1+ i)^n - 1$ = Where n = Equipment Life and i= Interest Rate	0.0806

Other parameters	Equation	Calculated Value	Units
Electricity Usage:			
Electricity Consumption (P) =	$A \times 1{,}000 \times 0.0056 \times (CoalF \times HRF)^{0.43}$ = where A = Bmw for utility boilers	1.54	kW

Cost Estimate

Total Capital Investment (TCI)

TCI for Oil and Natural Gas Boilers

For Oil and Natural Gas-Fired Utility Boilers between 25MW and 500 MW:

$$TCI = 86,380 \times (200/B_{MW})^{0.35} \times B_{MW} \times ELEVF \times RF$$

For Oil and Natural Gas-Fired Utility Boilers >500 MW:

$$TCI = 62,680 \times B_{MW} \times ELEVF \times RF$$

For Oil-Fired Industrial Boilers between 275 and 5,500 MMBTU/hour :

$$TCI = 7,850 \times (2,200/Q_B)^{0.35} \times Q_B \times ELEVF \times RF$$

For Natural Gas-Fired Industrial Boilers between 205 and 4,100 MMBTU/hour :

$$TCI = 10,530 \times (1,640/Q_B)^{0.35} \times Q_B \times ELEVF \times RF$$

For Oil-Fired Industrial Boilers >5,500 MMBtu/hour:

$$TCI = 5,700 \times Q_B \times ELEVF \times RF$$

For Natural Gas-Fired Industrial Boilers >4,100 MMBtu/hour:

$$TCI = 7,640 \times Q_B \times ELEVF \times RF$$

Total Capital Investment (TCI) =	$272,817	in 2023 dollars

Annual Costs

Total Annual Cost (TAC)

TAC = Direct Annual Costs + Indirect Annual Costs

Direct Annual Costs (DAC) =	$3,099 in 2023 dollars
Indirect Annual Costs (IDAC) =	$23,209 in 2023 dollars
Total annual costs (TAC) = DAC + IDAC	$26,308 in 2023 dollars

Direct Annual Costs (DAC)

DAC = (Annual Maintenance Cost) + (Annual Reagent Cost) + (Annual Electricity Cost) + (Annual Catalyst Cost)

Annual Maintenance Cost =	0.005 x TCI =	$1,364 in 2023 dollars
Annual Reagent Cost =	m_{sol} x $Cost_{reag}$ x t_{op} =	$21 in 2023 dollars
Annual Electricity Cost =	P x $Cost_{elect}$ x t_{op} =	$1,519 in 2023 dollars
Annual Catalyst Replacement Cost =		$195 in 2023 dollars
	n_{scr} x Vol_{cat} x ($CC_{replace}$/R_{layer}) x FWF	
Direct Annual Cost =		$3,099 in 2023 dollars

Indirect Annual Cost (IDAC)

IDAC = Administrative Charges + Capital Recovery Costs

Administrative Charges (AC) =	0.03 x (Operator Cost + 0.4 x Annual Maintenance Cost) =	$1,220 in 2023 dollars
Capital Recovery Costs (CR)=	CRF x TCI =	$21,989 in 2023 dollars
Indirect Annual Cost (IDAC) =	AC + CR =	$23,209 in 2023 dollars

Cost Effectiveness

Cost Effectiveness = Total Annual Cost/ NOx Removed/year

Total Annual Cost (TAC) =	$26,308	per year in 2023 dollars
NOx Removed =	0.2	tons/year
Cost Effectiveness =	$134,154	per ton of NOx removed in 2023 dollars

Attachment C

California Boiler NOx Cost Estimate for 9 ppm Boilers

Jeffrey Quok

From: Roehl Fabay <rfabay@californiaboiler.com>
Sent: Tuesday, January 31, 2023 5:26 PM
To: Jeffrey Quok
Subject: RE: Boiler NOx emissions for Boilers less than 2 MMBtu/hr

*** THIS EMAIL ORIGINATED OUTSIDE AIRQUALITY.ORG ***

Hi Jeffrey,

For industrial type boiler, the Powerflame NP2 burner can do 9ppm from 700MBH to 2000MBH. However this depends on which boiler it goes into. Since the NP2 burner are metal mesh element type burner, there are some boilers which have some tight combustion chamber dimension which this burner will not work. The Powerflame NPM premix burner can only do 20ppm and this can be use on some of those smaller boiler with tight combustion chamber that the NP2 can't work.

Most industrial type boiler package are built by two separate company, we have the boiler manufacturer and the burner manufacturer. The boiler manufacturer normally mounts the burner at their facility. Unlike the commercial packaged type boiler, the boiler manufacturer also designs the burner that goes into their equipment. The combustion chamber design limits them from lowering the NOx even further.

The price difference between NPM and NP2 is quite significant because of the use of more advance controls versus linkage type on the NPM, you're looking at around $10-14k difference.

Roehl Fabay
California Boiler

From: Roehl Fabay <rfabay@californiaboiler.com>
Sent: Wednesday, March 1, 2023 9:37 AM
To: Jeffrey Quok
Subject: RE: Boiler NOx emissions for Boilers less than 2 MMBtu/hr

***** THIS EMAIL ORIGINATED OUTSIDE AIRQUALITY.ORG *****

Jeffrey – see my response below in Red. – thanks!

Roehl Fabay
California Boiler

From: Jeffrey Quok <JQuok@airquality.org>
Sent: Tuesday, February 28, 2023 5:02 PM
To: Roehl Fabay <rfabay@californiaboiler.com>
Subject: RE: Boiler NOx emissions for Boilers less than 2 MMBtu/hr

Hi Roehl,

Thank you for providing this information. I did have a few follow up questions.

1. Is the 9 ppm for the NP2 burner and 20 ppm for the Powerflame NPM burner achievable for both natural gas and LPG? If not, what ppm is achievable for LPG? Only on natural gas. LP on NP2 will be around 12 or 15. LP on NPM is still 20ppm on both LP and NG.
2. Regarding the $10-$14k price difference, what are some rough estimated total costs for boilers in the 700 MBH to 2000 MBH range. This will vary depending on the type of boiler. NPM and NP2 can be use in different brand.

Thanks again for your help,

Jeffrey Quok
Air Quality Engineer
Desk: (279) 207-1145
JQuok@airquality.org
www.AirQuality.org
@AQMD

Jeffrey Quok

From:	Roehl Fabay <rfabay@californiaboiler.com>
Sent:	Thursday, March 23, 2023 7:43 PM
To:	Jeffrey Quok
Subject:	RE: Boiler NOx emissions for Boilers less than 2 MMBtu/hr

*** THIS EMAIL ORIGINATED OUTSIDE AIRQUALITY.ORG ***

Jeffrey,

See response below.

Thanks!

Roehl Fabay
California Boiler

From: Jeffrey Quok <JQuok@airquality.org>
Sent: Thursday, March 23, 2023 4:01 PM
To: Roehl Fabay <rfabay@californiaboiler.com>
Subject: RE: Boiler NOx emissions for Boilers less than 2 MMBtu/hr

Hi Roehl,

Thanks again for all your help. I've got a two more questions after receiving some comments on the proposed BACT.

1. Is the proposed 9 ppm NOx limit for the Powerflame NP2 burner guaranteed by the manufacturer? Yes, this is guaranteed by the manufacturer.
2. Have units been installed and were tested that meet the 9 ppm NOx limit in the 700MBH to 2000MBH range? Yes, this was commonly installed here in SCAQMD area.

Thank you,

Jeffrey Quok
Air Quality Engineer
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AIR QUALITY