Proposed Amended Rule 1146.2 – Emissions of Oxides of Nitrogen from Large Water Heaters and Small Boilers and Process Heaters

Working Group Meeting #3

August 30, 2023, 9:00 AM (PDT)

Join Zoom Meeting:

https://scaqmd.zoom.us/j/96510927128

Meeting ID: 965 1092 7128

Agenda

- Stakeholder Comments from Working Group Meeting #2
- Manufacturer Survey
- Federal, State, and Utility Incentives for Commercial Appliances
- Best Available Retrofit Control Technology (BARCT) Assessment
- Other Regulatory Requirements
- Technologies
- Cost-Effectiveness
- Next Steps and Staff Contact

PAR 1146.2 Working Group Meeting #2

In the second Working Group Meeting, Staff provided background on:

- Rule 1146.2 applicability, approach, and current status
- Alignment with rules and strategies of other agencies
- Stakeholder comments from Working Group Meeting #1
- Cost of zero-emission technology
- Electric grid infrastructure
- Manufacturer survey to gather information on zero-emission technologies

Stakeholder Comments from Working Group Meeting #2

Stakeholder Comments from WGM #2 – Fuel Cells

Stakeholder commented that fuel cells can supplement electric grid infrastructure and provide heat

South Coast AQMD Rule 1146.2 would be technology and fuel neutral

- Fuel cells have broad range of applications from multi-megawatt systems to small units
- Continue to expand with emerging technologies
- Cost and durability are still critical challenges
  - Studies indicated price range ~$4k-20k per kW
- Natural gas fuel cells produce some NOx emissions
- Staff recognize the applications of zero-emission fuel cells and are open to any emerging technology

https://www.energy.gov/sites/default/files/2017/05/f34/fcto_myrdd_fuel_cells.pdf

Fuel cells have been installed in residential and commercial applications

- Technology exists in California*
- Over 100,000 fuel cells deployed in Europe**
- Over 300,000 units deployed in Japan***

** https://www.bloomenergy.com/technology/*
*** https://www.viessmann.co.uk/en/products/fuel-cell/vitovalor-family.html*
https://www.itcenex.com/en/business/detail/enefarm/index.html
**** https://pace-energy.eu/fuel-cell-micro-cogeneration-reaches-another-milestone-in-japan/*

Stakeholder Comments from WGM #2 – Heat Pump Analysis and Cost of Commercial Units

Stakeholder recommended analysis on all types of heat pumps, including ground source heat pumps

Staff will do more detailed analysis on different types of heat pump technology if data is available

If data is limited, staff may have to analyze aggregate information

Encourage stakeholders to share further information for more accurate analysis

Stakeholder raised that staff should consider that commercial units are more costly than residential units

Staff recognize that commercial units are more costly and installation costs may differ on case-by-case basis

- Greater emissions with more operation hours than residential units, which may help drive cost-effectiveness down
- Staff will provide further cost estimates in later slides and future meetings

Stakeholder Comments from WGM #2 – Supply of Commercial Units

Stakeholder raised a concern about adequate supply of zero-emission technology

A future implementation date would allow for an expected increase in supply	
Manufacturers are already producing heat pumps and will adjust business operations based on policy direction and market conditions	▪ Expectation for supply chain to adjust to changing market conditions
Proposal for new installation and replacement at end of unit lifetime, with unit expected lifetime potentially 15-25 years depending on type of unit	▪ Not expecting sudden peak in demand due to unit turnaround time

Stakeholder Comments from WGM #2 – Rulemaking Approach and Webpage Posting

Stakeholder encouraged staff to emulate the Bay Area AQMD's approach utilizing future implementation time and implementation monitoring

Staff recognize the common approach for zero-emission appliance standards by other agencies

Stakeholder encouraged staff to utilize a technology-driven rule assessment with accurate estimates of future installation and operation costs

Staff is researching sources of capital, installations, and operational costs

Stakeholder asked if comment letters would be available on the South Coast AQMD webpage

Comment letters will be posted on the proposed rules webpage: *http://www.aqmd.gov/home/rules-compliance/rules/scaqmd-rule-book/proposed-rules/rule-1146-2*

Manufacturer Survey

The next slides summarize the responses staff received from space and water heating manufacturers following the survey sent on May 10, 2023:

Manufacturer Survey – Types of Commercial Zero-Emission Technologies

Manufacturers who responded to the survey provided the following heat pump water heater products:

Manufacturer reported availability of air source and water source heat pump water heater models and hybrid heating, cooling, and water heating:

- Split system units with heating capacity 60-250 kBtu/h
  - Variable speed, ducted or ductless, indoor/outdoor
  - Modular units (that can dynamically adjust their capacity) up to 2.2 MMBtu/h
- Integrated units up to 2 MMBtu/h output

Manufacturer mentioned challenges including:

- Space constraints, mechanical room without sufficient make-up air (integrated models)
- Low ambient or high output temperature requirements, sanitation (>180°F water temperature)
- Electric infrastructure and cost constraints
- Noise level of units

Manufacturer Survey – Types of Commercial Zero-Emission Technologies *(con't)*

Manufacturers reported plans for future heat pump water heater development:

- Reduce necessary storage tank capacity
- Improve capacity/efficiency at lower ambient temperatures
- Increase outlet water temperature
- Improve efficiency through variable speed compressor and pump control
- Modular design
- Alternate refrigerants that allow lower ambient and higher output temperature operation
- Commercial hydronic heating heat pumps
- Expand integrated and split-system all-electric heat pumps (air-to-water) to models with larger heating capacities
- Water source in addition to air source

Manufacturer Survey – Types of Commercial Zero-Emission Technologies *(con't)*

Manufacturers who responded to the survey provided the following on electric boiler products:

Manufacturer reported the availability of:

- Electric resistance elements for boilers, with individual element design offering ease of element replacement for low maintenance costs
  - 99%+ efficiency
  - Ability to match buildings' current electrical set up and upgrade to other electrical safety requirements

Manufacturer reported future development plan:

- Increasing electric model offering for higher outputs with main high voltage supply on larger applications

Manufacturer mentioned challenges including:

- Backup when electricity goes out
- Local electrical grid capacity
- Ensuring end user has appropriate electrical setup

Manufacturer Survey – Types of Commercial Zero-Emission Technologies *(con't)*

Manufacturers who responded to the survey provided the following on zero-emission pool heater products:

Manufacturer reported the availability of electric resistance single-stage compressor and fan

- Future development:
  - Decrease standby losses
  - Improve usable hot water
- Challenges:
  - High electrical amperage requirements
  - Limitation on electrical infrastructure for retrofits
  - Not allowed in new construction for California due to high energy requirements

Manufacturer reported the availability of all-electric air-to-water heat pumps

- Future development:
  - Increase heating capacities & outlet water temperature
  - Improve efficiency at lower ambient temperatures
  - Improve efficiency through variable speed compressor
- Challenges:
  - Indoor installation & noise mitigation
  - Running below 32°F
  - Structural building design to support weight of tanks or pipe runs for heat pumps on roofs

Manufacturer Survey – Types of Commercial Zero-Emission Technologies *(con't)*

Manufacturers who responded to the survey reported that they provide:

- Electric resistance storage water heater products up to 900kW input (~3 MMBtu/h)
- Electric resistance instantaneous (tankless) water heater products up to 150kW (~500 kBtu/h)

1 kW = 3,412.14 Btu/h

Staff will continue to review responses to the survey questions found on the webpage: *http://www.aqmd.gov/home/rules-compliance/rules/scaqmd-rule-book/proposed-rules/rule-1146-2*

Federal, State, and Utility Incentives for Commercial Appliances

Federal and State Incentives for Commercial Appliances

- Section 179D of the Internal Revenue Code allows deductions for energy-efficient commercial buildings
  - New or existing buildings
  - For further information and resources, visit: *https://www.energy.gov/eere/buildings/179d-commercial-buildings-energy-efficiency-tax-deduction*
  - The Inflation Reduction Act extended and expanded these tax deductions
    - Guidance will be forthcoming from IRS
      - Visit the Internal Revenue Service Inflation Reduction Act website for current information: *https://www.irs.gov/inflation-reduction-act-of-2022*
- Information on TECH Clean California incentives for multifamily water heating can be found here: *https://techcleanca.com/incentives/multifamily-information/*
- California Electric Homes – California Energy Commission provides $1,000 incentive for new all-electric multifamily pool heating and other incentives for new multifamily: *https://caelectrichomes.com/*

Utility Incentives for Commercial Appliances

Southern California Edison – Willdan Commercial Energy Efficiency Program

- Replacement of existing electric resistance or gas-fired water heater with packaged heat pump water heater
- Qualifying facilities include Assembly (Churches, Event Spaces / Banquet Halls), Grocery Stores, Hospitals and Medical Office Buildings, Office Buildings, Hotels and Motels, Nursing Homes, Refrigerated Warehouses, Restaurants, Multi-story Retail
- $2,000 - $18,300 depending on building/unit type
- Further information:
  https://willdanefficiency.com/commercial/
  mvilla@willdan.com, (714) 287-4302

San Diego Gas & Electric – Comprehensive Energy Management Solutions Program

- Heat pump water heater rebates available until November 15, 2023
- Total rebate varies by building type; approximately $1,800 per unit for "fast track" incentives
- Further information:
  http://www.savingwithcems.com/
  RStevens@trccompanies.com

Heat Pump Water Heater	Available Rebate
50-gallon	up to $13,388
80-gallon	up to $21,449
120-gallon	up to $56,715

Best Available Retrofit Control Technology (BARCT) Assessment

BARCT Assessment

First four steps of the BARCT assessment in previous Working Group Meetings:

Assess South Coast AQMD Regulatory Requirements: *Working Group Meeting #1*

Assess Emission Limits of Existing Units: *Working Group Meeting #1*

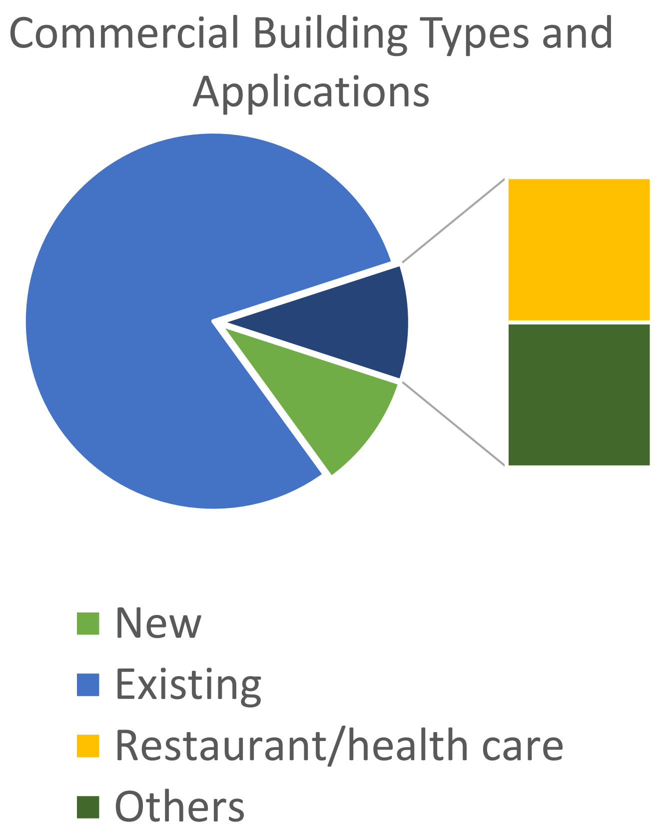
Other Regulatory Requirements: *Working Group Meetings #1 & #2*

Assess Pollution Control Technologies: *Working Group Meeting #1*

Further analysis will be conducted

BARCT Assessment

- Staff will consider dividing the analysis or creating different requirements for:
  - Units operated in new buildings, existing buildings, and new or existing restaurants and health care facilities
  - Challenging applications such as pool heaters with low use, steam generators, and boilers
- Staff previously discussed the following at Working Group and individual stakeholder meetings:
  - Technologies and cost
  - Other regulatory requirements and programs



Other Regulatory Requirements

Summary of Other Regulatory Requirements

- Over 60 cities and counties across California are considering policies to support all-electric new construction
- The table below summarizes examples of the regulatory requirements or plans by other agencies

Agency	Commercial Buildings Requirements
California Energy Commission	Title 24 2022 Energy Code: Further information in later slide
City of Glendale	Approved November 2022: New buildings all-electric with no exceptions; economic infeasibility provision applicable to commercial kitchens
City of Los Angeles	Approved December 2022: New buildings all-electric starting 2023, exceptions for commercial cooking
City of Pasadena	Approved August 2022: New mixed-use buildings, commercial buildings (except medical-health care facilities, food service/commercial kitchens), multi-family buildings > 3 units to utilize electric energy only
City of Riverside	Approved December 2022: New buildings ≤ 3 stories with building permit on or after 1/6/2023, to be all-electric; ≥ 4 stories with permit on or after 2026, to be all-electric; exceptions for commercial cooking
City of Santa Monica	Approved September 2022: New buildings all-electric starting 2023, some exceptions for commercial cooking and medical buildings

California Energy Commission Title 24

State building code effective in 2023 encourages the proliferation of zero-emissions solutions

- CEC Energy Code applies to newly constructed buildings and additions/alterations to existing buildings*
  - Contained in Title 24, Part 6 of the California Code of Regulations, and updated every three years
- 2022 Energy Code encourages efficient electric heat pumps, establishes electric-ready requirements for new homes, expands solar photovoltaic and battery storage standards, and more
  - Buildings whose permit applications are applied for on or after January 1, 2023, must comply with 2022 Energy Code
  - Mandatory requirements for electric ready and heat pump ready multifamily buildings
- Energy Code discourages use of electric resistance heating when an alternative method of heating is available
- For existing buildings: energy and water efficiency and indoor air quality requirements for additions and alterations

CEC Definitions:

Newly constructed building: "a building that has never been used or occupied for any purpose"

Alteration: "any change to a building's water-heating system, space-conditioning system, lighting system, electrical power distribution system, or envelope that is not an addition"

* *https://www.energy.ca.gov/sites/default/files/2022-12/CEC-400-2022-010_CMF.pdf*

Technologies

Summary of Technologies

This table provides a summary of technologies for new and existing buildings:

	Rule 1146.2 NOx Emission Limits	Achieved NOx Emissions By Natural Gas Units	Zero-Emission Technologies
Type 1 Units (≤ 400 kBtu/h)	14 ng/J (20 ppm @3% O2)	From 137 certification tests conducted since 2017: 39 models (28% of models) tested <12 ppm @3% O2; 21 models (15% of models) tested <10 ppm @3% O2	Heat Pump Water Heater; All-Electric Water Heater/Boiler; Electric Resistance; Solar Water Heater; Heat Pump Boiler
Type 2 Units (> 400 kBtu/h and ≤ 2 MMBtu/h)	14 ng/J (20 ppm @3% O2)		Heat Pump Water Heater; All-Electric Water Heater/Boiler; Electric Resistance; Solar Water Heater; Heat Pump Boiler
Pool Heaters (Type 1)	40 ng/J (55 ppm @3% O2)		Electric Pool Heater; Heat Pump Water Heater; Solar Heater

Hot Water – Large Restaurants and Hospitals

There are commercial air-to-water heat pumps that can provide hot water at 194°F

- CO_2 refrigerant, outside temperatures as low as -13°F, coefficient of Performance (COP) up to 4.3
  - COP is a measurement of how effectively a heat pump uses electricity to move heat

Distributed generation water system

- Primary heat pump water heater serves key points such as kitchen sinks
  - Point-of-use electric heaters serve most others
- Restaurant dishwashers use majority of hot water and need 180°F
  - Can use electric "booster heaters" to achieve required temperature

Further analysis needed

- Restaurants with high water capacity above 1,000 gallons per day
- Hospitals that have requirement for a backup fuel source in case of emergency

Type 1 Pool Heaters (≤ 400 kBtu/h)

Rule 1146.2 NOx limit for Type 1 pool heaters: 55 ppm (or 40 ng/Joule heat output)

- 2006 amendment cost-effectiveness analysis for type 1 pool heaters:
  - Not cost-effective to meet 20 ppm NOx limit primarily due to their low use
  - NOx emission limit maintained at 55 ppm
  - Certification tests conducted since 2017 indicate 33% certified pool heater models < 12 ppm

Other agencies:

- Bay Area AQMD Rule 9-6: zero-emission exemption for type 1 pool heaters
- California Air Resources Board: forthcoming standards may or may not exempt

Further analysis will be needed

- Potential zero-emission challenges include slower heating times and low use
- Lower NOx limit with current gas technology may be an interim option prior to zero-emission implementation

Steam and Hot Water Boilers

Zero-Emission Steam Boilers:

- Heat pumps that use waste heat and can achieve temperatures up to 250°F
- Many steam boilers generate even higher temperature with high pressure
  - Current heat pump technology may not be viable for those applications

Zero-Emission Hot Water Boilers:

- For certain industrial processes, heat pump technology is not as mature, and electric resistant options could be more expensive and draw more amperage from the grid

Cost-Effectiveness

Initial Baseline Emission Calculation

- Lifetime NOx Baseline Emission (tons) = Unit Size (MMBtu/h) × Baseline Emission Factor (lb/MMBtu) × Capacity Factor (or usage factor) × Annual Hours × Equipment Lifetime (years) ÷ 2,000 lbs/ton
- Baseline emission factor (lbs/MMBtu): 0.024 lbs of NOx per MMBtu for 20 ppm at 3% Oxygen
- Capacity Factor: the proportion of time the unit is expected to operate
  - 21.5%, from manufacturer survey in previous Rule 1146.2 rule development
  - For Type 1 pool heaters, assuming 7.16% for gas-fired units and 14.32% for heat pump pool heaters, which operate for longer time
  - For tankless units, assuming 10.75% since tankless on-demand operate at high heat for less time than tank-type
- Equipment useful life: 25 years
  - For pool heaters, assuming 15 years
- Assuming 100% emission reduction for zero-emission unit

Initial Baseline Emission Estimations

- Calculate lifetime NOx emissions per gas unit based on Btu, emission faction and operating hours
- Assume 100% emission reductions for electric units

Category	Total Lifetime NOx Baseline Emission (tons) per Unit
Type 1 Water Heater (76,000 Btu)	0.043
Type 2 Water Heater (500,000 Btu)	0.282
Pool Heater (125,000 Btu)	0.039
Type 1 Boiler (399,000 Btu)	0.225
Type 2 Boiler (1 MMBtu)	0.565
Type 2 Boiler (2 MMBtu)	1.130
Tankless Water Heater (150,000 Btu)	0.042

Initial Fuel Switching Cost Calculation

- Independent comparison method:
  - Bottom-up calculation: individual units that fill similar roles from different categories
  - Daily energy demand for each unit (kWh)
    - For non-heat pump electric units, assuming 10% more efficient than existing gas units
    - Where manufacturer provided annual kWh energy demand, divided by 365 days
      - Where annual kWh not provided, divided gas-fired unit Btu by electric unit COP (or multiplied by 0.9 for electric resistance units), divided by 3412.14 Btu, multiplied by 24 hours/day, multiplied by capacity factor
    - Heat pumps assumed to be at least three times more efficient than existing gas units
      - Some manufacturers provided higher COP for their units
  - Total annual energy cost for each unit and fuel type: multiply annual energy demand by price per kWh or therm

Initial Fuel Switching Cost Calculation *(con't)*

- Fuel switching cost referenced the commercial utility rate forecast
  - Electricity prices are sourced from 2022 California Energy Commission Energy Demand Update*
  - Gas prices sourced from California Energy Commission's 2021 Integrated Energy Policy Report Energy Forecast**
  - LADWP and SCE electricity prices differ
    - Staff estimated the electricity price by weighing according to population
      - LADWP: 4 million residents/businesses ÷ 17.2 million (region population in 2022 AQMP) = 0.23
      - SCE Weight: 13.2 million ÷ 17.2 million = 0.77

** 2022 CEC Energy Demand Update: https://www.energy.ca.gov/data-reports/reports/integrated-energy-policy-report/2022-integrated-energy-policy-report-update*

*** 2021 CEC IEPR: https://www.energy.ca.gov/data-reports/reports/integrated-energy-policy-report/2021-integrated-energy-policy-report*

Initial Fuel Switching Cost Calculation *(con't)*

- Annual fuel switching cost:
  - Difference between annual electricity cost to operate electric unit and annual natural gas cost to operate gas-fired unit
  - Used average annual costs from 2023 through 2035
    - Based on available data from California Energy Commission
      - For example, 2023 rates:
        - Commercial: 3.17 cents/kWh for natural gas; 17.73 cents/kWh for electricity
        - Residential (pool heaters): 3.67 cents/kWh for natural gas; 22.34 cents/kWh for electricity
  - Efficiency gains of heat pump technology compensate for and can even result in overall cost savings

Discounted Cash Flow Method

- Discounted cash flow, or DCF, is a common valuation technique that uses expected future cash flows in conjunction with a discount rate to estimate the present fair value
- Discounted cash method (DCF) with Present Value Factor (PVF): $PVF = \frac{(1+r)^N - 1}{r * (1+r)^N}$
  - r = real interest rate (discount rate, 4%)
  - N = years of equipment life
- Multiplied by Present Value Factor (PVF) of 11.118 for pool heaters and 15.622 for other categories

Initial Cost-Effectiveness Calculation

- Cost-effectiveness means the cost of the potential control option divided by emission reduction potential of the potential control option
  - Measured in cost per ton of pollutant reduced
  - **Cost-Effectiveness** = Total Capital Cost/Emissions Reduced Over Equipment Life

$$CE\left(\$/_{tons\ NOx\ reduced}\right) = \frac{Incremental\ Difference\ in\ Initial\ Capital\ Investment\ Cost + (Fuel\ Switching\ Cost\ \times PVF)}{Lifetime\ Emission\ Reductions}$$

  - For zero-emission units, staff utilized higher-end costs for a more conservative estimate
  - Assumptions:
    - Costs are the incremental costs for new installations and replacements of natural gas fueled units versus zero-emission units
      - Proposal considers replacement at the end of unit lifetime
    - No incremental difference in maintenance, labor, or installation cost compared to natural gas unit

Cost – Electrical Panel Upgrades

Electrical panel upgrades for existing residential buildings:

- E3 study assumed residential panel upgrades ~$4,200 for single family and ~$2,700 for low-rise multi-family homes
- Bay Area AQMD assumed lifespan of 30 years for residential panel upgrades
  - Annualized costs : ~$260 for single family and ~$170 for multi-family homes

Electrical panel upgrades for existing commercial buildings:

- 2022 Air Quality Management Plan estimated $4,000-5,000 cost for commercial building panel upgrade
- TECH Clean California Public Data for single-family indicates additional ~$2,000 for total cost

For panel upgrade cost in PAR 1146 cost-effectiveness calculation

- Estimating $5,000 AQMP panel cost with a useful lifetime of 30 years
- Adjusted panel costs to account for longer useful life of panel versus equipment (15 - 25 years)
- $2,500 utilized for pool heaters (considering 15-year useful lifetime)
- $4,200 utilized for other categories (considering 25-year useful lifetime)

Cost-Effectiveness Threshold

2022 Air Quality Management Plan (AQMP)

- Established cost-effectiveness screening threshold of $325,000 per ton of NOx reduced based on 2021 dollars
- AQMP stated that the threshold will be adjusted based on annual California Consumer Price Index (CPI)
- PAR 1146.2 currently considers a $349,000 cost-effectiveness screening threshold using 2022 dollars
- Note: 2022 AQMP threshold is neither considered a starting point for control costs, nor an absolute cap

Cost – Heat Pump Water Heaters

Examples from manufacturer for heat pump water heater costs sold to contractors:

- Integrated unit (heat pump, storage, and controls in a single package):
  - ~$6,000 - $7,000 for 190-gallon combined heat and power (CHP), plus expected additional 30-50% markup: ~$11,000 for higher end cost to consumer

Staff will consider the incremental unit cost for cost-effectiveness assessment as considering replacement at the end of unit useful lifetime

Cost – Multifamily Project Costs

Examples of multifamily heat pump water heater project costs per unit, including installation costs*

Heating Capacity (Btu/h)	Rated Storage Volume (gal)	Approx. Total Project Cost per Unit ($)	Previous Water Heater Volume (gal)**
154,000	119	12,236 - 26,500	75 - 100

- Assuming the 154 kBtu units are replacing higher-end Type 1 gas-fired water heater units
- Assuming 399 kBtu gas-fired unit estimated average cost is $10,623; taking the $26,500 heat pump example from the table
- Assuming installation cost is 25% of project cost, so unit cost is $26,000 * 0.75 = $19,500

** TECH Clean California Public Data: https://techcleanca.com/public-data/*

*** Previous water heater fuel type: natural gas*

Cost – Multifamily Project Costs *(con't)*

Examples of multifamily heat pump water heater project costs per unit, including installation costs*

Panel Capacity Post Install (Amps)	Approx. Heating Capacity (Btuh)	Rated Storage Volume (gal)	Approx. Total Project Cost per Unit ($)	Previous Water Heater Volume** (gal)
100 - 1200	154,000 - 136,480	83 - 1550	21,125 - 628,523	120 - 357

- Other than heat capacity, storage volume of a water heater is another determining factor for cost
  - Heat pumps with similar Btu rating cost more for a larger water storage volume
- Those multifamily project costs do not include panel update cost; assuming panel upgrades were not needed for these examples

** TECH Clean California Public Data: https://techcleanca.com/public-data/*

*** Previous water heater fuel type: natural gas*

Preliminary Cost-Effectiveness Calculations – Type 1 (≤ 400 kBtu/h) Water Heater Cost

Estimated costs from currently available data:

	Natural Gas Unit	Zero-Emission Unit: Heat Pump	Multifamily Data from TECH
Estimated Cost	$7,000	$11,000	$19,500
Unit and Source Description	Rule 1146.2 May 2006 staff report estimated cost for 100-300 kBtu unit adjusted to present value by CPI Inflation Calculator	Cost provided by manufacturer for indoor packaged commercial heat pump unit - 350 gallons per day used - Heat pump mode: 33,678 Btu/h - Electric resistance mode: 40,946 Btu/h - Hybrid mode: 74,624 Btu/h - COP: 4.6 (4.6 times more efficient than conventional unit, results in lower operating cost) - Annual 5,841 kWh (provided by manufacturer)	Energy Star annual kWh for comparable unit: 1491; Replacing 399k gas-fired unit
Source Link	*http://www.aqmd.gov/nav/about/governing-board/agendas-minutes*		*https://www.energystar.gov/*

Assumption: Heat pump unit would replace 76 kBtu Type 1 natural gas-fired unit

Preliminary Cost-Effectiveness Calculations – Type 1 (≤ 400 kBtu/h) Water Heater

Preliminary cost-effectiveness calculations for discussion:

	Replacement with heat pump	Multifamily example from TECH data
Lifetime fuel switching cost	$(6,500) (cost savings)	$(107,000) (cost savings)
Cost-Effectiveness in $/Ton, No Panel Upgrade	$(60,000) (cost savings)	$(419,296) (cost savings)
Cost-Effectiveness in $/Ton, $4.2k Panel Upgrade	$38,000	
Main reason for range of cost-effectiveness	Low emission reductions; addition of modest cost for panel upgrade magnifies number	

Preliminary Cost-Effectiveness Calculations – Type 2 (> 400 kBtu/h and ≤ 2 MMBtu/h) Cost Assumptions

Estimated costs from currently available data:

	Natural Gas Unit	Zero-Emission Unit: Heat Pumps (6 heat pump units)
Estimated Cost	14,000	$66,000 (cost of individual heat pump multiplied by 6)
Unit and Source Description	Rule 1146.2 May 2006 staff report estimated cost for 400-500 kBtu commercial tank type high efficiency unit adjusted to present value by CPI Inflation Calculator	Heat pump cost to customer provided by manufacturer * 6 Case study example: - Two 500 kBtu boilers were replaced by 7 heat pumps - Considering that second 500 kBtu/h boiler and seventh heat pump were for redundancy COP: 4.6 (4.6 times more efficient than conventional unit, resulting in lower operating cost) Annual kWh: 5,841 kWh (Los Angeles) * 6
Source Link	http://www.aqmd.gov/nav/about/governing-board/agendas-minutes	

Assumption: Six zero-emission units would replace one 500 kBtu/h natural gas-fired unit, based on case study

Preliminary Cost-Effectiveness Calculations – Type 2 (> 400 kBtu/h and ≤ 2 MMBtu/h)

Preliminary cost-effectiveness for discussion:

	Replacement with heat pumps
Lifetime fuel switching cost	$(52,000) (cost savings)
Cost-Effectiveness in $/Ton, No Panel Upgrade	$1,200
Cost-Effectiveness in $/Ton, $4.2k Panel Upgrade	$16,000
Main driver of cost	Panel upgrade of $4,200; higher capital cost of heat pump units

Considerations for Type 1 and Type 2 Water Heaters

- Heat pump water heaters are cost-effective to transition to zero
  - Higher capital costs than natural gas units
  - Potentially require additional costs for panel upgrades
    - Not all facilities will require upgrades
  - Higher efficiency results in cost savings for fuel switching
- Further analysis may be needed for specific applications

Staff's initial recommendation:

- Zero-Emission NOx limit for Type 1 and Type 2 Water Heaters
  - Technically feasible and well below the cost-effectiveness screening threshold

Cost – Natural Gas Boilers

Natural gas boiler cost examples from a local boiler manufacturer:

- Hot water:
  - 399,000 Btu/h condensing type: $24,000
  - 1 MMBtu/h: $32,500
  - 2 MMBtu/h: $43,500
- Steam:
  - 398,000 Btu/h, 9.5L: $35,900
  - 1,995,000 Btu/h: $86,000
- Installation costs for like-to-like replacement: ~$3,000

Cost – Electric Boilers

Type 1 commercial electric boiler cost examples from internet search:	Type 2 commercial electric boiler cost examples from internet search:	Electric boiler cost examples from manufacturer:
~$22,000 for 256 kBtu/h ~$25,000 for 358 kBtu/h	~$27,000 for 491 kBtu/h ~$30,000 for 750 kBtu/h ~$32,000 for 887 kBtu/h ~$34,000 for 1 MMBtu/h	$12,000 for 200 kBtu/h $24,000 for 500 kBtu/h

Preliminary Cost-Effectiveness Calculations – Type 1 Boiler Cost Assumptions

Estimated costs from currently available data:

	Natural Gas Unit	Zero-Emission Unit: Electric Boiler	Zero-Emission Unit: Heat Pump
Estimated Cost	$24,000	$25,000	$185,000
Unit and Source Description	399 kBtu hot water unit cost provided by manufacturer	358 kBtu hot water electric resistance boiler cost from internet search	365 kBtu heat pump (waste heat) cost to customer provided by manufacturer; COP 6.3 (6.3 times more efficient than conventional unit, resulting in lower operating cost)
Source Link		*https://www.ecomfort.com/*	*https://armstronginternational.com/products/armstrongcombitherm-heat-pumps/*

Assumption: 365 kBtu heat pump would replace 399 kBtu gas-fired unit

Preliminary Cost-Effectiveness Calculations – Type 1 Boiler

Preliminary cost-effectiveness calculations for discussion:

	Replacement with electric boiler	Replacement with heat pump
Lifetime fuel switching cost	$380,000	$(24,000) (cost savings)
Cost-Effectiveness in $/Ton, No Panel Upgrade	$1,700,000	$609,000
Cost-Effectiveness in $/Ton, $4.2k Panel Upgrade	$1,720,000	$627,000
Main driver of cost	Fuel switching	Capital cost

Preliminary Cost-Effectiveness Calculations – Type 2 Boiler (1 MMBtu) Cost Assumptions

Estimated costs from currently available data:

	Natural Gas Unit	Zero-Emission Unit: Electric Boiler	Zero-Emission Unit: Heat Pump
Estimated Cost	$32,500	$34,000	$280,000
Unit and Source Description	1 MMBtu hot water unit cost provided by manufacturer	1 MMBtu hot water electric resistance boiler cost from internet search	1.709 MMBtu heat pump (waste heat) cost to customer provided by manufacturer; COP 5.9 (5.9 times more efficient than conventional unit, resulting in lower operating cost)
Source Link		*https://www.ecomfort.com/*	*https://armstronginternational.com/products/armstrongcombitherm-heat-pumps/*

Assumption: 1.709 MMBtu heat pump would replace 1 MMBtu gas-fired unit

Preliminary Cost-Effectiveness Calculations – Type 2 Boiler (1 MMBtu)

Preliminary cost-effectiveness calculations for discussion:

	Replacement with electric boiler	Replacement with heat pump
Lifetime fuel switching cost	$957,000	$(45,000) (cost savings)
Cost-Effectiveness in $/Ton, No Panel Upgrade	$1,697,000	$358,000
Cost-Effectiveness in $/Ton, $4.2k Panel Upgrade	$1,705,000	$366,000
Main driver of cost	Fuel switching	Capital cost

Preliminary Cost-Effectiveness Calculations – Type 2 Boiler (2 MMBtu) Cost Assumptions

Estimated costs from currently available data:

	Natural Gas Unit	Zero-Emission Unit: Heat Pump
Estimated Cost	$43,500	$462,000
Unit and Source Description	2 MMBtu hot water unit cost provided by manufacturer	2.286 MMBtu heat pump (waste heat) cost to customer provided by manufacturer; COP 6.1 (6.1 times more efficient than conventional unit, resulting in lower operating cost)
Source Link		*https://armstronginternational.com/products/armstrongcombitherm-heat-pumps/*

Assumption: 2.286 MMBtu heat pump would replace 2 MMBtu natural gas-fired unit

Preliminary Cost-Effectiveness Calculations – Type 2 Boiler (2 MMBtu)

Preliminary cost-effectiveness calculations for discussion:

	Replacement with heat pump
Lifetime fuel switching cost	$(105,000) (cost savings)
Cost-Effectiveness in $/Ton, No Panel Upgrade	$277,000
Cost-Effectiveness in $/Ton, $4.2k Panel Upgrade	$279,000
Main driver of cost	Capital cost

Considerations for Type 1 and Type 2 Boilers

- Electric resistance boilers are not shown to be cost effective due to the high fuel switching costs
- Heat pump water heaters using waste heat technology are near the cost-effective threshold
  - Developing technology
  - High capital costs
    - Capital costs may go down in future as technology develops
  - Very high efficiency which can result in cost savings for fuel switching

Staff's initial recommendation:

- Continue to review and refine cost assumptions for Type 1 and Type 2 Boilers

Cost – Pool Heaters

- U.S. DOE estimates that a solar pool heating system usually costs between $2,500 - $4,000 to buy and install*
  - Estimates for outdoor pools in use 6-8 months per year, typically size systems at 60-70% of pool surface area
- Using solar blanket to cover pool when not in use will reduce total energy loss by 50%
  - Using a pool cover will reduce amount you need to run heat pump by 50%
- Natural gas water heater cost examples from internet search:

Heat Output Btu	Price	Heat Output Btu	Price	Heat Output Btu	Price
105,000 Btu	$2,000	206,000 Btu	$2,000	300,000 Btu	$4,000
125,000 Btu	$2,000	240,000 Btu	$3,000	333,000 Btu	$4,000
156,000 Btu	$2,000	264,000 Btu	$3,000	360,000 Btu	$4,000
180,000 Btu	$3,000	266,000 Btu	$3,000	404,000 Btu	$4,000

** https://www.energy.gov/energysaver/solar-swimming-pool-heaters*

Preliminary Cost-Effectiveness Calculations – Type 1 Pool Heater Cost Assumptions

Estimated costs from currently available data:

	Natural Gas Unit	Zero-Emission Unit: Heat Pump
Estimated Cost	$2,000	$4,000
Unit and Source Description	125 kBtu unit from internet search	90 kBtu heat pump pool heater cost from internet search
Source Link	https://intheswim.com/	https://intheswim.com/

Assumptions:

- 90 kBtu heat pump unit would replace 125 kBtu gas-fired unit (based on sizing guides)
- Heat pump pool heater would have to operate twice as long as a natural gas unit
  - Capacity factor of 7.16% versus 14.32%
  - Assumes 1,254 hours of annual operation for heat pump versus 627 for natural gas unit
- COP 5.7

Preliminary Cost-Effectiveness Calculations – Type 1 Pool Heater

Preliminary cost-effectiveness calculations for discussion:

	Replacement with heat pump
Lifetime fuel switching cost	$3,800
Cost-Effectiveness in $/Ton, No Panel Upgrade	$148,000
Cost-Effectiveness in $/Ton, $2.5k Panel Upgrade	$210,000

Staff's initial recommendation:

- Zero-Emission NOx limit for Type 1 Pool Heater
  - Technically feasible and below the cost-effectiveness screening threshold

Preliminary Cost-Effectiveness Calculations – Tankless Cost Assumptions

Estimated costs from currently available data:

	Natural Gas Unit	Zero-Emission Unit: Electric resistance tankless	Zero-Emission Unit: Electric resistance tank	Zero-Emission Unit: Heat pump tank type
Estimated Cost	$2,775	$2,300	$2,100	$2,000
Unit and Source Description	E3 study project cost (including installation)*0.75	Electric tankless unit cost high end of ranges from internet search	Electric 75-gallon tank unit cost from internet search	Energy Star 65-gallon storage volume; 1363 kWh/y electric usage; Uniform Energy Factor 3.64
Source Link		https://www.forbes.com/ https://carbonswitch.com/	https://www.homedepot.com/	

Assumptions:

- Residential heat pump with COP 3.0 replacing 150 kBtu gas-fired unit
- Installation cost ~25% of project cost, so unit cost is $3,700 * 0.75 = $2,775
- Tankless units are operated on demand – when hot water is turned on
    - Assumed they are fired half as often as typical water heater; used 10.75% capacity factor

Preliminary Cost-Effectiveness Calculations – Tankless

Preliminary cost-effectiveness calculations for discussion:

	Replacement with electric resistance tankless	Replacement with electric resistance tank type	Replacement with heat pump tank type
Lifetime fuel switching cost	$9,500	$22,000	$650
Cost-Effectiveness in $/Ton, No Panel Upgrade	$1,705,000	$3,930,000	$(3,000) (cost savings)
Cost-Effectiveness in $/Ton, $4.2k Panel Upgrade	$2,495,000	$4,720,000	$96,000
Main driver of cost	Fuel switching	Fuel switching	Panel Upgrade

Considerations for Tankless Water Heaters

- Electric Resistance Tankless Water Heater technically feasible but not cost-effective
  - High fuel switching costs
- Transitioning to Heat Pump Tank Type is cost-effective
  - Consumers would be transitioning from tankless to tank type water heater

Staff's initial recommendation:

- Zero-Emission NOx limit for Tankless Water Heaters

Summary of Preliminary Cost-Effectiveness Calculations

- Based on preliminary calculations, certain categories are cost-effective to transition to zero-emission
  - Type 1 and 2 water heaters, pool heaters, tankless water heaters being replaced by heat pump tank type
- Certain factors impact cost-effectiveness including panel upgrades and fuel switching for electric resistance heating
- High-temperature applications show higher cost-effectiveness values
  - Further consideration for high-temperature applications
- May consider longer implementation timelines for technology that is not widely available
- Further evaluation:
  - If current assumptions overestimate the size of the heat pump replacing the gas-fired unit
  - If heat pump operation hours (capacity factor) should be less than that of a comparable gas unit

Future Analyses

- Seek further input from stakeholders on cost, capacity factors, and specific considerations
- Improve the cost-effectiveness analysis with:
  - More cost information and examples for each category;
  - More accurate capacity factors for tankless and heat pump units;
  - More accurate heat pump sizing for replacement of natural gas-fired units;
  - More accurate emission reduction estimates; and
  - Other relevant information
- Conduct analysis on the feasibility of zero-emission water heaters for:
  - Restaurants with high water capacity above 1,000 gallons per day;
  - Hospitals that have requirements for a backup fuel source in case of emergency

Next Steps and Staff Contact

Next Steps

Tentative Schedule for Proposed Amended Rule 1146.2:

- Initial Draft Rule Language – Fall 2023
- Continue Public Process
  - Working Group and Stakeholder Meetings
- Public Hearing – 1st Quarter 2024

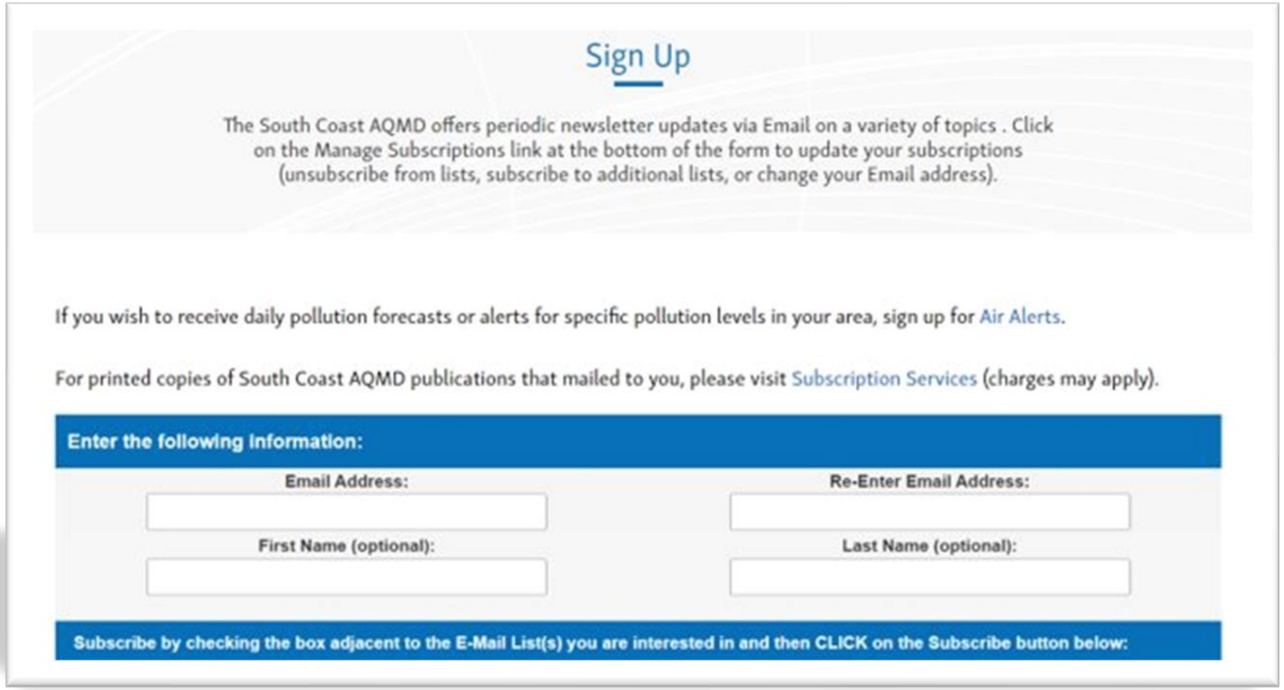
Incentives:

- Developing a new rebate program for building appliances, potentially similar to the previous Clean Air Furnace Rebate Program (CAARP)

Webpage for more information on Building Appliances Rules:
http://www.aqmd.gov/home/rules-compliance/residential-and-commercial-building-appliances

Sign Up for Notifications

- To receive newsletter updates via email for notifications regarding the 1146.2 rule development and other forthcoming building appliances rules, please subscribe by checking the **Rule 1146.2** and **Building Appliances** check boxes located under Rule Updates: *http://www.aqmd.gov/sign-up*


Sign Up

The South Coast AQMD offers periodic newsletter updates via Email on a variety of topics . Click on the Manage Subscriptions link at the bottom of the form to update your subscriptions (unsubscribe from lists, subscribe to additional lists, or change your Email address).

If you wish to receive daily pollution forecasts or alerts for specific pollution levels in your area, sign up for Air Alerts.

For printed copies of South Coast AQMD publications that mailed to you, please visit Subscription Services (charges may apply).

Enter the following information:

Email Address:
Re-Enter Email Address:
First Name (optional):
Last Name (optional):

Subscribe by checking the box adjacent to the E-Mail List(s) you are interested in and then CLICK on the Subscribe button below:

- To receive printed copies of South Coast AQMD publications via mail, please visit: *http://www.aqmd.gov/nav/contact/subscription-services*

Staff Contact

Michael Krause	Assistant DEO	mkrause@aqmd.gov	909.396.2706
Heather Farr	Planning and Rules Manager	hfarr@aqmd.gov	909.396.3672
Yanrong Zhu	Program Supervisor	yzhu1@aqmd.gov	909.396.3289
Emily Yen	Assistant AQ Specialist	eyen@aqmd.gov	909.396.3206
Peter Campbell	AQ Specialist	pcampbell@aqmd.gov	909.396.3185