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 #4
June 25, 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 #3

Stakeholder Comments

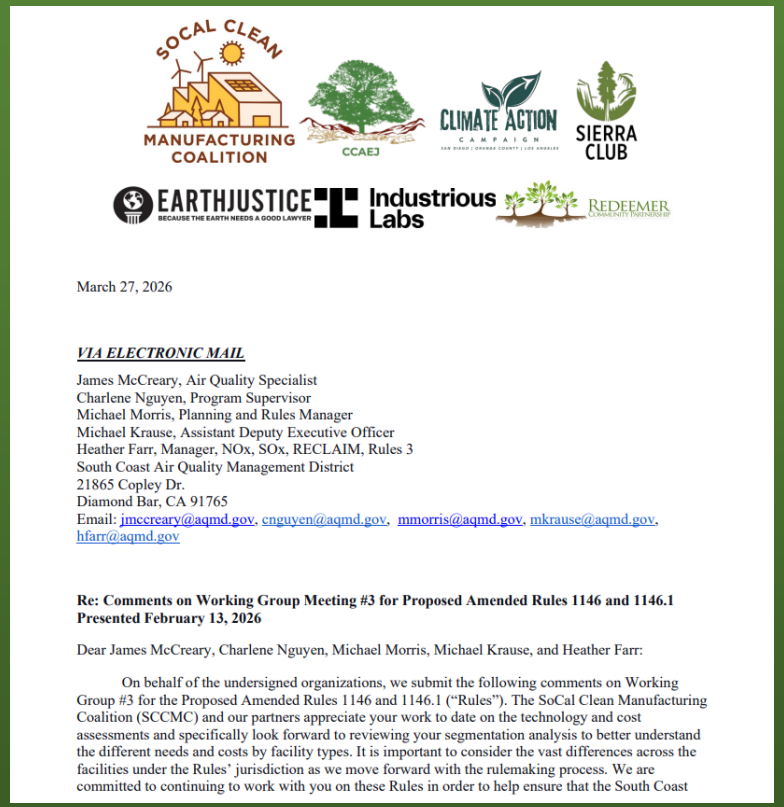
Cost-Effectiveness Additional Analyses

Initial Rule Concepts

Next Steps

Stakeholder Comments

SoCal Clean Manufacturing Coalition – March 27, 2026



March 27, 2026

VIA ELECTRONIC MAIL

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Re: Comments on Working Group Meeting #3 for Proposed Amended Rules 1146 and 1146.1 Presented February 13, 2026

Dear James McCreary, Charlene Nguyen, Michael Morris, Michael Krause, and Heather Farr:

On behalf of the undersigned organizations, we submit the following comments on Working Group #3 for the Proposed Amended Rules 1146 and 1146.1 ("Rules"). The SoCal Clean Manufacturing Coalition (SCCMC) and our partners appreciate your work to date on the technology and cost assessments and specifically look forward to reviewing your segmentation analysis to better understand the different needs and costs by facility types. It is important to consider the vast differences across the facilities under the Rules' jurisdiction as we move forward with the rulemaking process. We are committed to continuing to work with you on these Rules in order to help ensure that the South Coast

Comment	Staff Response
South Coast AQMD must adopt zero-emission rules to meet air quality standards to send market signal.	Staff continues to explore how zero-emission limits can be implemented through both regulatory and incentive pathways.

SoCal Clean Manufacturing Coalition – COP

Comment	Staff Response
Many industrial sectors can achieve higher COPs [Coefficient of Performance] of 4 to 5. An industry segmentation should be conducted for COP assignment instead of a single COP assigned for all facilities.	Staff has segmented the facility universe for COP assignment and the analysis is provided later in this presentation. Staff did not observe a COP of 4 to 5 across both vendor quotes and active installations for industrial sectors. Staff recognizes that some facilities may have waste heat of a high enough temperature to utilize in a heat pump. Facilities may take advantage of this to reduce their expenses with heat pumps.

SoCal Clean Manufacturing Coalition – CAPEX

Comment	Staff Response
ULNB [Ultra-Low NOx Burner] and SCR [Selective Catalytic Reduction] CAPEX [Capital Expenditures] may be understated due to only considering retrofit costs rather than full replacement costs, when necessary. Zero-emission technology CAPEX may be overstated due to sizing and cost-correlation used.	Staff's analysis assumes retrofit/replacement upon the end of the existing equipment's useful life. The cost-effectiveness analysis also accounts for the savings realized by not replacing the original equipment with another natural gas boiler/burner. Staff assumed replacement with zero-emission equipment (ZE Equipment) for the same thermal output capacity. Efficiency gains were accounted for in determining electrical input capacity.

SoCal Clean Manufacturing Coalition – Alternative Rate Structure

Comment	Staff Response
Staff should consider alternative or proposed rate structures. Staff should also consider the price hunting ability afforded by the use of thermal batteries.	Staff conducted a scenario where 100% of electrified load is shifted to off-peak times and the analysis is provided later in this presentation. Staff assessed the cost benefits of shifting 100% of electrified load without the use of additional CAPEX items such as thermal batteries or hot water buffer tanks to maximize the benefit.

Cost-Effectiveness Additional Analyses

Summary of Previous Cost-Effectiveness Analysis

	Electric Boiler	Heat Pump[1]
Cost-Effectiveness	$3.3–$7.4 million/ton NOx reduced	$0.6–$1.3 million/ton NOx reduced

Cost Component	Electric Boiler[2] % of Total Project Lifetime Costs	Heat Pump[2] % of Total Project Lifetime Costs
Equipment and Installation	1%	19%
Electrical Infrastructure	2%	6%
Fuel Switch Premium	97%	75%

Current electric utility rates are primary driver of high costs

[1] Heat pump total costs corrected from data presented in Working Group Meeting #3 to account for thermal efficiencies reducing heat pump CAPEX
[2] Percentages shown are averaged across entire Sample Set

Additional Analyses

- Staff continues to gather data from stakeholders to inform the cost-effectiveness analysis
- Staff has conducted several additional analyses to refine the preliminary cost-effectiveness
- Objective is to assess the impacts of these analyses to assess whether zero-emission technologies are cost-effective

1. *Revised Utility Rates*
2. *Heat Pump COP Segmentation*
3. *Alternative Electric Load Structures*
4. *Revised Equipment Inputs*
5. *On-Site Power Generation*

To illustrate impacts of additional analyses, a representative median-sized unit served by Southern California Edison electric utility was selected to showcase revisions

1 Revised Utility Rates

- Cost-Effectiveness analysis in Working Group Meeting #3 utilized the California Energy Commission's Integrated Energy Policy Reports (IEPR)[1]
- Staff analyzed utility tariff rates to estimate facility-specific utility charges

Gas Utility	IEPR Average Rate	Tariff Average Rate	Impact to Costs
Southern California Gas Company	$0.0343/kW	$0.0295/kW	**Minor decrease in natural gas baseline costs**

Electric Utility	IEPR Average Rate	Tariff Average Rate	Impact to Costs
Southern California Edison (SCE)	$0.18/kW	$0.44/kW	**Significant increase in electricity baseline costs**

[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 Heat Pump COP Segmentation

- Staff segmented facility universe based on process type and assigned an average process temperature and COP based on vendor quotes and project installations
- Staff did not observe a COP higher than 3 and medium- and high-temperature applications may achieve a COP between 2-3

Impact to Costs
Low-temperature applications (~120 °F) may have same cost estimates as originally estimated **Higher temperature applications may see an increase in CAPEX and operating expenses due to lower COP**

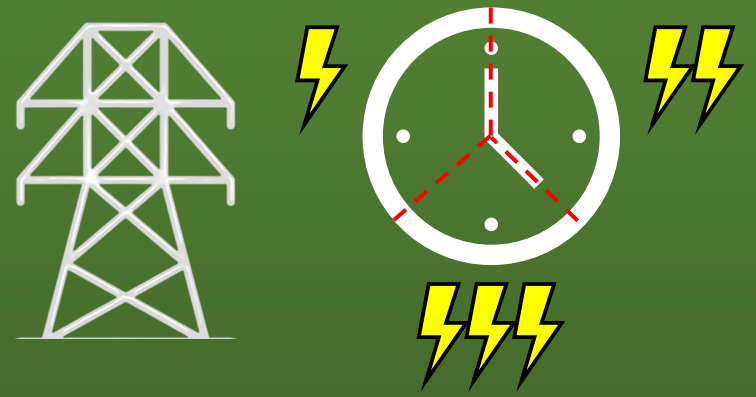
3 Alternative Electric Load Structures

Staff assessed alternative methods of electricity usage for potential cost savings

1. **Load Shift to Non-Peak Times**
   Facilities may realize moderate savings by shifting load to lower-cost hours

2. **SCE Flexible Pricing Rate Pilot[1]**
   Staff did not observe cost savings

3. **SCE's Proposed Marginal Cost-Based Dynamic Rate[2]**
   Not yet finalized; may lead to moderate savings for load-flexible facilities



Impact to Costs
Moderate decrease in electricity costs

[1] https://www.sce.com/sce-expanded-flexible-pricing-rate-pilot
[2] https://docs.cpuc.ca.gov/PublishedDocs/SupDoc/A2406014;A2412008/9189/605328560.pdf

4 Revised Equipment Inputs

Staff revised various CAPEX inputs for further accuracy based on literature and vendor quotes

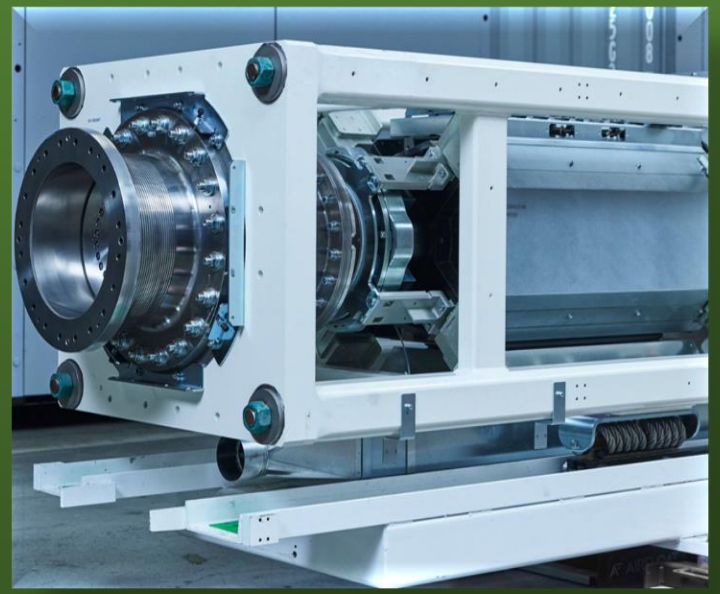
Cost Item	Working Group Meeting #3	Working Group Meeting #4	Impact to Costs[1]
Electric Boiler[2]	$167/kW	< 5 MW: $100/kW ≥ 5 MW: $202,364 * (Rated Heat Input: MMBtu/hr)$^{0.627}$	**Significant decrease in CAPEX for both electric boilers and heat pumps**
Natural Gas Boiler	$40,000/MMBtu	Firetube: $69,000 * (Rated Heat Input: MMBtu/hr) Watertube: $94,000 * (Rated Heat Input: MMBtu/hr)	
Annual Maintenance	No increased or decreased costs assumed	Natural Gas Boiler: 3% of CAPEX annually Heat Pump: 2% of CAPEX annually Electric Boiler: 1% of CAPEX annually	
Electric Infrastructure	Upgrades assessed at unit-level	Upgrades assessed at fleet level (multiple units may share single transformer)	

[1] Overall costs of project includes operating expenses and other costs, which may more than offset these savings.

[2] Electrode boiler (≥ 5 MW) costs scaled for Producer Price Index-based inflation from U.S. Department of Energy – Office of Manufacturing and Energy Supply Chains. https://industrialapplications.lbl.gov/sites/default/files/pdf-embeds/IAC%20Decarb%20Tipsheet%203.pdf

5 On-Site Power Generation

- Staff analyzed the cost premium above baseline of powering ZE Equipment with electricity from an on-site linear generator vs. electricity from the grid
- Staff included $3,000/kW of CAPEX and accounted for 1.5 ppm NOx emissions from linear generator



Impact to Costs
Significant decrease in overall costs but only moderate improvement to cost-effectiveness due to on-site emissions[1]

[1] While cost savings with usage of on-site power generation can be significant, linear generator NOx emissions lead to reduced net emission reductions. For representative unit, usage of a linear generator resulted in lower cost-effectiveness of 17% and 30% for electric boiler and heat pump, respectively.

Additional Analyses Impact Summary

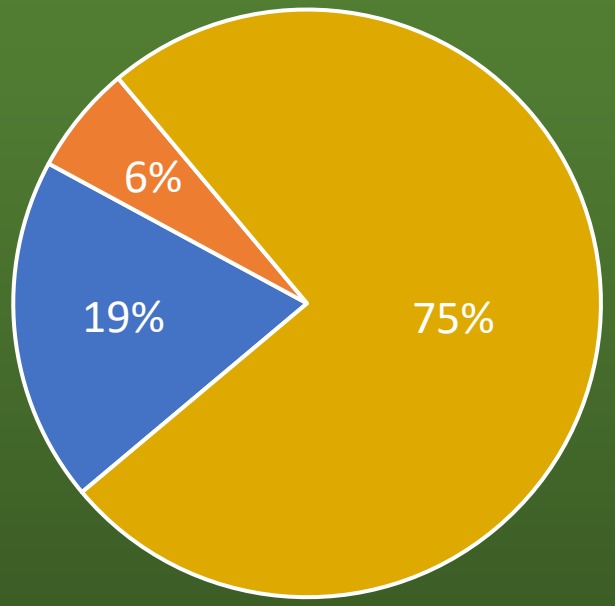
Additional Analysis	Impact
1 Revised Utility Rates	Minor decrease in natural gas baseline costs Significant increase in electricity baseline costs
2 Heat Pump COP Segmentation	No change to costs for low-temperature units Increase in costs for some high-temperature units
3 Load Shift to Non-Peak Times	Moderate decrease in electricity costs
4 Revised Equipment Inputs	Significant decrease in CAPEX
5 On-Site Power Generation	Moderate improvement to cost-effectiveness

Additional Analyses Relative Impact

Working Group Meeting #3

Percentage of Total Lifetime Costs: Heat Pump

While CAPEX may decrease with additional analyses, CAPEX is a minor component of overall costs and savings will have an undersized impact on overall lifetime costs



Significant increases in an already-majority component may outweigh other savings and lead to overall increases in lifetime costs

Additional Analyses Summary

Low baseline NOx emission inventory presents challenge by limiting emission-reduction potential associated with equipment retrofits or replacements

Majority of lifetime costs associated with fuel switch premium from natural gas to electricity

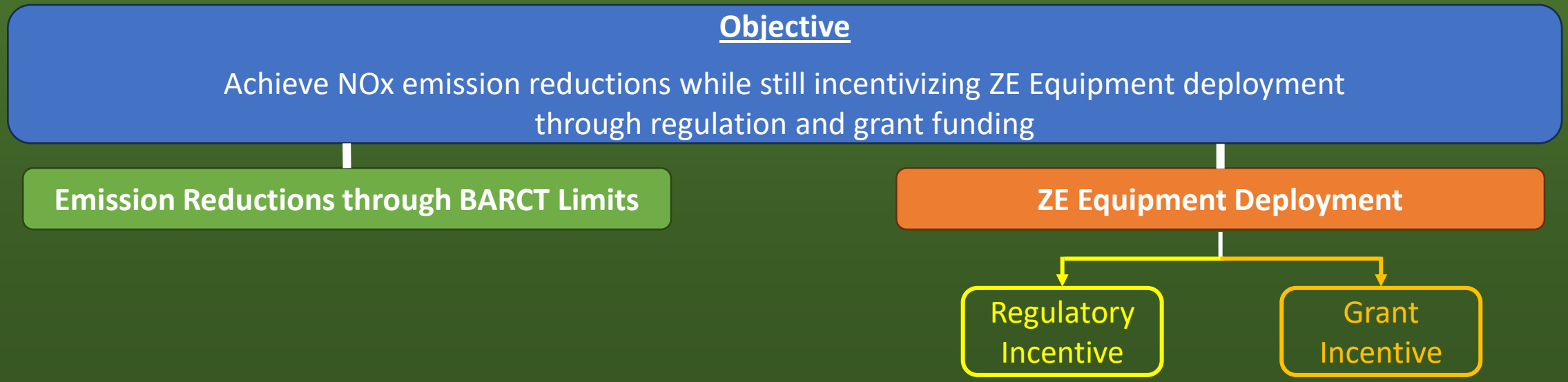
Load shifting and usage of linear generators can reduce lifetime costs and improve cost-effectiveness, but cost-effectiveness levels remain a magnitude above cost-effectiveness threshold of $400,000 per ton NOx reduced

Staff still seeks to facilitate deployment of zero-emission technologies and proposes incentive pathways through both regulation and grant funding

Initial Rule Concepts

Zero-Emission Equipment Cost-Effectiveness

- High baseline cost-effectiveness of ZE Equipment presents challenge to requiring 0 ppm at this time
- Additional cost-savings techniques such as load-shifting or on-site power generation improve cost-effectiveness but cost-effectiveness remains above threshold
- To still achieve NOx emission reductions, staff assessed whether near-zero emission technologies such as Ultra-Low NOx Burners (ULNBs) are both technologically feasible and cost-effective
- Staff seeks to achieve NOx emission reductions while still facilitating ZE Equipment deployment



BARCT Assessment - ULNB

Emission Reductions through BARCT Limits

- In previous Working Group meeting, staff analyzed Ultra-Low NOx Burners (ULNB) capable of achieving 2.5 ppm NOx
  - These ULNBs were calculated to be cost-effective
  - However, while they have been demonstrated in a testing environment, they are currently not commercially available
  - Therefore, staff is no longer considering 2.5 ppm NOx ULNBs for this rule development

Staff identified and analyzed commercially available ULNBs to achieve emission reductions

ULNB Cost-Effectiveness Inputs

Emission Reductions through BARCT Limits

- Staff engaged with a vendor of a 5 ppm burner with current installations in the South Coast AQMD
- Cost-effectiveness was calculated using vendor quote **cost** data and **emission reduction** potential
- Similar to previous cost-effective analyses, only costs above and beyond current replacement costs (9 ppm burner for most units) are accounted for

Costs

Permit Fee[1] $6,460

5 ppm ULNB[2] $15,000 * (Rated Heat Input: MMBtu/hr)

9 ppm ULNB[3] -$10,300 * (Rated Heat Input) + $48,600 (Baseline Cost)

Emission Reductions

Lifetime Emission Reductions[4] =
(Current ppm – 5 ppm) *
1.26 (Unit Conversion Factor: ppm to lbs/MMScf) *
Annual Fuel Usage (MMScf/year) / 2,000 (lbs per ton) *
15 years

[1] Based on Rule 301 Schedule C for Non-Title V modification
[2] For capacities above 50 MMBtu/hr, cost formulas scale up by 1.3x to account for requirement of two-burner configuration
[3] Formulas from 2018 amendment to Rule 1146/1146.1, adjusted for inflation. Equipment and installation costs merged.
[4] Fuel usage efficiency and equipment useful life assumed to be identical between 9 ppm and 5 ppm ULNBs

ULNB Cost-Effectiveness Summary

Emission Reductions through BARCT Limits

- Vendor data suggests 5 ppm ULNB not available for units less than 10 MMBtu/hr in size at this time
- Cost-effectiveness analysis not conducted for units less than this size to mirror commercial availability
- Staff is actively engaging with other vendors of 5 ppm ULNBs to collect additional data

Category[1]	Lifetime Costs	Lifetime Emission Reductions (tons NOx)	Cost-Effectiveness ($ per ton NOx Reduced)
Rule 1146 – Group III (5-20 MMBtu/hr)	$19,042,000	428	$44,500
Rule 1146 – Group II (20-75 MMBtu/hr)	$19,259,000	418	$46,100

A 5 ppm NOx limit via ULNBs for medium-sized boilers (> 10 MMBtu/hr) is cost-effective

[1] Rule 1146 – Group I units (> 75 MMBtu/hr) already subject to a 5 ppm NOx limit and not included in cost-effectiveness analysis

ULNB – Initial BARCT Emission Limit

Emission Reductions through BARCT Limits

Limits for units < 10 MMBtu/hr remain unchanged based on current vendor data

Boilers and Steam Generators

- Initial BARCT Emission Limit set at 5 ppm for both boilers and steam generators > 10 MMBtu/hr based on current vendor data
- Staff will consider reclassifying rated heat input capacity thresholds in Rule 1146, based on commercial availability of 5 ppm ULNBs

Thermal Fluid Heaters

- Vendor data suggests a higher limit of 7 ppm for thermal fluid heaters due to higher fluid and process temperatures
- Staff did not observe installations of burner for thermal fluid heaters in equipment universe and will not consider revising NOx limit at this time

ULNB – Revised Limits

Emission Reductions through BARCT Limits

Unit Category	Current NOx Limit	Proposed NOx Limit
Rule 1146 – Group I (≥ 75 MMBtu/hr)	5 ppm	Unchanged
Rule 1146 – Group II (≥ 20 to < 75 MMBtu/hr)	5-9 ppm	**Units > 10 MMBtu/hr: 5 ppm** Units < 10 MMBtu/hr: Unchanged
Rule 1146 – Group III (≥ 5 to < 20 MMBtu/hr)	7-9 ppm	
Rule 1146 – Other Unit Types (Atmospheric, Liquid Fuel-Fired, Thermal Fluid Heater)	12 and 40 ppm	Unchanged
Rule 1146.1 (> 2 to < 5 MMBtu/hr)	7-30 ppm	Unchanged

Approximately 80% of units subject to proposed limit of 5 ppm NOx are already required to meet a lower-than-existing NOx limit before December 2033*

* Most units currently subject to a 9 ppm limit. Per Rule 1146 (c)(6)(A), these units required to lower their NOx limit to either 5, 7, or 9 ppm depending on their permitted NOx limit as of December 7, 2018.

Regulatory Incentive

ZE Equipment Deployment

Regulatory Incentive

- Staff recognizes the benefits of ZE Equipment deployment and offers flexibility for how emission reductions are achieved
- A *regulatory* incentive option may allow for an exemption from the 5 ppm initial BARCT emission limit for certain units
  - Objective is to reduce fleet-wide emissions while facilitating ZE Equipment deployment
  - Utilization of ZE Equipment may lower fleet-wide emissions such that another unit may remain at its current permit limit (9 ppm for most boilers)

Regulatory Incentive Illustration

ZE Equipment Deployment

Regulatory Incentive

Baseline

9 ppm 9 ppm 9 ppm 9 ppm

Fleet-Wide: 36 ppm

Standard Path: All 5 ppm

5 ppm 5 ppm 5 ppm 5 ppm

Fleet-Wide: **20 ppm**

Incentive Path: ZE Equipment Allows Other Unit to Remain

0 ppm **9 ppm** 5 ppm 5 ppm

Fleet-Wide: **19 ppm**

Emissions for **Incentive Path** must be equal or less than that for **Standard Path**

Incentive Grant Program

ZE Equipment Deployment

Grant Incentive

- Staff is considering a *grant* incentive program to complement the fleet-wide regulatory incentive
- Zero-Emission Equipment Upgrade Subsidy (*ZEUS*)
  - South Coast AQMD grant funds for supporting commercial and industrial zero-emission heat production technology deployment
- Program objectives
  - Drive deployments across a variety of commercial and industrial sectors
  - Accelerate equipment cost standardization
  - Strengthen installer and operator expertise and familiarity
- Grant program will have a dedicated public process separate but in-parallel to rulemaking

Summary of Cost-Effectiveness and Grant Program

Zero-emission limits are not cost-effective to require regulatorily, even with modifications such as load shifting

In light of cost-effectiveness challenges, staff is proposing two concepts

Regulatory Incentive

- ULNBs are both commercially available and cost-effective for mid-sized boilers
- Two pathways available: each unit to meet 5 ppm; or fleet to meet emission reduction equivalent through ZE Equipment deployment

Grant Incentive

- ZEUS grant program to provide an incentive pathway for early ZE Equipment deployment

Combination of regulatory incentive and grant incentive concepts will provide both emission reductions and support for ZE Equipment deployment

Next Steps

Next Steps

Hold Next Working Group

- Gather additional vendors' data
- Share additional rule concepts
- August 2026

Release Draft Public Documents

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

Public Process Timeline

- Public Hearing: Q4 2026

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

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