Proposed Amended Rules 1146 & 1146.1 Emissions of Oxides of Nitrogen from Industrial, Institutional, and Commercial Boilers, Steam Generators, and Process Heaters

Working Group Meeting #3
February 13, 2026

Zoom Meeting Information

URL: https://aqmd.zoomgov.com/j/1601239471
Meeting ID: 160 123 9471
Dial-In: +1 (669)-254-5252

Agenda

- Summary of Working Group Meeting #2
- Staff Activities Update
- BARCT Assessment – Technology Background
- BARCT Assessment – Initial BARCT Emission Limits and Initial Cost-Effectiveness Analyses
- Initial Staff Proposal and Next Steps

Summary of Working Group Meeting #2

Summary of Working Group Meeting #2

- Equipment universe refined and finalized at approximately 1,892 units
- Sample set of equipment universe statistically developed at 138 units
- Estimated Total Set NOx emission inventory at 0.57 tons per day
- Review of other regulations at State, Federal, and International levels
    - South Coast AQMD boilers already have some of lowest NOx concentration limits in the world (5-9 ppm for most units)
    - South Coast Air Basin still in extreme ozone non-attainment and requires further NOx emission reductions

Staff Activities Update

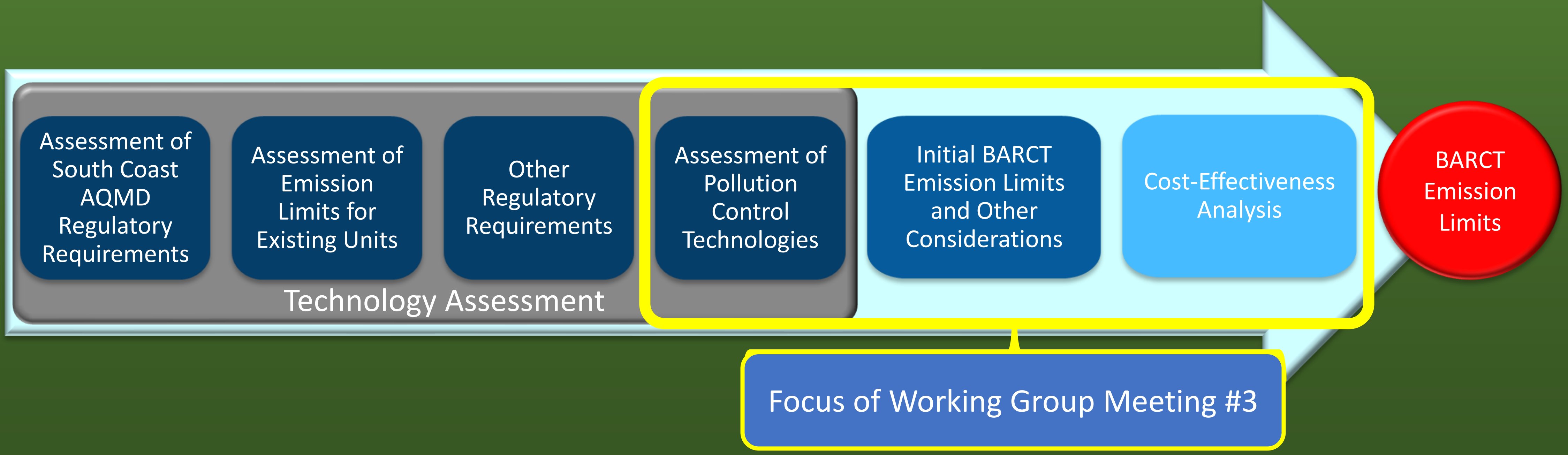
Staff Outreach and Research

- Staff has conducted extensive outreach to industry and NGOs
  - Goal was to understand industrial decarbonization efforts and state of NOx pollution control and zero-emission technologies
- Staff met with over 20 vendors of various NOx pollution control technologies
- Staff conducted in-person site visits and spoke with six end-user commercial and industrial facilities
- Traditional rule-making approach of lower NOx limits challenging due to existing low NOx requirements

BARCT Assessment – Technology Background

BARCT Assessment

- BARCT assessment was conducted for each class and category of equipment in PARs 1146 and 1146.1
- Working Group Meeting #2 discussed assessment of current emission limits and reviewed regulations outside of South Coast AQMD for industrial and commercial boilers and process heaters
- Working Group Meeting #3 encompasses assessment of pollution control technologies, review of initial BARCT emission limits, and initial cost-effectiveness analyses for potential control technologies



Assessment of Pollution Control Technologies

- Equipment categories for Rule 1146 and Rule 1146.1 include various unit types: water tube and fire tube boilers, natural gas-fired, gaseous-fired, liquid fuel-fired, and thermal fluid heaters
  - Each category has its own NOx limit and compliance schedule
- Permit data analyzed for the 138 units in the Sample Set
  - Nearly all units are natural gas-fired and either water tube or fire tube boilers
  - Five units belong to other categories: thermal fluid heaters (2), steam generators (2), and liquid fuel-fired (1)
- Category analysis
  - Initial cost-effectiveness analysis was conducted on natural gas-fired water tube and fire tube boilers
  - Staff will continue to assess applicability of initial BARCT emission limits for these other categories
  - Staff's initial compliance schedule will be to phase-in units to meet initial BARCT emission limits upon natural end of equipment life

State-of-the-Art NOx Control Technologies Survey

Assessment of Pollution Control Technologies

- Staff adopts a "technology neutral" approach to analyzing pollution control technologies
- The most technologically feasible NOx control technologies were considered

Control Category	Technology	High Level Summary
Near-Zero Emission (< 2.5 ppm NOx)	Ultra-Low NOx Burners	Process NOx control
	Selective Catalytic Reduction	Post-process high-efficiency NOx control
Zero Emission (< 0.1 ppm NOx)[1]	Electric Boiler	Emission-free heat production
	Heat Pump	Emission-free heat movement
	Hydrogen Boiler	Fuel-switching to reduce products of combustion

[1] Although electrically-powered equipment is not a source of combustion and does not generate NOx emissions, staff does not define zero-emission equipment operation as an absolute zero ppm, in recognition of instrument detection limits and ambient background concentrations.

Ultra-Low NOx Burners (ULNB)

Assessment of Pollution Control Technologies

- Every natural gas-fired boiler equipped with a burner (wide applicability)
- Fuel and ambient air are mixed to combust and produce heat for heating or boiling water
- Various techniques employed to achieve the lowest NOx concentrations in ULNB
  - Flue gas recirculation: recirculating exhaust gases back into combustion chamber to reduce peak flame temperature
  - Fuel and air mixing staging: mixes at various points along multiple zones to disrupt high-temperature conditions
  - Excess air dilution: introducing more air than stoichiometrically required to absorb heat from the flame

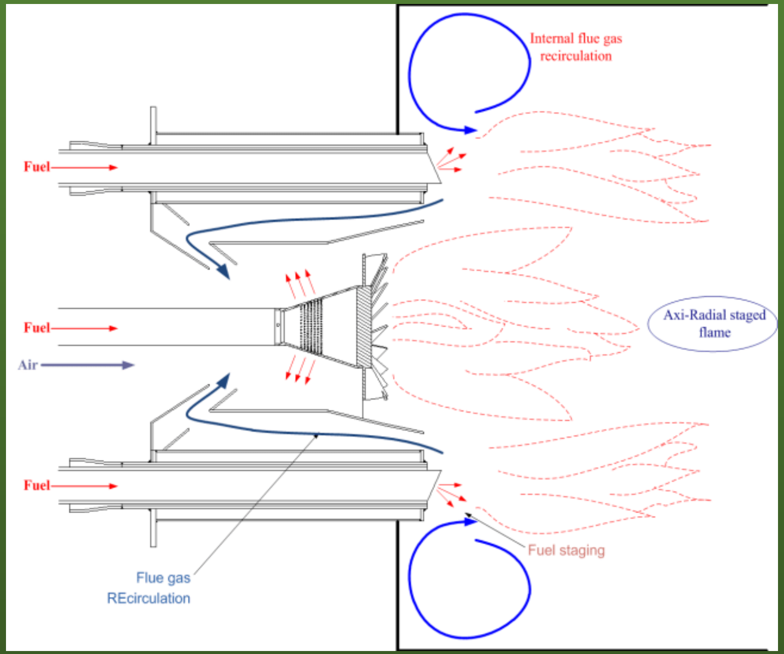
Source: U.S. EPA SBIR Program.

Limitations of ULNB

Assessment of Pollution Control Technologies

Limitations

- Turndown ratio for commercial and industrial boilers range from 5:1 to 10:1
- High turndown ratio mitigates boiler short cycling and allows for greater efficiency
- ULNB typically have a max turndown of 3:1 to 4:1 due to excess air and flame stability considerations
- Ultra Low NOx Burners may require specific fuel pressures up to 10 psig

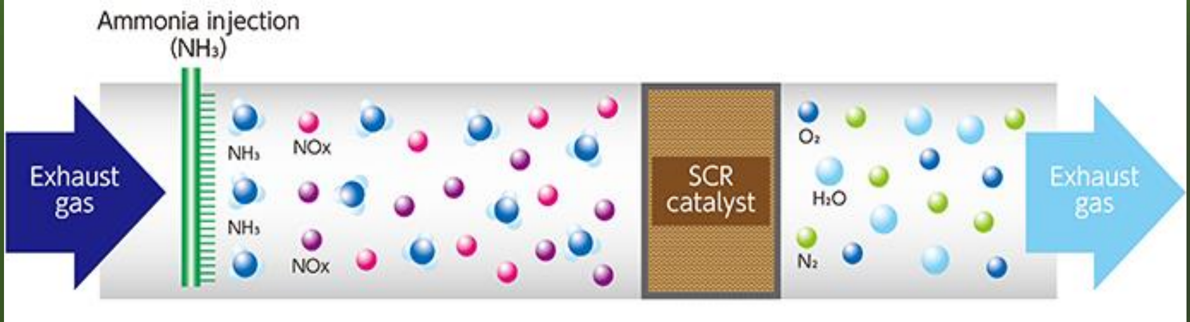


Source: Kwon, M. "An Experimental Study on Industrial Boiler Burners Applied Low NOx Combustion Technologies".

Selective Catalytic Reduction (SCR)

Assessment of Pollution Control Technologies

- SCR is an established NOx control technology in-use since the 1990s
- Currently installed on approximately 15 Rule 1146 and 1146.1 boilers in the South Coast Air Basin
- NOx reduction efficiencies can range from 80-95%
- Operation is designed based on injection of ammonia or urea into flue stream to reduce NOx to N2 and H2O in the presence of a catalyst
- Flue temperature must be at least 450 °F to ensure proper chemical reaction



SCR NOx Removal System; Source: Kanadevia Corporation

Limitations of Selective Catalytic Reduction (SCR)

Assessment of Pollution Control Technologies

Limitations

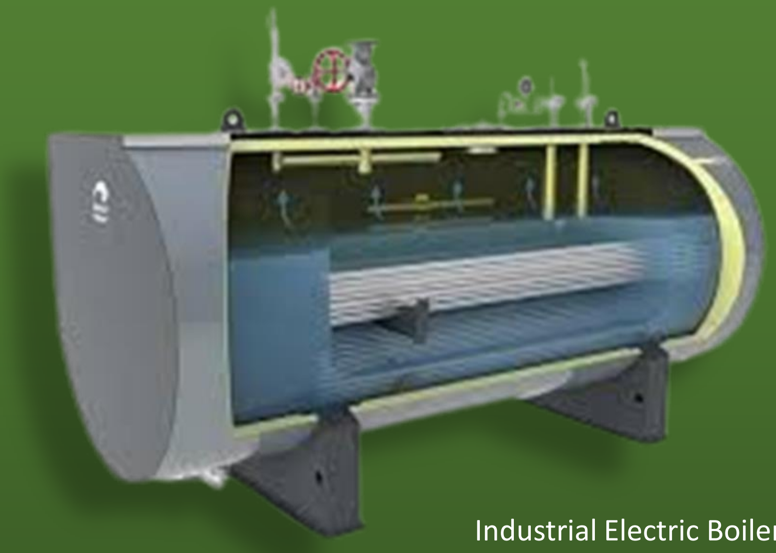
- Ammonia storage must be installed to house aqueous ammonia or urea
- Unreacted ammonia emissions between 1-10 ppm can serve as a precursors to particulate matter
- Requires significant space
  - Can be scaled down to 2-5 MMBtu/hr range
- Catalyst blocks must be replaced over time (additional expense)

SCR System; Source: Exhaust Control Industries

Electric Boiler

Assessment of Pollution Control Technologies

- Used in industrial applications for over a century
  - Mostly used for niche applications instead of main workhorse applications
- Manufactured in two types
  1. Resistance
     - Use resistive elements to heat water
     - For commercial applications up to ~ 5 MW
  2. Electrode
     - Use electric arc between two electrodes
     - For industrial applications, can use a higher voltage
- Can produce steam and scale up to any size
  - Popular US vendors up to 102 MW



Industrial Electric Boiler;
Source: Babcock Wanson

Limitations of Electric Boilers

Assessment of Pollution Control Technologies

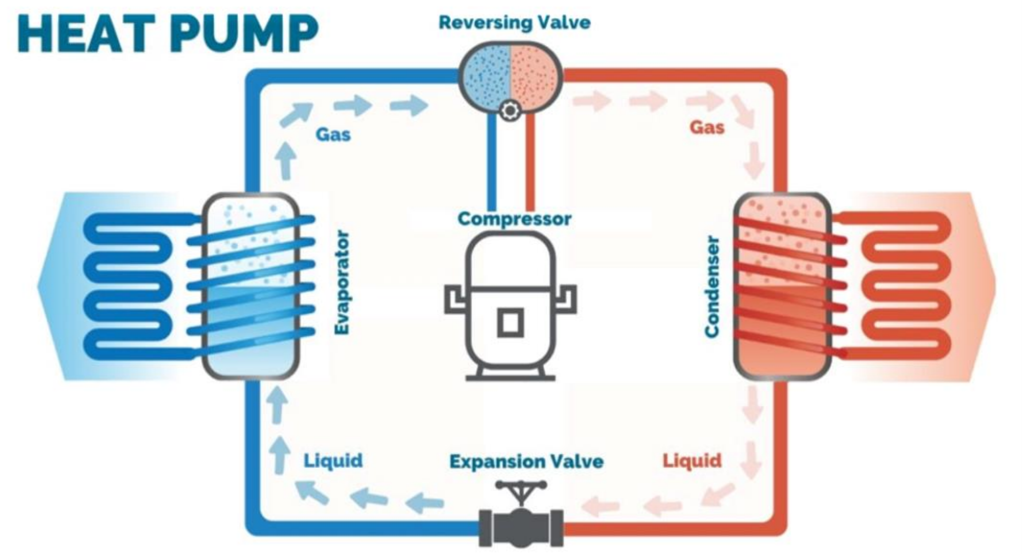
Limitations

- Requires a large amount of power (COP ≈ 1.0)
- May require electrical infrastructure upgrades to facility
- Electricity rates may increase operational cost considerably

Heat Pump

Assessment of Pollution Control Technologies

- Similar to electric boilers, heat pumps use a different input medium than natural gas-fired boilers (electricity vs. gas)
- Multiple Types
    - Air-Source
    - Water-Source
    - Waste Process Heat
- Typically uses a refrigerant and phase-change evaporation/condensation to transfer heat, instead of creating heat through combustion
- Coefficient of Performance (COP), ratio of desired output (heating or cooling) over the energy input, ranges between:
    - Air-Source: 2-5
    - Water-source and Waste Heat: > 4



Source: Berg Chilling Systems Inc.

Limitations of Heat Pumps

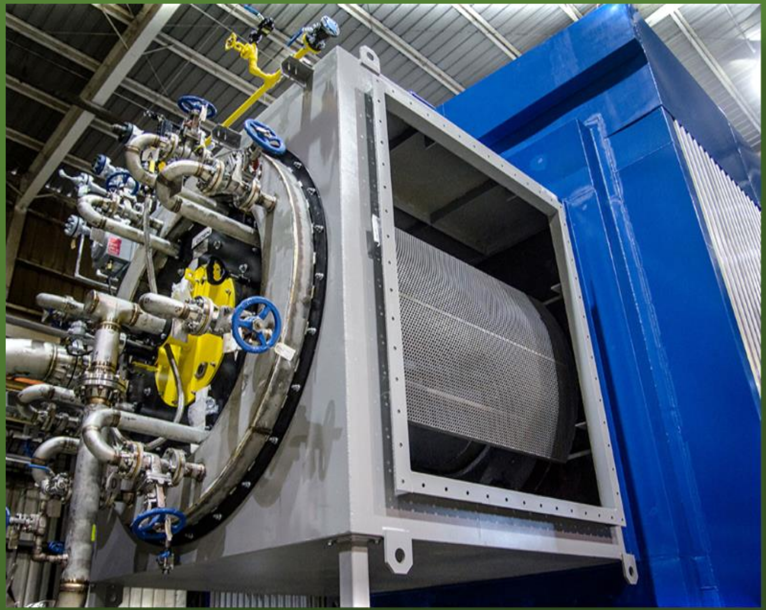
Assessment of Pollution Control Technologies

Limitations

- Existing air-source heat pump installations in South Coast Air Basin face difficulty achieving temperatures above 140 °F
- Limited vendors in the U.S.
- Some heat pump installations can be as large as 40 feet long
- Refrigerants include many classifications
  - Hydrofluoroolefins (HFOs) have good performance and low global warming potential (GWP) but there are environmental toxicity concerns
  - Natural refrigerants have ≤ 1 GWP and are non-environmentally toxic but may have operational safety concerns such flammability (*Ex: ammonia or R-717*)
- Spark Gap: higher electric rates vs. natural gas rates for a same size heating unit
- Southern California Edison electricity rates range 5-10x higher than natural gas rates

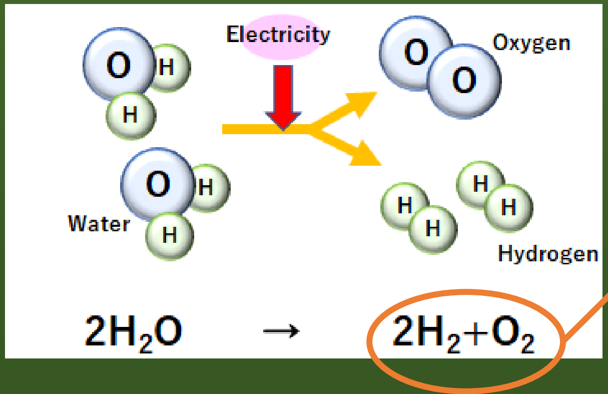
Hydrogen Boiler

- Similar operation to natural gas boilers
- Fuel type is hydrogen instead of hydrocarbons
- Method of production can greatly affect life-cycle emissions

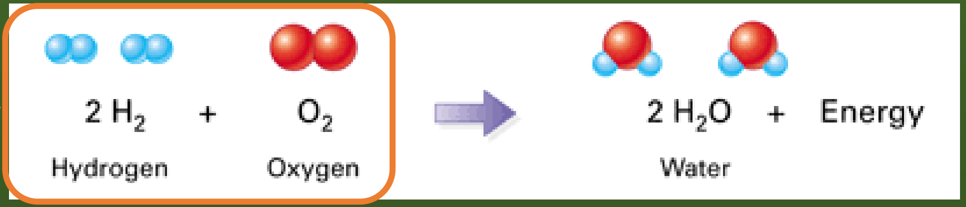


Industrial Hydrogen Boiler
Source: Babcock Wilcox.

H2 Electrolysis Production Method



H2 Combustion

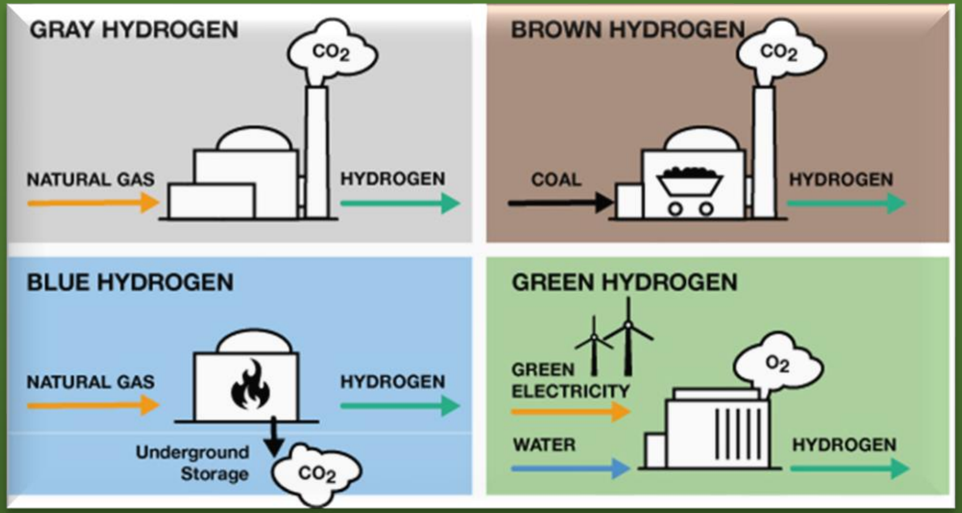


Hydrogen Boiler

Assessment of Pollution Control Technologies

Limitations

- Challenges with pipeline transport and storage
- Much more flammable than natural gas
- Higher NOx emissions due to greater flame temperature (3,400˚F)
- Not evaluating as separate technology as NOx emissions would be similar to or higher than natural gas



Source: ENERVEX Inc.

NOx Control Technologies Summary

Assessment of Pollution Control Technologies

Control Category	Technology	Operation	Pros	Cons
Near-Zero Emission (< 2.5 ppm NOx)	ULNB	Control combustion at the burner-level	Easily retrofittable Widely applicable Established technology	Lower efficiencies with gas combustion and high excess air
	SCR	Utilize ammonia and catalyst to bind to NOx	Widely applicable for larger units Large NOx reductions Established technology	Not practical for smaller units Requires ammonia storage Ammonia slip
Zero-Emission (< 0.1 ppm NOx)	Electric Boiler	Resistance or electrode heating	Widely applicable Established technology	Potential need for infrastructure upgrades Large power draw and operational cost
	Heat Pump	Refrigerant used to move heat from source to sink	High efficiency High degree of innovation for temperature and capacity	Large capital cost Limitations to meet temperature and capacity needs Higher operational cost with fuel-switch
	Hydrogen Boiler	Combust hydrogen instead of natural gas with a burner	No carbon emissions	Increases NOx emissions Blending in pipelines not yet analyzed Difficult to transport and handle

BARCT Assessment – Initial BARCT Emission Limits and Initial Cost-Effectiveness Analyses

Staff Outreach for Cost Estimates and Technology Considerations

Staff conducted an outreach and research effort to better understand these technologies

Staff sought quotes and cost information for equipment, installation, and operating costs for each technology from vendors and facilities

↓

Initial cost-effectiveness calculated for each individual unit and aggregated to a category-level: Rule 1146.1, Group I, Group II, and Group III units

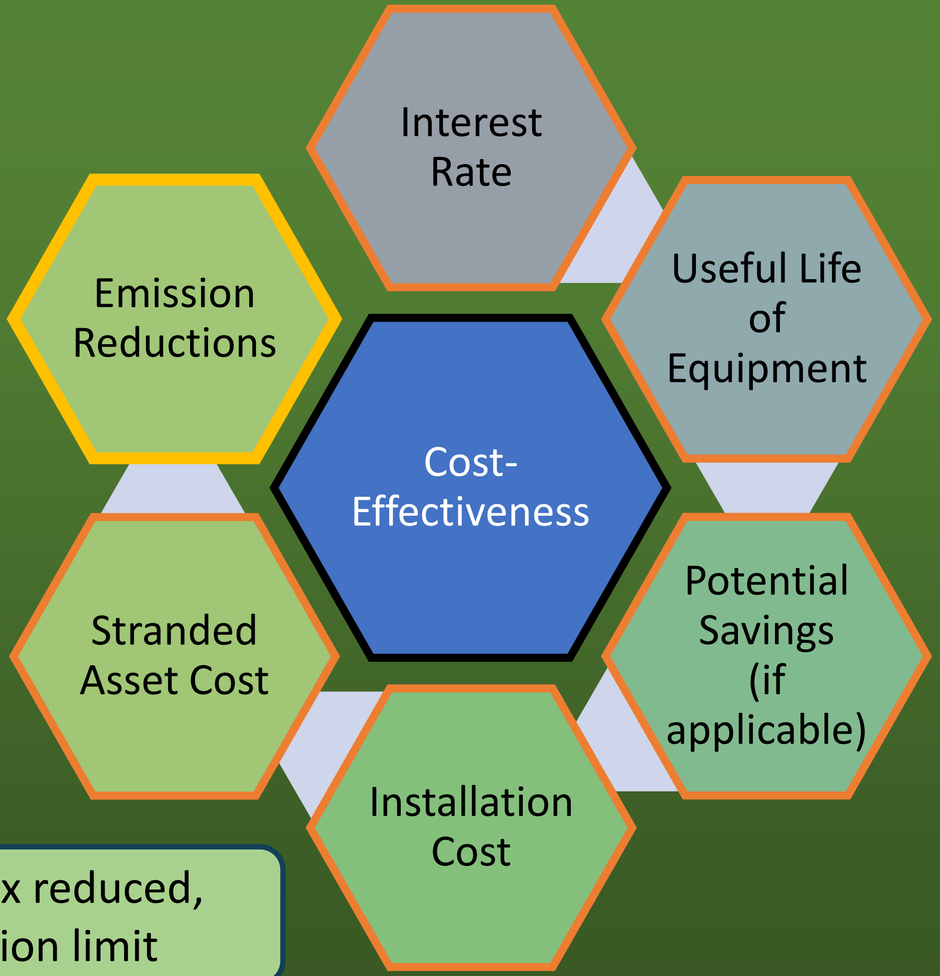
↓

Objective is to share initial findings and solicit feedback

Overview of Cost-Effectiveness

Cost-effectiveness is the total cost (capital and annual operating costs) over the emission reductions for the life of the equipment

- Cost-effectiveness is expressed in dollars per ton of pollutant reduced
- Costs and emission reductions calculated for each class and category of equipment in the Sample Set, and scaled up to the Total Set based on the unit count ratio (refer to WGM #2)
- Units with very little or no fuel usage were not included in initial cost-effectiveness analysis



Staff used the 2022 AQMP[1] cost-effectiveness of $325,000/ton of NOx reduced, adjusted by inflation, as guidance for establishing the BARCT emission limit

[1] South Coast AQMD 2022 AQMP, Page 4-76. http://www.aqmd.gov/docs/default-source/clean-air-plans/air-quality-management-plans/2022-air-quality-management-plan/final-2022-aqmp/final-2022-aqmp.pdf?sfvrsn=16. Threshold adjusted to 2024 dollars is $394,000/ton of NOx reduced.

Overview of Cost-Effectiveness: Costs

Cost-Effectiveness Analysis

Capital Costs
(Increased One-Time Expenses)

- Equipment
- Installation
- Infrastructure
- Permit fees

Annual Operating Costs
(Increased Recurring Expenses)

- Labor and maintenance
- Fuel and electricity
- Catalyst (SCR Only) (*as an annual cost*)
- Reagent (SCR Only)
- Monitoring, Reporting, and Recordkeeping

Overview of Cost-Effectiveness: Emission Reductions

Cost-Effectiveness Analysis

Emission Reductions = Baseline Emissions – Proposed Emissions

Baseline Emissions:

AER Annual Fuel Usage (MMScf/year) *
***Permit Limit (ppm @ 3% O2)* * Conversion Factor[1]**

Proposed Emissions:

AER Annual Fuel Usage (MMScf/year) *
***Initial BARCT Emission Limit Concentration (ppm @ 3% O2)* * Conversion Factor[1]**

[1] Conversion factor from NOx ppm concentration to lbs NOx per MMScf natural gas is approximately 1.26

Cost-Effectiveness: ULNB – Inputs

- Staff engaged with a boiler and burner vendor with a technology capable of achieving emissions below 2.5 ppm NOx @ 3%
- Costs based on quoted data for varying rated heat input capacities
- Staff used existing burner costs as a baseline and subtracted out from retrofit costs of a 2.5 ppm NOx ULNB[1]
- Capital costs: Equipment, Installation, Permit Application[2]
- Annual costs: Assumed no additional maintenance beyond existing burner equipment and no fuel efficiency gains

[1] Based on Rule 1146 2018 Final Staff Report, page 2-18, and adjusted to 2024 dollars. https://www.aqmd.gov/docs/default-source/agendas/governing board/2018/2018-dec7

[2] Based on South Coast AQMD Rule 301, Schedule C

Cost-Effectiveness: ULNB – Input Data

Cost-Effectiveness Analysis

Input	Value
Capital Costs	
2.5 ppm ULNB	Equipment: $6,300 * (Heat Input: MMBtu/hr) + $194,600 Installation: $6,900 * (Heat Input) + $104,000
Replacement 9 ppm Standard Burner Savings	Equipment: -[$7,000 * (Heat Input) + $11,600] Installation: -[$2,100 * (Heat Input) + $31,300]
Annual Costs (15-Year Lifetime)	
Maintenance & Fuel Efficiency	No additional costs
Emission Reductions	
Existing NOx Level	9 ppm @ 3% O2
New NOx Level	2.5 ppm @ 3% O2

Cost-Effectiveness: ULNB – Results

Cost-Effectiveness Analysis

Size Classification	Total Costs	Total Emission Reductions (lifetime tons of NOx)	Cost-Effectiveness ($/ton)
Rule 1146.1 (2-5 MMBtu/hr)	$54,410,000	225	$242,000
Rule 1146 – Group III (5-20 MMBtu/hr)	$134,490,000	1,538	$87,000
Rule 1146 – Group II (20-75 MMBtu/hr)	$64,059,000	740	$87,000
Rule 1146 – Group I (> 75 MMBtu/hr)	$14,508,000	119	$122,000

Retrofitting with ULNB capable of achieving 2.5 ppm NOx may be cost-effective for each class and category of equipment

Cost-Effectiveness: SCR – Inputs

Cost-Effectiveness Analysis

- Staff utilized U.S. EPA's 2019 SCR Cost Calculator[1] to estimate both capital and annual costs for SCR installation
- Analysis excluded units already equipped with SCR (all Group I units)
- Staff utilized actual fuel consumption data and scaled costs by rated heat input capacity
- Capital Costs: Equipment, Installation, Permit Application[2]
- Annual Costs: Maintenance, Reagent, Electricity, Catalyst, Annual Permit Renewal, Administration
- Emission Reductions: Assumed 83% NOx control efficiency from baseline emissions

Air Pollution Control Cost Estimation Spreadsheet
For Selective Catalytic Reduction (SCR)

U.S. Environmental Protection Agency
Air Economics Group
Health and Environmental Impacts Division
Office of Air Quality Planning and Standards
(June 2019)

[1] U.S. EPA SCR Cost Calculator. https://www.epa.gov/sites/default/files/2019-06/scrcostmanualspreadsheet_june-2019vf.xlsm.
[2] Based on South Coast AQMD Rule 301, Schedule C

Cost-Effectiveness: SCR – Input Data

Cost-Effectiveness Analysis

Input	Value
Capital Costs	
Equipment & Installation	$\$10,500 * [\$1,640/(\text{Heat Input})]^{0.35} * (\text{Heat Input})$
Annual Costs (25-Year Lifetime)	
Maintenance	0.5% * Capital Cost
Reagent	Reagent Usage Rate * Reagent Cost * Operating Time
Electricity	Power Draw * Power Cost * Operating Time
Administration Cost	Labor Cost for SCR Operator
Emission Reductions	
Existing NOx Level	9 ppm @ 3% O2
New NOx Level[1]	1.5 ppm @ 3% O2

[1] NOx reduction efficiency assumed at 83%

Cost-Effectiveness: SCR – Results

Cost-Effectiveness Analysis

Size Classification	Total Costs	Total Emission Reductions (lifetime tons of NOx)	Cost-Effectiveness ($/ton)
Rule 1146.1 (2-5 MMBtu/hr)	$732,904,000	343	$2,137,000
Rule 1146 – Group III (5-20 MMBtu/hr)	$1,308,000,000	2,750	$476,000
Rule 1146 – Group II (20-75 MMBtu/hr)	$391,881,000	1,507	$260,000

SCR may be practical for some facilities to install depending on footprint availability

Cost-Effectiveness: Electric Boiler – Inputs

Cost-Effectiveness Analysis

- Capital Costs
  - Staff utilized cost figures from various government and non-profit publications for equipment and installation costs
  - Staff subtracted a baseline replacement cost for a natural gas-fired boiler of existing size
  - Staff applied electrical infrastructure costs based on unit size ranging from small transformers for mid-sized units to substations for the largest units
- Annual Costs
  - Effective boiler heat input and fuel usage account for an increase in efficiency from 85% (natural gas-fired boiler) to 100% (electric boiler)
  - Accounted for cost of "Fuel Switch Premium" from natural gas to electricity
- Capital costs: Equipment, Installation, Infrastructure, Permit Application Savings[2]
- Annual costs: Fuel Switch Premium, Annual Permit Renewal Savings

[1] Based on Rule 1146 2018 Final Staff Report, page 2-18, and adjusted to 2024 dollars. https://www.aqmd.gov/docs/default-source/agendas/governingboard/2018/2018-dec7

[2] Based on South Coast AQMD Rule 301, Schedule C

Cost-Effectiveness: Electric Boiler – Input Data

Cost-Effectiveness Analysis

Input	Value
Capital Costs	
Equipment & Installation	$167 * Power Requirement (kWh)
Electric Infrastructure	$475,000–$2,000,000
Replacement Natural Gas Boiler Savings	-$30,600 * (Heat Input)
Permit to Operate Savings	-$6,529.78
Annual Costs (25-Year lifetime)	
Fuel Switch Premium	Electricity: 18.52 cents/kWh Natural Gas: 3.43 cents/kWh
Annual Permit Renewal Savings	-$2,025.92/yr
Emission Reductions	
Existing NOx Level	9 ppm @ 3% O2
New NOx Level	~ 0 ppm @ 3% O2

Rates based on California Energy Commission Integrated Energy Policy Reports[1]

Forecasts based on U.S. Energy Information Administration[2]

[1] https://www.energy.ca.gov/publications/2021/2021-integrated-energy-policy-report; https://www.energy.ca.gov/data-reports/reports/integrated-energy-policy-report/2022-integrated-energy-policy-report-update

[2] https://www.eia.gov/outlooks/aeo/tables_ref.php

Cost-Effectiveness: Electric Boiler – Results

Cost-Effectiveness Analysis

Size Classification	Total Costs	Total Emission Reductions (lifetime tons of NOx)	Cost-Effectiveness ($/ton)
Rule 1146.1 (2-5 MMBtu/hr)	$1,552,000,000	482	$3,220,000
Rule 1146 – Group III (5-20 MMBtu/hr)	$10,985,000,000	3,273	$3,356,000
Rule 1146 – Group II (20-75 MMBtu/hr)	$7,869,000,000	1,747	$4,504,000
Rule 1146 – Group I (> 75 MMBtu/hr)	$2,926,000,000	396	$7,389,000

Fuel switch premium accounted for > 94% of the total lifetime costs. With zero fuel switch premium[1], category cost-effectiveness ranges from $5,400 to $213,000 per ton of NOx reduced

[1] Zero fuel switch premium defined as electricity costs in parity with natural gas costs at approximately $0.034/kW

Cost-Effectiveness: Heat Pump – Inputs

Cost-Effectiveness Analysis

- Capital Costs
  - Staff obtained cost figures from several industrial heat pump manufacturers
  - Staff applied electrical infrastructure costs based on unit size ranging from small transformers for mid-sized units to substations for the largest units
- Annual Costs
  - Effective boiler heat input and fuel usage account for an increase in efficiency from 85% (natural gas-fired boiler) to 300% (COP of 3.0; based on air-source heat pumps)
  - Accounted for cost of "Fuel Switch Premium" from natural gas to electricity
  - Assumed no additional costs due to refrigerant top-off
- Capital costs: Equipment, Installation, Infrastructure, Permit Application Savings[2]
- Annual costs: Fuel Switch Premium, Annual Permit Renewal Savings

[1] Based on Rule 1146 2018 Final Staff Report, page 2-18, and adjusted to 2024 dollars. https://www.aqmd.gov/docs/default-source/agendas/governingboard/2018/2018-dec7

[2] Based on South Coast AQMD Rule 301, Schedule C

Cost-Effectiveness: Heat Pump – Input Data

Cost-Effectiveness Analysis

Input	Value
Capital Costs	
Equipment & Installation	$1,000,000 * Power Requirement (MWh)
Electric Infrastructure	$475,000–$2,000,000
Replacement Natural Gas Boiler Savings	-$35,000 * (Heat Input)
Permit to Operate Savings	-$6,529.78
Annual Costs	
Fuel Switch Premium	Electricity: 18.52 cents/kWh Natural Gas: 3.43 cents/kWh
Annual Permit Renewal Savings	-$2,025.92/yr
Emission Reductions	
Existing NOx Level	9 ppm @ 3% O2
New NOx Level	~ 0 ppm @ 3% O2

Rates based on California Energy Commission Integrated Energy Policy Reports[1]

Forecasts based on U.S. Energy Information Administration[2]

[1] https://www.energy.ca.gov/publications/2021/2021-integrated-energy-policy-report; https://www.energy.ca.gov/data-reports/reports/integrated-energy-policy-report/2022-integrated-energy-policy-report-update

[2] https://www.eia.gov/outlooks/aeo/tables_ref.php

Cost-Effectiveness: Heat Pump – Results

Cost-Effectiveness Analysis

Size Classification	Total Costs	Total Emission Reductions (lifetime tons of NOx)	Cost-Effectiveness ($/ton)
Rule 1146.1 (2-5 MMBtu/hr)	$868,000,000	482	$1,801,000
Rule 1146 – Group III (5-20 MMBtu/hr)	$4,095,000,000	3,273	$1,251,000
Rule 1146 – Group II (20-75 MMBtu/hr)	$2,767,000,000	1,747	$1,006,000
Rule 1146 – Group I (> 75 MMBtu/hr)	$829,352,000	396	$2,094,000

Fuel switch premium accounted for 25-49% of the total lifetime costs due to high efficiency.
With zero fuel switch premium[1], category cost-effectiveness ranges from
$0.82 million to $1.4 million per ton of NOx reduced.

Ongoing product innovation and market adoption may help decrease the cost of this control technology

[1] Zero fuel switch premium defined as electricity costs in parity with natural gas costs at approximately $0.034/kW

Cost-Effectiveness: All Tech Sample Calculation

Cost-Effectiveness Analysis

Input	ULNB	SCR	Electric Boiler	Heat Pump
Effective Heat Input	20 MMBtu/hr	20 MMBtu/hr	17 MMBtu/hr (5 MW equivalent)	6.7 MMBtu/hr (2 MW equivalent)
Capital Costs				
Equipment & Installation	$561,900	$1,413,000	$833,000	$5,862,000
Electric Infrastructure	$0	$0	$900,000	$475,000
Existing Equipment Savings	-$224,800	$0	-$611,300	-$611,300
Permit to Operate Savings	$0	$6,260	-$6,260	-$6,260
Annual Costs				
Fuel Switch Premium	$0	$0	$2,340,000	$337,800
Annual Permit Renewal Savings	$0	$31,600	-$31,600	-$31,600
Emission Reductions				
Existing NOx Level	5.41 tons (15 years)	9.0 tons (25 years)	9.0 tons (25 years)	9.0 tons (25 years)
Total Lifetime Costs	**$337,100**	**$1,451,000**	**$37,637,000**	**$10,964,000**
Lifetime Emission Reductions	**3.91 tons**	**7.52 tons**	**9.0 tons**	**9.0 tons**
Cost-Effectiveness	**$86,200**	**$193,000**	**$4,182,000**	**$1,218,000**

Cost-Effectiveness: Summary

Cost-Effectiveness Analysis

Control Category and Initial BARCT Emission Limit	Technology	Cost-Effectiveness ($/ton)	Considerations
Near-Zero Emission (2.5 ppm)	ULNB	$87,000–$242,000/ton	Fuel pressure requirement
Near-Zero Emission (83% reduction; 1.5 ppm for 9 ppm units)	Selective Catalytic Reduction	Group II Only - $260,000	Footprint restrictions; Ammonia storage
Zero-Emission (< 0.1 ppm)	Electric Boiler	$3.4–$7.4 million/ton	High fuel switch premium; Infrastructure
Zero-Emission (< 0.1 ppm)	Heat Pump	$1.0–$2.1 million/ton	High equipment costs; High fuel switch premium; Infrastructure

Initial cost-effectiveness analysis shows a wide range of cost-effectiveness values across NOx control technologies

Staff is open to receiving additional information to inform the analysis and is actively gathering more data from vendors and facilities

Next Steps

Summary of Initial Cost-Effectiveness and Other Considerations

Zero-Emission Technology

Electric boilers may be most feasible for smaller units at favorable electricity rates

Industrial heat pumps are being installed across the country in locations with grant funds, favorable electricity rates, or greenhouse gas emission reduction initiatives

Some facilities may not have footprint to accommodate transformers/substations or building code restrictions for refrigerant usage

Both technologies require substantially lower electricity rates to mitigate fuel switch premium

Summary of Initial Cost-Effectiveness and Other Considerations (cont.)

Near-Zero Emission Technology

May have much lower equipment and installation costs

ULNB may offer the most applicability: more facilities can implement the technology

Due to low baseline emissions, near-zero emission technologies may achieve majority (> 70%) of emission reductions expected to be achieved by zero-emission technologies

Staff is seeking feedback on initial cost-effectiveness analysis before proceeding with initial rule concepts

Next Steps

Further Assess Technologies

- Meet vendors for additional quote and retrofit considerations
- Conduct additional site visits to assess retrofit feasibility

Hold Next Working Group

- Share additional findings
- Present initial rule concepts
- March or April

Release Draft Public Documents

- Share preliminary draft rule language and draft staff report
- Q3 2026

Public Process Timeline

- Public Hearing: Q4 2026

****Note:*** Dates are subject to change

Keep Connected

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Proposed Rules Page

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