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REGULATORY ASSISTANCE PROJECT

NO_x Standards for Water Heaters: Model Rule Technical Support Document

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Introduction

The Regulatory Assistance Project (RAP)[1] has developed a model rule[2] for nitrogen oxide (NO_x) emissions standards for water heaters for use by U.S. state and local air quality regulators.[3] This document was produced to assist regulators and staff in understanding and making use of the model rule. It describes why water heaters are a significant source of air pollution, why NO_x emissions standards are an excellent tool for reducing the environmental impact of water heaters and how those standards can promote electrification and market transformation. It also explains in detail the design and structure of the model rule.

RAP chose to focus on water heaters and NO_x standards for reasons discussed in this document — the prevalence of water heaters, the feasibility of establishing and updating NO_x standards and the limited number of sizes and scenarios of water heaters to consider (a contrast from the more complex market landscape for space heating appliances). Our model rule builds on existing rules in California, Texas and Utah, as well as a model rule for water heating standards developed by the Ozone Transport Commission (OTC) states[4] in the Northeast.

RAP decided that a model rule format would be most easily utilized by local and state air quality agencies, based on a history of agencies using such models. Our goal is to encourage and assist several state and local agencies in adopting NO_x standards for water heaters based on the model rule. Ideally, the U.S. Environmental Protection Agency (EPA) would develop a national water heater rule. The willingness of local and state agencies to step out ahead of the federal government many times over the past 50 years has led to significant improvements in air quality and paved the way for federal action. For example, in the absence of a federal rule for levels of hydrocarbons and toxics in indoor paints, the Northeast states and California stepped up with model rules, which were then followed by a national standard.[5] In a similar fashion, in 2012, when the EPA had not updated its woodstove emissions standard in over 20 years, two regional air quality groups, the Northeast States for Coordinated Air Use Management (NESCAUM) and the Western

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[1] RAP is a global nonprofit organization, composed primarily of former state and federal energy and environmental regulators providing technical and policy assistance to government officials, agency staff and others to design an equitable clean energy future. The authors have spent a large portion of their careers in state agencies developing and implementing environmental and energy regulations. For more information, visit http://www.raponline.org.

[2] A model rule is designed to include many of the provisions a state or local rule would require and provides a template for state and local agencies to follow to make their regulatory process easier. If designed to cover more than one jurisdiction, the model rule can help ensure consistency across jurisdictions to provide certainty for manufacturers or the regulated party.

[3] The model rule can be found at http://www.raponline.org/wp-content/uploads/2023/02/rap-model-rule-nox-water-heaters-2023-february.pdf. The rule was reviewed primarily with states in the Ozone Transport Commission and the NESCAUM staff. We particularly thank Dwight Alpern, working with NESCAUM, for his legal review and advice. The model rule and this document is by RAP and does not constitute an endorsement by any of those states.

[4] The OTC was established by the 1990 federal Clean Air Act, Section 184, to promote regional strategies to address ozone in the Northeast corridor.

[5] The OTC model rule for architectural and industrial coatings (paints) was first completed in March 2001 and has been updated since. See Ozone Transport Commission (OTC). (2001, March 28). *Update on Cancelled OTC Meeting and Actions Taken to Date.* https://otcair.org/upload/Documents/Reports/010516_model%20rule%20page_final.htm

States Air Resources Council (WESTAR),[6] started a multistate process that ultimately led to a new federal standard in 2020.[7,8]

RAP chose to focus this model rule on NO_x standards for water heaters for three important reasons. First, NO_x contributes to a host of environmental hazards and is formed whenever fuel[9] is combusted. Figure 1 on the following page demonstrates how NO_x is a key component in many important environmental problems. For example, it is one of two components of summer ozone, or smog, which affects over 125 million Americans each summer.[10] NO_x is also a precursor to fine particle formation,[11] and fine particle pollution leads to premature mortality of around 100,000 Americans each year.[12] Finally, NO_x contributes to visibility impairment,[13] acid rain[14] and water eutrophication.[15] NO_x is truly a pollutant that warrants attention.

Second, because of the above impacts, local and state air quality agencies have very clear authority to regulate NO_x emissions. Frequently, state legislatures have granted broad authority to air pollution regulators that allows them to act to reduce air pollution that harms their citizens. But even where such broad authority has not been granted, if a jurisdiction does not attain the national ozone or $PM_{2.5}$ public health standard, then the agency is mandated by federal law to develop and execute a plan to attain the health standards. That plan must be approved by the EPA, and the agency has oversight of its implementation. Another mandatory air quality program requires a plan to improve visibility in national parks or other federal scenic areas within their "airshed" as part of the federal Regional Haze program.[16]

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[6] NESCAUM and WESTAR are two regional associations of air quality agencies. Both groups work to coordinate policies in their member states, but they are not regulatory bodies; they function like the regional energy efficiency organizations in the United States.

[7] Johnson, D., & Marin, A. (2012, August 3). Letter to Lisa Jackson, Administrator, U.S. EPA. https://www.nescaum.org/documents/westar_nescaum-joint-nsps-res-wood-devices-letter-20120803.pdf

[8] Northeast States for Coordinated Air Use Management (NESCAUM). (2020). *Residential Wood Smoke Workshop.* https://www.nescaum.org/documents/residential-wood-smoke-workshop

[9] The RAP model rule proposes to regulate fossil gas including methane, propane and heating oil. We have not proposed standards for renewable natural gas, biomethane or fossil gas and hydrogen mixtures. When this document refers to gas, we mean methane or its commonly used name, "natural gas." If we are discussing propane or oil, we will use those terms.

[10] U.S. Environmental Protection Agency (EPA). (2022). *Summary Nonattainment Area Population Exposure Report*. https://www3.epa.gov/airquality/greenbook/popexp.html

[11] The EPA has established a national ambient air quality standard for fine particles, or $PM_{2.5}$, those particles smaller than 2.5 microns. For reference, the diameter of a human hair is about 50 microns. See U.S. EPA. (2021). *Particulate Matter (PM) Pollution*. https://www.epa.gov/pm-pollution

[12] Goodkind et al. (2019). *Fine-Scale Damage Estimates of Particulate Matter Air Pollution Reveal Opportunities for Location-Specific Mitigation of Emissions*. Proceedings of the National Academy of Sciences 116 (18). https://www.pnas.org/doi/10.1073/pnas.1816102116

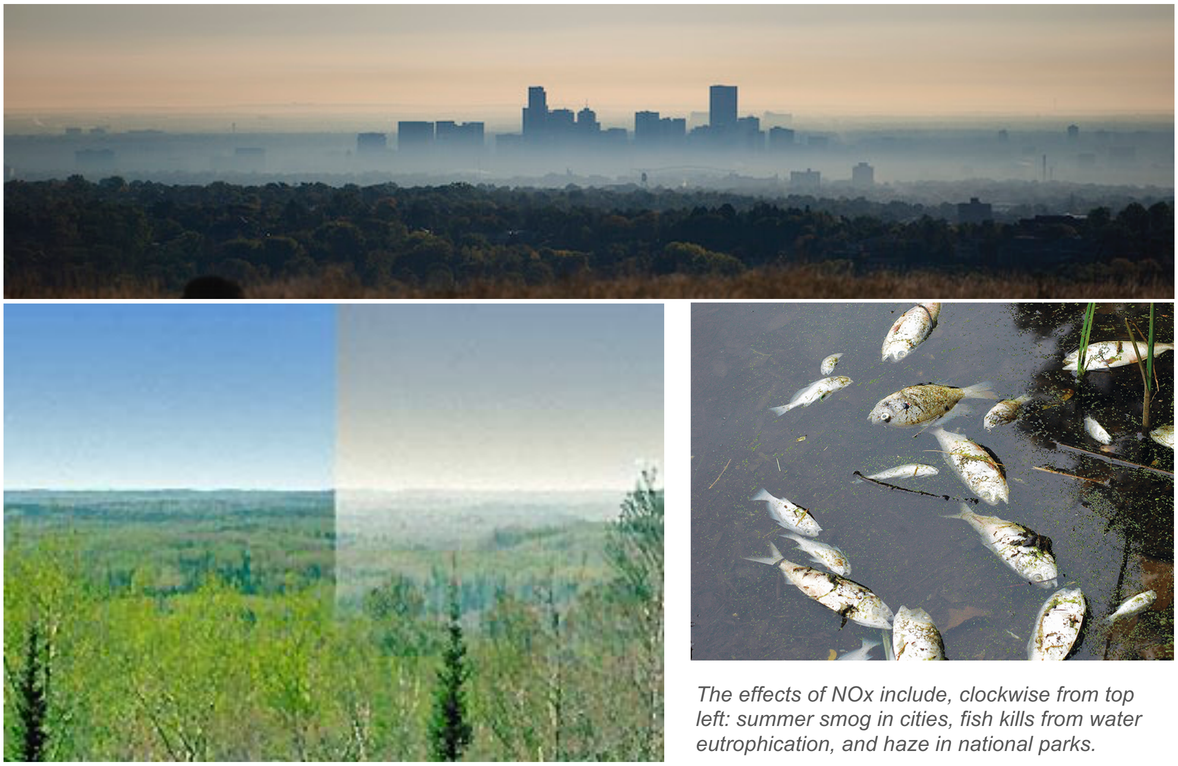
[13] U.S. EPA. (2022a). *Regional Haze Program*. https://www.epa.gov/visibility/regional-haze-program

[14] U.S. EPA. (2021a). *What Is Acid Rain?* https://www.epa.gov/acidrain/what-acid-rain

[15] U.S. EPA. (2021b). *Nutrient Pollution: The Issue*. https://www.epa.gov/nutrientpollution/issue

[16] U.S. EPA, 2022a.

Figure 1. Harmful effects from nitrogen oxide pollution



The effects of NOx include, clockwise from top left: summer smog in cities, fish kills from water eutrophication, and haze in national parks.

Third, because of the air quality impacts of NO_x, air quality agencies (local, state and federal) have spent decades, since the 1970s, regulating NO_x emissions. They have primarily regulated the largest emissions sources, such as power plants and light-duty vehicles, but as public health standards get more stringent and the technological options to further regulate these large sources diminish, air quality agencies have looked for cost-effective ways to regulate NO_x emissions from consumer products and other small emissions sources. As discussed below, fossil-fueled appliances represent an underregulated source of NO_x emissions. Though they represent just a small percentage of total NO_x national emissions, there are appliances in almost all homes using fossil fuels and emitting NO_x. These appliances warrant a closer look, particularly if emissions reductions can be achieved cost-effectively compared to other available options.

RAP chose to focus our model rule on limiting NO_x emissions rather than carbon dioxide (CO_2) or other greenhouse gas (GHG) emissions, but any reduction in fossil fuel combustion to meet a more stringent NO_x standard will drive down GHG emissions as a cobenefit. And, although all U.S. states' air quality agencies have authority to regulate NO_x or are required to reduce NO_x to achieve public health standards, only 14 states have statutory climate targets requiring those agencies to achieve reductions in GHG emissions and another 10 have targets set through executive action.[17] For example, in Utah and Texas, NO_x reductions are necessary to meet federal public health standards, but no authority to regulate GHGs exists.

[17] Center for Climate and Energy Solutions. (n.d.). *State Climate Policy Maps.* https://www.c2es.org/content/state-climate-policy/

Market transformation of water heaters to lower-emitting appliances does not need to be driven by GHG standards but can come through NO_x standards. This effort can also be combined with efforts from energy agencies to improve efficiency and the use of water heaters in distributed energy programs (such as interoperability standards) that would further lower their impact on air quality and climate change. Regulating NO_x emissions is a policy lever that can be implemented more widely across the United States, and the resulting market transformation will also have the desired effect of reducing GHGs.

Market transformation of the water heater sector must be accompanied by policies and programs that make low-emission water heaters available to all consumers. This will require that environmental agencies work with their peers in other agencies — those who work on energy efficiency, climate strategies, housing upgrades and replacement and related programs — to ensure equal access to information and funding. Another important equity aspect is ensuring that the workforce is expanded and trained to ensure that low-emission options for water heater replacements are available and installed.

Why Water Heaters: Effects on Air Quality

RAP began our work looking at the impact of water heaters on air quality. We knew this would be key to interest from air quality agencies around the United States — to demonstrate why it would be worth their time to adopt a new rule. Research done by RMI documented the emissions impact of appliances in the United States, as shown in Figure 2 on the following page.[18] The RMI researchers examined detailed emissions inventory data from the 2017 National Emissions Inventory submitted by air quality agencies to the EPA.[19] They separated the relevant categories of fuel usage that are most likely to include appliances (commercial and residential gas fuel combustion).[20] RMI found that NO_x emissions from all gas appliances totaled more than twice the emissions of gas power plants and that emissions of $PM_{2.5}$ from gas appliances equaled about 25% of gas power plant $PM_{2.5}$ emissions. Power plant emissions have been regulated for decades and, as states move to regulate small sources of emissions to attain their air quality goals, we believe this data supports examining the potential for regulating NO_x from water heaters. Before proceeding, states are likely to review the expected emissions reductions from regulating water heaters and will want to examine their emissions inventories and compare their estimates of expected emissions reductions to their other options for NO_x reductions to meet state and federal air quality deadlines.

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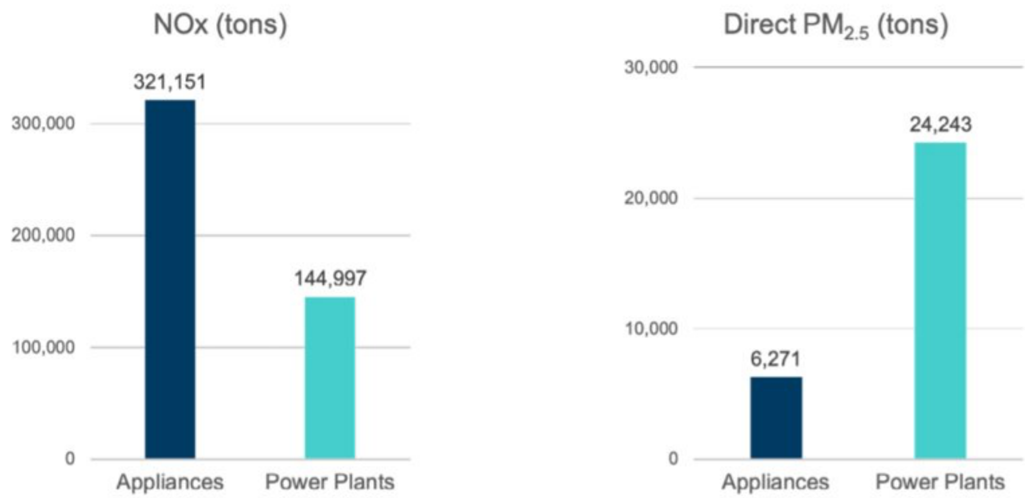
18 RMI and Sierra Club. (2021, April). *Why EPA Must Address Appliance Pollution* [Fact sheet]. https://rmi.org/wp-content/uploads/2021/04/rmi_factsheet_appliance_pollution.pdf.

19 U.S. EPA. (2017). *2017 National Emissions Inventory (NEI) Data.* https://www.epa.gov/air-emissions-inventories/2017-national-emissions-inventory-nei-data

20 The NEI has a category for commercial/institutional gas use, so RMI worked to eliminate sources that would not be easily electrified, like compressor stations (L. Louis-Prescott, personal communication, January 2023). For further information on RMI's work in this area, see Dennison, J., Louis-Prescott, L. & Gruenwald, T. (2021). How Air Agencies Can Help End Fossil Fuel Pollution from Buildings. RMI. https://rmi.org/insight/outdoor-air-quality-brief/

Figure 2. U.S. gas appliance pollution rivals or exceeds gas power plant pollution



Source: RMI, 2021.

We recognize that comparing power plant emissions to appliances may be considered by some to be comparing "apples to oranges" when it comes to ozone formation because of where the NO_x pollution is emitted. Power plants emit higher in the atmosphere while appliances emit at ground level. Therefore, power plant emissions may be transported long distances. Low-elevation NO_x emissions tend to reduce nearby ozone concentrations due to NO_x scavenging, although whatever NO_x survives can contribute to downstream ozone formation. The contributions to ambient NO2 and $PM_{2.5}$ from low-elevation sources are important, though the impacts are felt at different locations (low-level emissions closer to the source) than for pollutants emitted by power plants. All NO_x emissions contribute to degradation of public health, so they are important to reduce.

We compared RMI's figures to work done by the Bay Area Air Quality Management District (BAAQMD). BAAQMD is considering establishing a zero-emissions standard for water heaters in less than a decade. As part of that effort, the agency documented that gas appliances emit more NO_x than passenger vehicles in the San Francisco area and that water heaters account for about 30% of gas appliance emissions.[21] Therefore, RAP feels that water heaters should be considered as a source category to regulate if states are looking for additional control strategies to reduce NO_x and $PM_{2.5}$.

Zero-emissions water heating can be achieved with electric water heaters, including heat pump water heaters, and a greening of the electric grid, though, depending on which electric grid in the U.S. services the water heater, electrification provides air quality benefits now. Though we recognize that not all agencies would share BAAQMD's interest in requiring new water heaters to have zero emissions in less than a decade, we chose to

[21] Bay Area Air Quality Management District (BAAQMD). (2021). Proposed Rule, Regulation 9, Rule 6: Nitrogen Oxides Emissions from Natural Gas-Fired Boilers and Water Heaters. https://www.baaqmd.gov/~/media/dotgov/files/rules/reg-9-rule-6-nitrogen-oxides-emissions-from-natural-gasfired-water-heaters/2021-amendment/documents/20210930_03_rg0906_draftrule-pdf.pdf?la=en

write our model with decreasing emissions limits over the decade, based on technological feasibility.

The first draft of our model rule proposed to lower NO_x emissions over time based on one of two options:

1. An option based on a schedule: emissions limits that take effect in specified years, with the emissions limits declining over time based on ***projections*** of how fast the electric power sector is expected to lower NO_x emissions.
2. An option based on a formula: emissions limit would be expressed as a formula, with the applicable emissions limit recalculated periodically based on ***actual reductions*** in electric power sector NO_x emissions.

In either case, by including a phased lowering of the emissions standard by 90–95%, an agency does not have to repropose a rule to lower the emissions standard in future years, and manufacturers get advanced notice and can plan accordingly for the standards between now and 2035. Our calculations showing how these limits compare to existing standards is discussed in the next section. Based on comments received from states, the final version includes only the schedule option with initial standards based on existing standards in California districts and Utah. While the formula option would involve more dynamic changes to emissions limits, it would require tracking grid emissions closely and was seen as a “moving target” providing less certainty and perhaps regional differences.

We also investigated the European Union’s (EU) Ecodesign program,[22] which includes standards for propane and oil water heaters, the only standards for those fuels we found. The final model rule includes phase-out dates for oil and propane water heaters. We decided not to include starting or interim standards for those fuels, as discussed later in this document.

Where We Started: Existing State and Local Rules

Our model rule was able to build on existing district and state regulation of water heaters.

Multiple jurisdictions have adopted NO_x emissions limits for gas-fueled water heaters: several local air agencies in California, including those in the Bay Area and Los Angeles, along with the states of Utah and Texas.[23] The current versions of those rules date back 5

[22] European Commission. (n.d.). *Products – labelling rules and requirements: space and water heaters.* https://commission.europa.eu/energy-climate-change-environment/standards-tools-and-labels/products-labelling-rules-and-requirements/energy-label-and-ecodesign/energy-efficient-products/space-and-water-heaters_en

[23] In California and some other states, the state has delegated some aspects of air pollution regulatory authority to local air quality districts.

to 20 years.[24,25] These regulations generally cover about the same sizes of water heaters with the standards split into two to three categories based on heat input ratings. The categories in our model rule and our rationale for regulating specific fuels and sizes are discussed in the next section.

California has led the way in regulating water heaters, with the first agency being the South Coast Air Quality Management District (SCAQMD) in 1998.[26] Currently, nine California air districts regulate NO_x emissions from gas-fueled space heaters and water heaters. These include the Bay Area, San Joaquin Valley, South Coast, Yolo-Solano, San Diego County and Sacramento Metro. Those districts enforce the most stringent emissions limit of 10 nanograms/Joule (ng/J) NO_x for water heaters.

There are two states regulating gas water heaters: Texas and Utah. The Texas limits were established in 2000[27] and the Utah regulation in 2015.[28] Utah's regulation of gas water heaters is of particular interest since it was promulgated to be included in Utah's State Implementation Plan (SIP) for particulate matter, and includes the most stringent current limits from California air districts of 10 and 14 ng/J for small and larger water heaters, respectively.

Importantly, in 2021, BAAQMD proposed a gas water heater NO_x emissions standard that will decline to zero by 2027–2031, depending on the size of the water heater.[29] If finalized, this would be a first for appliance standards. The California Air Resources Board voted in September 2022 to propose zero-emissions appliance standards to be implemented in 2030 and included in its climate plans and ozone SIP.[30] The regulations proposing zero-GHG appliances are likely to be proposed in the next year or two.

There are no emissions limits in any jurisdiction in the United States for oil- and propane-fired water heaters. RAP looked instead to the EU's Ecodesign program, which incorporates energy efficiency standards with NO_x emissions standards for water heaters burning any gaseous or liquid fuel.[31] As part of the Ecodesign program, European regulators have adopted NO_x emissions limits for different fuels as well as "indicative benchmark" values that indicate the approximate emissions rate of the lowest-emitting

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24 Utah Administrative Code. (2015). Rule R307-230: NO[x] Emission Limits for Natural Gas-Fired Water Heaters. https://casetext.com/regulation/utah-administrative-code/environmental-quality/title-r307-air-quality/rule-r307-230-nox-emission-limits-for-natural-gas-fired-water-heaters

25 Texas Administrative Code. (2007). Title 30, Part 1, Chapter 117, Subchapter E, Division 3: Water Heaters, Small Boilers and Process Heaters (effective June 14). https://texreg.sos.state.tx.us/public/readtac%24ext.ViewTAC?tac_view=5&ti=30&pt=1&ch=117&sch=E&div=3&rl=Y

26 South Coast Air Quality Management District (SCAQMD). Rule 1121.

27 30 Texas Admin. Code §117.3205(b).

28 Utah Code §15A-6-102 and Utah Admin. Code R307-230-2 and -3.

29 BAAQMD. (2023). *Rules 9-4 and 9-6 Building Appliances*. https://www.baaqmd.gov/rules-and-compliance/rule-development/building-appliances

30 California Air Resources Board (CARB). (2022, November). *2022 Scoping Plan – Appendix F: Building Decarbonization.* https://ww2.arb.ca.gov/sites/default/files/2022-11/2022-sp-appendix-f-building-decarbonization.pdf. Also see CARB. (2022). *2022 State Strategy for the State Implementation Plan.* https://ww2.arb.ca.gov/resources/documents/2022-state-strategy-state-implementation-plan-2022-state-sip-strategy

31 European Commission. *Harmonised Standards: Ecodesign and Energy Labelling – Water Heaters.* https://single-market-economy.ec.europa.eu/single-market/european-standards/harmonised-standards/ecodesign-and-energy-labelling-water-heaters_en

models currently available on the market. Appendix A includes a summary of the EU emissions limits along with those of other jurisdictions.

Review of Water Heating Technologies

Virtually all residential and commercial buildings in the United States have water heaters that use one or more of the following technologies:

- **Conventional storage water heaters**: Water is heated using either electric resistance, combustion of a gaseous fuel (gas or propane in virtually all cases) or combustion of a liquid fuel (oil in virtually all cases) and then stored in a tank for future use.
- **Instantaneous, tankless or demand-type water heaters:** Water is heated directly at the time it is used, without storing the water in a tank. Units are available that use either electric resistance, gas combustion or propane combustion.
- **Electric heat pump water heaters:** Water is heated by using electricity to efficiently transfer and concentrate heat from a ground source or an air source to water that is, in most cases, stored in a tank. No fuels are combusted, so there are no local emissions from these heaters, but separate backup water heaters that do burn fuels are often used to supplement the heat pump. An electric heat pump water heater can be two to three times more efficient than an electric resistance water heater, saving money and fuel over the life of the equipment[32] as well as reducing demand for electricity and emissions.
- **Solar water heaters:** Water is heated using solar energy and stored in a tank. No fuels are used, so there are no emissions. Again, a backup water heater may combust fuels.
- **Combination heaters:** Water is heated indirectly using a heat exchanger connected to the building's space heating system (i.e., boiler or furnace). These can rely on any energy source used for space heating. Storage tank and tankless versions are available ("indirect water heaters" and "tankless coil water heaters"). Combination heaters are exempt from the requirements of our model rule because the emissions are associated with the fuel burned in the boiler or furnace. Our model rule does not regulate stand-alone boilers and furnaces, so regulating combination heaters would create an unfair regulatory environment for space heating appliances.

The same technologies are used for residential and commercial water heaters, but the size of the units can vary substantially. Although residential consumers are more accustomed to thinking of water heater "sizes" in terms of the volume of a storage tank, rated heat input capacity (typically expressed in units of BTU per hour for fuel-burning water heaters and watts for electric models) is a more useful measure of "size" since it applies to all technologies. Most residential water heaters are rated at less than 75,000 BTU per hour.

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[32] U.S. Department of Energy. (n.d.). *Energy Saver: Heat Pump Water Heaters.* https://www.energy.gov/energysaver/heat-pump-water-heaters

Commercial water heaters can be much larger, but most require less than 2,000,000 BTU per hour.

RAP was unable to find reliable, authoritative, publicly available data on the market share of each water heating technology. Based on information gleaned from a variety of sources, we believe that approximately 9 to 10 million new water heaters were sold in the United States in 2020. Of those, it is likely that over 90% were conventional storage water heaters, a small percentage were instantaneous or solar and just 2% were electric heat pump water heaters.[33,34,35]

Fuels Used

Based on preliminary results from the U.S. Energy Information Administration's (EIA) 2020 Residential Energy Consumption Survey,[36] most households in the United States currently use electricity or gas to heat water (see Table 1 on the following page). Propane and fuel oil are used by a much smaller but still significant share of households. The fuels used vary quite significantly by geography.[37] For example, fuel oil and kerosene are essentially not used for residential water heating in 40 states, but these fuels serve more than 10% of households in eight states (Alaska, Connecticut, Maine, Massachusetts, New Hampshire, New York, Rhode Island and Vermont).

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[33] A 2009 U.S Department of Energy report indicated over 9 million water heaters shipped annually, with 80% of the total replacing existing water heaters and 20 percent installed in newly constructed buildings. See U.S. DOE. (2009). *New Technologies New Savings: Water Heater Market Profile*. https://www.energystar.gov/ia/partners/prod_development/new_specs/downloads/water_heaters/Water_Heater_Market_Profile_Sept2009.pdf

[34] Data from the Air Conditioning, Heating and Refrigeration Institute (AHRI) indicate over 9 million storage water heaters were shipped in 2020: See HVAC and Refrigeration Insider Online. (2021, March). *AHRI Releases December 2020 U.S. Heating and Cooling Equipment Shipment Data*. https://hvacinsider.com/ahri-releases-december-2020-u-s-heating-and-cooling-equipment-shipment-data/

[35] Market share estimate for heat pump water heaters is based on: Daigle, B., & David, A. (2022, February). *Residential Heat Pump (Hybrid) Water Heater Market, Production, and Trade* [Executive briefing]. U.S. International Trade Commission. https://www.usitc.gov/publications/332/executive_briefings/ebot_residential_heat_pump_hybrid_water_heaters.pdf

[36] U.S. Energy Information Administration (EIA). (2022). *Residential Energy Consumption Survey, 2020*. https://www.eia.gov/consumption/residential/

[37] "Fuel use" encompasses whatever source of energy (whether electricity or a fossil fuel) is used in a device to heat water.

Table 1: Highlights for water heating in U.S. homes by state, 2020

	Total number of homes (millions)[a]	Number and percentage of homes by water heating fuel used							
		Electricity		Gas		Propane		Fuel oil or kerosene	
All U.S. homes	123.53	58.24	47%	57.96	47%	4.28	3%	2.64	2%
Alabama	1.90	1.36	72%	0.49	26%	Q	Q	N	N
Alaska	0.26	0.08	31%	0.13	50%	0.01	4%	0.04	14%
Arizona	2.68	1.38	51%	1.19	44%	0.08	3%	Q	Q
Arkansas	1.14	0.67	59%	0.43	37%	0.04	4%	N	N
California	13.18	2.78	21%	9.91	75%	0.46	3%	Q	Q
Colorado	2.26	0.59	26%	1.55	69%	0.09	4%	Q	Q
Connecticut	1.38	0.56	41%	0.46	33%	0.05	4%	0.30	21%
Delaware	0.38	0.21	54%	0.12	32%	0.04	10%	Q	Q
District of Columbia	0.32	0.17	53%	0.14	45%	Q	Q	Q	Q
Florida	8.06	7.08	88%	0.84	10%	0.11	1%	N	N
Georgia	3.88	2.36	61%	1.40	36%	0.11	3%	N	N
Hawaii	0.47	0.31	66%	0.05	11%	0.02	5%	N	N
Idaho	0.66	0.33	50%	0.31	47%	0.02	4%	N	N
Illinois	4.90	1.44	29%	3.31	68%	0.13	3%	Q	Q
Indiana	2.60	1.12	43%	1.36	52%	0.09	4%	Q	Q
Iowa	1.28	0.43	34%	0.74	58%	0.11	8%	N	N
Kansas	1.13	0.41	36%	0.64	56%	0.08	7%	N	N
Kentucky	1.74	1.12	65%	0.59	34%	Q	Q	N	N
Louisiana	1.73	1.08	63%	0.60	35%	Q	Q	N	N
Maine	0.56	0.21	36%	0.07	13%	0.08	14%	0.19	34%
Maryland	2.28	1.29	56%	0.88	38%	Q	Q	Q	Q
Massachusetts	2.71	0.81	30%	1.42	52%	0.07	3%	0.40	15%
Michigan	3.92	1.17	30%	2.50	64%	0.21	5%	Q	Q
Minnesota	2.23	0.89	40%	1.26	56%	0.08	4%	N	N
Mississippi	1.08	0.70	65%	0.32	29%	0.07	6%	N	N
Missouri	2.43	1.22	50%	1.14	47%	Q	Q	N	N
Montana	0.43	0.19	43%	0.22	50%	Q	Q	Q	Q
Nebraska	0.77	0.29	38%	0.45	59%	Q	Q	N	N
Nevada	1.14	0.32	28%	0.76	67%	0.06	5%	N	N
New Hampshire	0.54	0.20	37%	0.13	24%	0.09	17%	0.12	22%
New Jersey	3.39	0.91	27%	2.31	68%	Q	Q	0.11	3%
New Mexico	0.79	0.15	20%	0.54	69%	0.09	11%	N	N
New York	7.52	2.17	29%	4.16	55%	0.30	4%	0.86	11%
North Carolina	4.01	3.02	75%	0.89	22%	0.09	2%	N	N
North Dakota	0.32	0.18	58%	0.11	36%	0.02	5%	N	N
Ohio	4.74	1.84	39%	2.64	56%	0.24	5%	Q	Q
Oklahoma	1.49	0.69	46%	0.73	49%	0.07	5%	N	N
Oregon	1.65	1.10	66%	0.52	31%	Q	Q	N	N
Pennsylvania	5.13	2.37	46%	2.28	44%	0.17	3%	0.28	6%
Rhode Island	0.42	0.12	30%	0.20	48%	Q	Q	0.08	19%
South Carolina	1.97	1.51	77%	0.42	21%	Q	Q	N	N
South Dakota	0.35	0.18	51%	0.15	42%	0.02	7%	N	N
Tennessee	2.66	1.99	75%	0.61	23%	0.05	2%	N	N
Texas	10.26	5.43	53%	4.49	44%	0.31	3%	Q	Q
Utah	1.04	0.19	18%	0.83	80%	Q	Q	N	N
Vermont	0.26	0.10	39%	0.05	18%	0.05	20%	0.06	22%
Virginia	3.24	2.08	64%	1.02	31%	0.13	4%	Q	Q
Washington	2.94	1.88	64%	0.97	33%	0.08	3%	N	N
West Virginia	0.70	0.47	68%	0.22	32%	Q	Q	N	N
Wisconsin	2.39	1.00	42%	1.30	54%	0.08	3%	Q	Q
Wyoming	0.23	0.08	37%	0.13	58%	0.01	5%	N	N

Source: U.S. Energy Information Administration, Office of Energy Demand and Integrated Statistics, Form EIA-457A of the *2020 Residential Energy Consumption Survey*

Notes: Because of rounding, data may not sum to totals. Percentages are calculated on unrounded numbers. See RECS Terminology for the definitions of terms used in these tables. Differences in characteristics between states may not be statistically significant.

[a] Total includes all primary occupied housing units. Vacant housing units, seasonal units, second homes, military houses and group quarters are excluded.

Q = Data withheld because either the relative standard error (RSE) was greater than 50% or fewer than 10 households were in the reporting sample.

N = No households in reporting sample.

The EIA also surveys energy end uses in commercial buildings, but the most recent available data are less detailed than for the residential sector. Data released in 2021, based on surveys conducted in 2018, indicate that 47% of commercial buildings use electricity to heat water, 32% use gas, 2% use propane and just 1% use fuel oil.[38] These percentages total less than 100%, presumably because some commercial buildings use other means to heat water (e.g., district heating systems) and some don't heat water at all.

NO_x Emissions from Water Heating

Water heaters that combust gaseous or liquid fuels mixed with air, or in the presence of air, will directly emit products of combustion, including NO_x. These emissions are vented to outdoor air and typically treated as "area sources" by air pollution regulators. Faulty or improperly installed water heaters can potentially release air pollutants to indoor spaces.

Water heaters that use electricity (exclusively) to heat water do not directly create emissions of NO_x, but they may indirectly contribute to NO_x emissions if fossil fuels or biomass are combusted to produce the electricity that powers the water heater.

Uncontrolled Emissions

Information about the uncontrolled emissions rates of water heaters is surprisingly hard to find. When local air management districts in California first started adopting NO_x emissions limits for this source category in the early 2000s, some assumed baseline (uncontrolled) emissions of 110 ppm, which translates to roughly 80 ng/J heat output.[39] However, data from the EPA's AP-42 Compilation of Air Pollutant Emissions Factors suggest that the uncontrolled emissions rates for fossil-fueled water heaters may be lower than 80 ng/J for all fuels, as shown in Table 2.

Table 2. AP-42 emissions factors for external combustion

Section	Year of last update	Fuel	NO_x emissions factor for small boilers	Equivalent emissions rate (lb/MMBTU)	Equivalent emissions rate (ng/J heat output)
1.4 Gas combustion	1998	Gas	100 lb/10^6 scf	0.098 lb/MMBTU	42 ng/J
1.5 LPG combustion	2008	Propane	13 lb/10^3 gal	0.142 lb/MMBTU	61 ng/J
1.3 Fuel oil combustion	2010	Distillate	20 lb/10^3 gal	0.144 lb/MMBTU	62 ng/J

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38 U.S. EIA. (2018). *Commercial Buildings Energy Consumption Survey (CBECS), 2018 CBECS Survey Data.* https://www.eia.gov/consumption/commercial/data/2018/

39 For example, the 110 ppm value is cited in documents that supported SCAQMD's adoption of a rule in 2004. See SCAQMD. (2004). *Agenda No. 21: Report on Implementation Study for Rule 1146.2 – Emissions of Oxides of Nitrogen from Large Water Heaters and Small Boilers* [Minutes of Governing Board meeting, July 9. 2004].

The emissions factors noted in the table are specifically for small boilers, but RAP believes that the burner technologies and emissions characteristics for water heaters are virtually the same as for boilers. Recent data support that belief. When the Imperial County Air Pollution Control District in California proposed new NO_x emissions limits for gas-fueled water heaters in 2019, a staff report asserted that unregulated gas-fueled water heaters can be assumed to have an NO_x emissions factor of 55 ppm at 3% O_2 dry.[40] This is equivalent to approximately 40 ng/J heat output, a rate that is largely consistent with the 42 ng/J emissions rate shown for gas-fired small boilers in the table above.

Emissions Control Techniques

A July 2004 report[41] from SCAQMD in California summarizes the techniques used to reduce NO_x emissions from gas-fueled water heaters. We believe this description from nearly 20 years ago still suffices as an explanation of control techniques, not only for gas but also for propane-fueled water heaters:

> "The manufacturers of boilers, water heaters and process heaters use similar approaches to achieve low NO_x levels. The principle [sic] technique involves premixing of fuel and air before combustion takes place. This results in a lower and more uniform flame temperature. A lower flame temperature reduces formation of NO_x. Some premix burners also use staged combustion with a fuel rich zone to start combustion and stabilize the flame and a fuel lean zone to complete combustion and reduce the peak flame temperature.
>
> Burners can also be designed to spread flames over a larger area to reduce hot spots and lower NO_x emissions. Radiant premix burners with ceramic, sintered metal or metal fiber heads spread the flame and produce more radiant heat. When a burner produces more radiant heat, it can result in less heat escaping the boiler through exhaust gasses.
>
> Most premix burners require the aid of a blower to mix the fuel with air before combustion takes place (primary air). Increasing the amount of primary air can reduce flame temperature but it also reduces the temperature of combustion gasses through dilution and can reduce heat transfer efficiency. To maintain efficiency, a manufacturer may modify the burner design or use different materials in the burner head to reduce the amount of excess air required. Alternatively, they may add surface area to the heat exchanger to maintain efficiency. Increasing primary air may

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40 For the most recent technical analysis of emissions rates that the authors could find in their research, see Air Pollution Control District, Imperial County, Calif. (n.d.) *Staff Report: Amended Rule 400.2 for Boilers, Process Heaters and Steam Generators. Newly Proposed Rule 400.5 for Natural Gas-Fired Water Heaters, Small Boilers and Process Heaters.* https://apcd.imperialcounty.org/wp-content/uploads/2019/11/02-Staff-Report-Boiler-Rules-NOx-Full.pdf.

41 SCAQMD, 2004.

> destabilize the flame. Ultra-low- NO_x burners require sophisticated controls to maintain emissions levels, efficiency and a stable flame."

For oil-fired water heaters, similar techniques have been used to develop high-performance and low-NO_x burners. In addition, reducing the sulfur content of heating oil can reduce the NO_x emitted by the water heater. A 2005 NESCAUM report referenced by Connecticut for its Regional Haze State Implementation Plan cites an estimated 10% reduction in NO_x emissions for a standard burner when conventional heating oil (>2000 ppm sulfur) is replaced with 500 ppm sulfur oil and even greater reductions when ultra-low-sulfur oil is used.[42]

Controlled Emissions

NO_x limits for gas-fueled appliances have been in force in parts of California for almost 25 years. Over those years, manufacturers have tested the emissions rates of hundreds of water heaters and small boilers with rated heat-input capacities of up to 2,000,000 BTU per hour.

We note that even in the early 2000s, manufacturers were able to achieve substantial reductions from the uncontrolled NO_x emissions rates cited above and certify water heaters that met California's emissions standards. In 2006, when SCAQMD proposed amendments to its original rules for these appliances, a staff report summarized emissions test results up to that point.[43] The results are shown in the following tables excerpted from that staff report.

Table 3. Certification test results for Type 2 units > 400,000 to 2 MMBTU/hour

NO_x (ppm)	Hot water boilers, pool & instant water heaters	Steam boiler & process heater	Tank-type water heater	> 400,000 total
Tests < 20 ppm	40	11	3	54
Total tests	79	35	9	123
Percentage meeting 20 ppm	53%	31%	33%	46%
Estimated number in district	11,000	5,500	5,500	22,000

[42] Northeast States for Coordinated Air Use Management (NESCAUM). (2005, December). *Low Sulfur Heating Oil in the Northeast States: An Overview of Benefits, Costs and Implementation Issues.* https://www.nescaum.org/documents/report060101heatingoil.pdf/view.

[43] SCAQMD. (2006, April). *Staff Report: Proposed Amended Rule 1146.2 - Emissions of Oxides of Nitrogen from Large Water Heaters and Small Boilers and Process Heaters.* https://www.aqmd.gov/docs/default-source/ceqa/documents/aqmd-projects/2006/final-ea-for-proposed-amended-rule-1146-2.doc?sfvrsn=4

Table 4. Certification test results for Type 1 units ≤ 400,000 BTU/hour

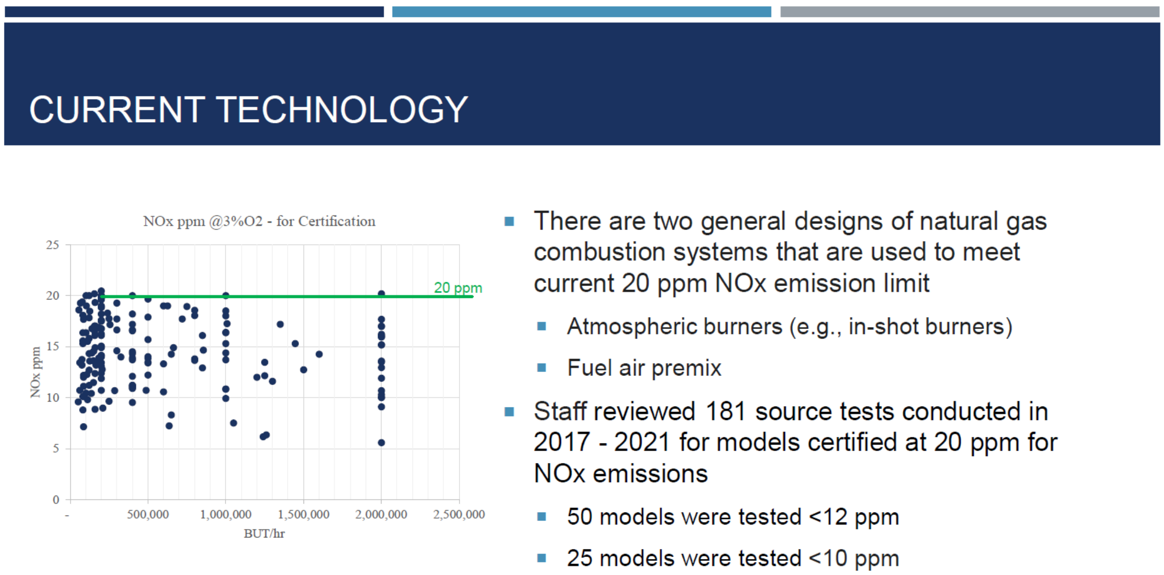
NO_x (ppm)	Hot water boilers & instant water heaters	Steam boilers & process heaters	Residential Instant water heaters	Tank-type water heater	<400,000 total
# Tests > 20–30 ppm	12	6	0	7	25
# Tests ≤ 20 ppm	15	3	0	5	23
Total tests	50	11	15	50	126
% < 20 ppm	30%	27%		10%	18%
Estimated number in district	21,800	10,900	Included in instant WHs	10,900	43,600

SCAQMD found 33% of larger storage water heaters tested prior to 2006 were below a 20 ppm emissions rate, which translates into roughly 14 ng/J heat output and a 65% reduction below uncontrolled NO_x emissions rates. For smaller (mostly residential) units, 10% of storage water heaters tested below the same 14 ng/J emissions rate. The same 2006 report noted that some models were able to achieve a 10 ppm emissions rate, equivalent to just 7 ng/J heat output.

In the 15 years since SCAQMD published those findings, NO_x limits for gas-fueled water heaters have been adopted in more jurisdictions, emissions limits have tightened in some cases and manufacturers have continued to improve their products and certify compliance with those emissions limits. In a December 2021 presentation, SCAQMD reported on more recent emissions test data, summarized in Figure 3.[44] The data show that more than 180 gas-fueled boilers and water heaters tested from 2017 to 2021 achieved an NO_x emissions rate of around 20 ppm (14 ng/J) or less and 25 models tested at less than 10 ppm (7 ng/J). Appliances of many different sizes were able to achieve the 7 ng/J emissions rate.

44 SCAQMD. (2021). *Rule 1146.2. Emissions of Oxides of Nitrogen from Large Water Heaters and Small Boilers and Process Heaters* [Presentation to working group meeting]. http://www.aqmd.gov/docs/default-source/rule-book/Proposed-Rules/par-1146/rule-1146-wgm-1_dec-2021_final.pdf?sfvrsn=20

Figure 3. Emissions test results for appliances certified by SCAQMD



Emissions data are not available from SCAQMD for propane- and oil-fueled water heaters because water heaters burning those fuels are not regulated by the district — or any other U.S. jurisdiction. In fact, we struggled to find any publicly available data on emissions from appliances burning fuels other than gas.

The principal difference between burning propane and gas is in the heat output generated per unit of heat input, which is significant because the emissions limits in our model rule are expressed as ng/J heat output. Propane-fueled water heaters will have higher emissions than identically designed gas-fueled water heaters. But because the control techniques used for propane-fueled water heaters are identical to those used for gas-fueled water heaters and boilers, we believe similar emissions reductions (as a percentage of uncontrolled emissions rates) are achievable.

For oil-fired water heaters, we found some indication of controlled emissions rates in the previously cited 2005 NESCAUM report on low-sulfur heating oil,[45] as well as some data from the EU — the only jurisdiction in the world, that we know of, that currently regulates NO_x emissions from oil-fired water heaters. The NESCAUM report indicated (though without much accompanying data or explanation) that "high performance" flame retention oil burners combusting ultra-low-sulfur fuel could reduce NO_x emissions by about 50%, while a "new generation of low NO_x oil burners" using ultra-low-sulfur fuel could reduce emissions about 70%, when compared to standard burners and standard-sulfur-content fuels. If we apply the latter figure to our presumed uncontrolled emissions rate of 62 ng/J, it suggests that 19 ng/J could be achieved. This value is consistent with data RAP has seen from an unpublished draft copy of potential revisions to the EU [46] standards for water heaters that states that the best-performing liquid-fueled water heaters on the market today in the EU are achieving a NO_x emissions rate of approximately 18 ng/J.

[45] NESCAUM, 2005.

[46] M. Grippa, Ecostandard.org, personal communication, September 2021.

Design of the Rule

Applicability

The model rule applies to water heaters with a rated heat input capacity of 2,000,000 BTU per hour or less, with some exemptions. The rule defines *water heater* and defines all the types of water heaters that are exempt from the rule. The capacity cutoff for applicability is based on similar cutoffs in existing rules regulating water heater NO_x emissions that have been adopted in California, Texas and Utah. (Rules in the European Union cut off at a lower capacity rating, as noted in Appendix A). There are fundamental differences in smaller point-of-use water heaters and larger ones that serve, for example, hotels or food processors. Units larger than 2,000,000 BTU per hour may be custom designed to meet specific process needs, may require very rapid heating rates or may have other characteristics that affect their emissions rates. Emissions from these large units may in some cases be covered under existing air pollution rules for stationary sources, lessening the need to regulate them at point of sale or installation. And importantly, electrification of these big central water heating systems is still impractical in many cases and could be years away. For all these reasons, we followed the existing examples and adopted a cutoff of 2,000,000 BTU per hour for model rule applicability.

Exemptions

The model rule exempts some water heaters that have rated heat input capacities of less than 2,000,000 BTU per hour. In each of these cases, we have chosen to provide an exemption based on practical reasons, rather than because we believe the exempt appliances should not be subject to emissions limits. We want the scope of the model rule to be clear and to focus on devices that significantly contribute to air pollution, and we want potential adopters of the rule to understand the impacts it would have. The model rule would have had to be far more complicated without some of these exemptions and would have regulated devices that are not common and contribute little to total NO_x emissions.

We exempt boilers, steam generators and process heaters that heat water exclusively for space heating or use in an industrial process, and we exempt combination heaters (devices used for both space heating and water heating), even though these appliances are regulated under current rules in some jurisdictions. In some of the existing examples, different emissions limits apply to boilers, steam generators, process heaters or combination heaters, while in other examples, the rules for these devices are similar to but separate from the rules for the types of water heaters covered by our model rule. In any event, including these types of appliances would greatly complicate the rule. We opted for simplicity, with the understanding that some jurisdictions may want to regulate these devices. Those who are interested in that option can find precedents in California and Europe.

Pool heaters are exempt from the model rule even though they are already regulated in some jurisdictions. We chose to exempt pool heaters for simplicity's sake because they are a niche product and, in most jurisdictions, a negligible contributor to total NO_x emissions.

Again, jurisdictions that want to regulate pool heater emissions can find precedential rules in California and Utah.

Water heaters designed for use in a recreational vehicle are exempt from all the currently existing rules we reviewed. Lacking useful precedents for emissions limits, we exempted recreational vehicle water heaters from our model rule.

The model rule also exempts from the emissions limits water heaters that are manufactured or sold in the jurisdiction adopting the rule if they are intended for shipment and use outside of that jurisdiction. This exemption is included to steer clear of potential conflicts with constitutional protections for interstate commerce.

Categories

In every example of an existing rule that regulates NO_x emissions from water heaters, regulators have sorted water heaters into categories with different applicable emissions limits based on what was considered reasonably achievable at the time of rule adoption. Each jurisdiction has adopted slightly different categories, but they tend to be based on combinations of:

- The fuel used by the water heater.
- The rated heat input capacity of the water heater.
- The type (e.g., storage versus instantaneous) or function of the water heater (e.g., pool heater, mobile home water heater or other).

The rules we reviewed from U.S. jurisdictions were all limited in applicability to water heaters combusting gas. Regulators from California air districts told us the reason for this was primarily that propane- and oil-fired water heaters were not common in their district and contributed very little to total NO_x emissions. Regulators in Utah and Texas presumably exempted propane and oil in part for the same reason and in part to avoid having to develop their own emissions-testing protocols and certification processes for those fuels. In almost all cases, these U.S. jurisdictions separated smaller (mostly residential) gas-fired water heaters and larger (mostly commercial) water heaters into distinct categories.

Regulators in Europe, in contrast, adopted Ecodesign standards for water heaters that vary based on whether the appliances consume a gaseous or a liquid fuel. In other words, the European rules place gas- and propane-fueled water heaters in the same category and oil-fired water heaters in a separate category.

In developing our model rule, we recognized that propane and oil constitute a sizable share of water heating fuels and emissions in some U.S. jurisdictions (nearly 50% in Maine, for example). If we exempt these fuels, as Texas, Utah and the California districts have, we will not only limit the air quality impact of the rules but also create a comparative advantage for propane- and oil-fired water heaters over gas. Since both fuels emit NO_x at higher rates than gas, we believe the rule should cover these water heaters.

Considering these factors, our model rule includes two separate categories for gas-fired water heaters based on rated heat input capacity. This reflects the fact that most existing rules in the U.S. have more stringent emissions limits for water heaters with a rated heat input capacity of less than 75,000 BTU per hour than for larger models. Mobile home water heaters that combust gas are excluded from these two categories in our rule. We also include a third category that regulates emissions from all other nonexempt water heaters, which encompasses oil- and propane-fueled water heaters and mobile home water heaters of all sizes up to 2,000,000 BTU per hour.

Standards/Emission Limits: Values and Timelines

The model rule establishes a schedule whereby the allowable emissions from new water heaters will decrease over time. For each category of water heater covered by the rule, a separate schedule is provided. The key variables in each schedule are:

1. A series of applicable emissions limits.
2. The dates after which all water heaters sold, installed or offered for sale must comply with each applicable emissions limit for that category of water heater.

The **initial emissions limits** for Category 1 and 2 water heaters are based on (but not necessarily identical to) the most stringent similar emissions limit in effect as of October 1, 2022, in any of the jurisdictions we reviewed. A summary of all the emissions limits reviewed is provided in the Appendix. We reason that emissions limits based on these precedents are demonstrably achievable using existing technologies and NO_x control techniques, given that appliances are sold in these jurisdictions that comply with the applicable emissions limits. The initial emissions limit for each category takes effect 24 months after the rule is promulgated. The reason for this two-year lag between when the rule is promulgated and when the initial emissions limits take effect is to allow manufacturers, distributers, retailers and installers of water heaters to develop new products, expand production of compliant products, work through their preexisting inventories of noncompliant products with no or minimal financial loss and train workers (if needed) to install compliant products. For Category 3, the model rule does not currently include a comparable initial emissions limit for practical reasons that will be explained later. However, if we had applied the same rationale for Category 3 as we did for Categories 1 and 2, we would have adopted an initial emissions limit for Category 3 of 20 ng/J heat output, based on rules in effect today for propane-fired water heaters in the European Union.

A more stringent **interim emissions limit** takes effect for Category 1 and 2 appliances sold, installed or offered for sale on or after January 1, 2030. The interim emissions limit (7 ng/J heat output) is based on actual emissions test results for a "best performing" subset of appliances that have already been certified by SCAQMD, as previously seen in Figure 3. (Note that a 10 ppm emissions rate is roughly equal to 7 ng/J.) These emissions limits are demonstrably achievable given that a nontrivial number of appliances sold in 2022, with varying rated heat input capacities, can comply with the limits. Manufacturers would have until 2030 to develop additional models capable of achieving a 7 ng/J emissions limit. For Category 3, the model rule does not currently include a comparable interim emissions limit (again, for practical reasons to be explained later), but we determined that an interim emissions limit that is 50% of the initial emissions limits (i.e., 10 ng/J heat output) would likely be appropriate. The rationale for this decision is that emissions for Category 3 water heaters should be required to decline at roughly the same rate as those for Categories 1 and 2.

The 2030 date for the interim emissions limits was selected as roughly a midpoint between when the initial and final emissions limits take effect.

The **final emissions limit** for all categories of water heaters is zero ng/J of heat output, beginning on January 1, 2035. Water heaters that combust any fossil fuel mixed with or in the presence of air will not be able to meet this emissions limit, but consumers will have practical water-heating options. To begin with, the model rule exempts combination water heaters, so consumers would be able to purchase and install combination water heaters that rely on fossil-fueled boilers and furnaces. In addition, and more importantly, we believe that by 2035 zero-emissions electric heat pump water heaters will be commercially available, competitively priced and practical to install for virtually every application covered by this rule, with other zero-emissions electric water heaters available for the remaining applications. The 2035 date for the final emissions limit was selected because water heaters have an average life of roughly 15 years. Using this date for the final emissions limit will ensure that by 2050, a substantial majority of water heaters installed in the United States (probably 80% or more) will emit no NO_x, and by 2064, the ultimate deadline for meeting goals under the Clean Air Act's Regional Haze program,[47] this will be true for nearly all water heaters.

Certification of Low NO_x Models

The RAP model rule bases certification requirements for gas water heaters on the protocol and test procedures[48] developed by SCAQMD. These procedures were developed and updated in the 1990s and are used by other districts in California and Utah. BAAQMD developed its own procedures but accepts SCAQMD certification as well.

The SCAQMD procedures detail the emissions tests necessary to certify a gas water heater for NO_x, CO and CO_2 emissions. They include a process for submitting data to SCAQMD so that the agency maintains a list of water heaters that are certified to meet its requirements. In discussions with states in the Northeast, many indicated that they would like to accept certification by SCAQMD instead of developing their own test methods and procedures. States have used this approach in the past with, for example, regulations for certifying Stage II vapor recovery equipment being used at gasoline stations, where California Air Resources Board certifications are referenced and used around the country and accepted by the EPA in other state programs. Test procedures for other stationary and area sources, such as emissions testing at power plants, are frequently detailed by the EPA in the Federal Register.

This section of the model rule allows for a state commissioner or secretary to accept an SCAQMD certification or other forms of certification. This enables an agency to accept a

[47] As noted earlier, NO_x emissions are a main contributor to degradation of visibility. The regional haze program sets deadlines for states to achieve visibility goals in scenic areas like national parks and recreation areas. See EPA, 2022a.

[48] SCAQMD. (1998, January). *Nitrogen Oxides Emissions Compliance Testing for Natural Gas-Fired Water Heaters and Small Boilers*. http://www.aqmd.gov/docs/default-source/laboratory-procedures/methods-procedures/r1121_1146-2_prot.pdf

different agency's certification or develop its own test methods, testing capabilities or procedures.

SCAQMD does not have test or certification procedures for propane- or oil-fired water heaters. However, we believe the SCAQMD gas protocol could be adapted to propane by revising provisions for fuel supply pressure, required heating value of the fuel, requirements for a fuel pump versus a gas pressure regulator and several calculation constants in the protocol specific to gas.[49] With these revisions, it could become an accurate protocol for testing propane water heaters. That would mean that another agency would need to modify the protocol, ensure accuracy of that test and develop procedures, including a certification process, labeling requirement and tracking system. RAP intends to discuss this option with environmental and energy agencies, and regional associations for both, in the next few months to determine whether developing a test procedure and certification process for oil or propane is viable.

In the meantime, the model rule avoids testing and certifying propane and oil heaters by including only a final limit of zero emissions for both types in 2035. Therefore, the sale of oil and propane water heaters would be phased out beginning in 2035, which is 15 years before many states have pledged to reduce their GHG emissions by at least 85%. States could choose another date as appropriate.

For oil water heaters, RAP investigated the EU Ecodesign program to determine whether its test procedures could be adopted in the United States. However, initial reactions from the Northeast states indicate that they did not see accepting EU certification as a viable option. RAP plans to discuss other options with energy agencies to see whether there is interest in reviewing the EU test protocol and process and adapting it for the United States.

RAP believes it is important to set an emissions limit for oil and propane water heaters considering, as previously mentioned, their significant use in some Northeast states. We also believe that establishing a date when oil and propane heaters can no longer be sold avoids backsliding by not allowing consumers to opt to fuel switch from gas to oil or propane as the deadlines for phaseout are reached. However, since oil and propane are frequently used in rural areas where gas is not available, ensuring that consumers have access to alternatives at similar costs to those water heaters is critical. Other sections of this document describe our thoughts for enabling all consumers to access cleaner alternative water heaters.

Enforcement/Penalties and Record Keeping/Reporting/ Labeling

The enforcement and penalties and the record keeping, reporting and labeling sections of our model rule include provisions that:

[49] D. Maxie, South Coast Air Quality Management District, personal communication, September 2022. Maxie noted that the protocol for gas was modified in accordance with ANSI Z21.10.3-1978 and 10 CFR Appendix E to Subpart B of Part 430 (Uniform Test Method for Measuring the Energy Consumption of Water Heaters).

- Cover anyone in the water heater supply chain (manufacturers — including those who refurbish water heaters — distributers, retailers and installers) and holds them accountable for selling, offering to sell or installing water heaters that meet the required emissions limit.
- Allow state agencies to inspect manufacturing facilities in the state to review records or otherwise audit testing, certification or labeling of any models being sold or offered for sale in the state.
- Allow state agencies to conduct preinstallation emissions tests of water heaters or to require manufacturers to submit emissions test results.
- Allow state agencies to inspect wholesalers, retailers and installers in the state to review records or otherwise audit to ensure they are selling, offering for sale or installing only compliant water heaters in the state.
- Require manufacturers to display on the shipping container and nameplate of gas-fueled water heaters certain identifying information, including information on certification status.
- Establish record-keeping and record-submission requirements for manufacturers, wholesalers and retailers so their records can be reviewed to ensure only compliant water heaters were sold, offered for sale or installed.
- Allow fines and penalties, according to the authority in each state, for violations per water heater that is sold, offered for sale or installed without the appropriate certification.
- Allow for penalty limits for each violation according to the authority in each state.
- Include an option for fines and penalties to be used for supplemental environmental programs to offset the cost of water heater replacements in low-income homes.

These sections reflect ideas collected from existing water heater rules and our knowledge of enforcement processes in states. For example, the labeling provisions expand upon requirements of the California and Utah agencies that information on certification status or emissions be included on the shipping container or nameplate of each water heater.[50] Further, the record-keeping provisions requiring regulated parties to keep at least five years of information on models, manufacture date, sales and delivery are new but draw from record-keeping requirements in model rules developed by the Ozone Transport Commission.[51] These provisions are designed to ensure that if noncompliant water heaters are sold, offered for sale or installed in the state, the chain of events can be reconstructed,

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[50] See, e.g., BAAQMD Rule 9-6-403 and SCAQMD Rule 1121(c)(5), requiring certification status on shipping container and nameplate, and Utah Code §15A-6-102(4), requiring NO_x emission rate on permanent label on water heater.

[51] See, e.g., Ozone Transport Commission (OTC). (2019, May 14). *Regulatory and Technical Guideline for Control of Nitrogen Oxides (NO_x) Emissions from Natural Gas Pipeline Compressor Fuel-Fired Prime Movers,* Section 9.1. https://otcair.org/upload/Documents/Model%20Rules/OTC_RegAndTechGuideline_NGPipelineCompressorPrimeMovers_Final_05142019.pdf Also see OTC. (2011, August 31). *Model Rule for Control of Nitrogen Oxide (NO_x) Emissions From New Natural Gas-Fired Boilers, Steam Generators, Process Heaters, and Water Heaters 75,000 BTUs/hr to 5,000,000 BTUs/hr.* Finally, a 2010 OTC Model Rule for Stationary Generator Control Measures [see section 07(b)] requires regulated entities to keep records for at least five years.

and anyone who is liable for selling, offering for sale or installing the noncompliant water heater can be held accountable.

Impact of the Regulation

Expected Emissions Reductions

Based on data presented above on uncontrolled and controlled emissions from water heaters, we expect the initial emissions limits to result in a 65–75% reduction in NO_x emissions from each gas water heater sold through 2030. The interim standards would result in an 83% reduction in NO_x emissions for each gas water heater sold from 2030 until 2035, and the final standards would eliminate NO_x emissions from covered water heaters beginning in 2035. The extent of the emissions reductions will of course depend on the magnitude of the water heater market in each jurisdiction, the mix of technologies sold in each compliance period and the technologies used by any water heaters that are replaced.

Expected Consumer Costs for Compliant Water Heaters

Regulators will want to know the expected incremental costs for consumers if the model rule is adopted in their jurisdiction. This involves comparing not just the upfront purchase and installation costs of compliant and noncompliant water heaters but also the lifetime "O&M" costs of operating and maintaining these devices. Both pieces of information are important. In some cases, upgrades to the electrical or ventilation system of a building might also be required, particularly if an electric heat pump water heater is installed as a replacement for a fossil-fueled model.

We reviewed several information sources to evaluate incremental costs imposed by the model rule. But before describing our conclusions, below we explain our assumptions about how we assess "incremental" costs. The costs associated with the model rule must be evaluated in comparison to what would happen in the absence of the rule. Thus, the term "incremental" implies that there is a reference case describing what we assume would happen in the absence of the rule.

Assumptions about Reference Case and Incremental Costs

The model rule imposes no emissions limits or regulatory burden on any water heaters other than gas-fueled water heaters prior to 2035. After 2035, a zero-emissions limit kicks in for all covered water heaters.

For gas-fueled water heaters, we assume in our reference case that until 2035, consumers would purchase a noncompliant gas-fueled water heater in the absence of the model rule. Thus, we will compare the costs of compliant and noncompliant gas-fueled water heaters to assess incremental costs. From 2035 onward, for all fossil-fueled water heaters, the reference case assumes a noncompliant water heater of the specified fuel type would be purchased in the absence of the model rule. But in this case, because the model rule sets emissions limits at zero, we assume that the best option under the rule for almost all consumers will be to purchase an electric heat pump water heater. There may be some circumstances where building characteristics make it impractical or impossible to install heat pumps, in which case electric resistance water heaters will likely be the best option.[52] Thus, after 2035, incremental costs should be based on a comparison of the costs of a noncompliant fossil-fueled water heater with the costs of an electric heat pump or, in a minority of cases, an electric resistance water heater.

Incremental Costs Prior to 2035

Gas-fueled water heaters that comply with the initial and interim emissions limits in our model rule are available for sale today in many, if not all, parts of the country. In most of the country, models that do not comply with the emissions limits are available. This makes it feasible and relatively simple to assess incremental costs.

Our primary source of information is a technical support document (TSD) published by the U.S. Department of Energy (DOE) just this year.[53] DOE's purpose in publishing this document was to support its water heater energy efficiency rulemaking efforts, but the analysis covers emissions characteristics of water heaters and is useful for assessing the potential incremental costs of our model NO_x emissions rule. In this report, DOE defines "ultra-low- NO_x" gas storage water heaters essentially to mean a model that complies with our initial Category 1 limits: "Ultra-low- NO_x" water heaters produce no more than 10 nanograms per Joule. The report then includes two key conclusions relevant for our assessment of incremental costs:

- Upfront purchase costs: Tables 5.13.1 and 5.13.2 in the DOE TSD offer data on the manufacturer selling prices of standard (noncompliant with Category 1 limits) and ultra-low- NO_x gas (compliant) storage water heaters. A comparison of those tables reveals that the incremental cost of ultra-low- NO_x models depends on the "draw" of the water heater (the amount of hot water from a storage tank that can be "drawn" before the temperature is no longer hot) and the energy efficiency of the model. The incremental costs generally range from about $100 to $125.
- O&M costs: DOE determined that "models with ultra-low- NO_x burners can still achieve approximately the same range of efficiencies as models with standard or low NO_x burners based on a review of market efficiency data."

To validate the purchase cost information in the DOE TSD, we reviewed online sales prices for residential gas storage water heaters offered by a major nationwide retailer. Our comparison was conducted August 31, 2022, and was based on online prices offered for purchase from a Colorado store. We found a price premium of $140–160 for 40-gallon ultra-low- NO_x models, compared to standard models, but a premium of only $80–90 for 50-gallon models, as suggested in Table 5 on the following page.

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[52] "Retrofit ready" electric heat pump water heaters arrived on the market in 2022. These models can normally be installed without an electrical upgrade in almost any building. This technological innovation leads us to believe that the only buildings where electric heat pump water heaters will not be feasible will be a small minority of buildings that lack adequate potential for the air exchange needed to operate a heat pump.

[53] U.S. DOE (2022, March). *Preliminary Analysis Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial And Industrial Equipment: Consumer Water Heaters.* https://downloads.regulations.gov/EERE-2017-BT-STD-0019-0018/content.pdf

Table 5. Online sales price comparison for residential gas storage water heaters

Type	Capacity	BTU	Warranty	Cost
Ultra-low-NO_x	40 gal.	38,000	6-year	$ 729.00
Gas	40 gal.	36,000	6-year	$ 569.00
Ultra-low-NO_x	40 gal.	38,000	9-year	$ 829.00
Gas	40 gal.	40,000	9-year	$ 689.00
Ultra-low-NO_x	50 gal.	38,000	6-year	$ 779.00
Gas	50 gal.	38,000	6-year	$ 689.00
Ultra-low-NO_x	50 gal.	38,000	9-year	$ 879.00
Gas	50 gal.	40,000	9-year	$ 799.00

Recognizing that the DOE TSD is based on more thorough research than a single online search, we conclude that the incremental purchase costs for compliant gas-fueled water heaters will likely range from $100 to $125. The incremental O&M costs are likely to be zero or negligible. Compliant models should cost no more than noncompliant models in terms of any electrical or ventilation upgrades necessary for installation. We further assume, based on the 14-year average lifetime of today's water heaters, that any water heater purchased between now and 2035 will more likely than not still be functioning in 2035. Thus, we would expect very few consumers to have to purchase two ultra-low- NO_x water heaters before 2035.

We view this assessment of incremental costs through 2035 as close to the maximum costs per household associated with rule adoption. Actual incremental costs are likely to be smaller, for several reasons. First, the costs of compliant models may drop due to either technology learning curves or economies of scale as more jurisdictions adopt water heater NO_x limits and the demand for compliant models increases. Second, some consumers will find that they can save money by replacing an old, noncompliant gas storage water heater with an electric heat pump water heater. Heat pump water heaters are already cost-effective in some circumstances (meaning they reduce lifetime costs of ownership compared to a fossil-fueled water heater because of their increased efficiency), depending on local electricity costs, building characteristics and climatic zone.

Incremental Costs After 2035

Electric water heating and solar water heating are likely to be the only technologies that can, as a practical matter, meet the zero-emissions limits that take effect in 2035 under our model rule.[54] We believe, based on all the sources of information we've reviewed, that electric water heating is feasible, technologically, in virtually every building. Solar water

[54] Theoretically, fossil gas and propane could be combusted in a nitrogen-free environment without producing NO_x.

heating will be feasible for some but not all homes and businesses. In either case, there may be incremental costs to replace fossil-fueled water heaters.

Based on our research, in 2022, electric resistance water heaters typically cost less to purchase and install than standard (i.e., *not* ultra-low- NO_x) gas storage water heaters. For example, our search of online prices from that same major nationwide retailer in August 2022 found that the lowest-cost electric resistance water heater cost $70 less than the lowest-cost gas storage water heater and $260 less than the least expensive propane water heater. (The Colorado store did not offer oil-fired water heaters for sale.) Electric heat pump water heaters, on the other hand, can cost more to purchase and install than a standard gas storage water heater, and solar water heating systems can cost much more. We offer this evidence from one state, knowing that any state proceeding with a regulation would be interested in data specific to their state.

We believe, however, that regulators should look at costs other than those of purchase and installation. The lifetime costs of ownership of any water heater depend heavily on O&M costs, principally fuel costs (i.e., electricity costs for electric water heaters and gas or other fossil fuel used for fossil-fueled water heaters). The fuel costs associated with heating a gallon of water in a gas storage water heater are often lower than for an electric resistance water heater but higher than for an electric heat pump model. We say "often" because the fuel costs for electric water heaters depend heavily on retail electricity prices, and those prices vary widely across the United States,[55] as well as on whether solar panels are providing at least some of the electricity used in a household. Solar water heaters have no fuel costs. These factors and considerations make it extremely difficult to assess the incremental O&M costs of the model rule in a way that applies to all jurisdictions that might potentially adopt the rule. An analysis based on local data will probably be necessary for each jurisdiction.[56]

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[55] For example, the average retail price for residential customers in New York is almost 20 cents per kilowatt-hour, while in Virginia the average is 12 cents per kilowatt-hour. See U.S. Energy Information Administration. (n.d.). *2021 Average Monthly Bill – Residential.* https://www.eia.gov/electricity/sales_revenue_price/pdf/table5_a.pdf

[56] For one such example, we refer to the California Air Resources Board's recent assessment of a potential zero emissions appliance rule in its draft SIP. CARB estimated the net cost of a statewide zero emissions standard taking effect in 2030 would be approximately $10 billion. See CARB. (2022, September). *Proposed 2022 State SIP Strategy* – Appendix A, Table A-5. https://ww2.arb.ca.gov/sites/default/files/2022-09/2022_State_SIP_Strategy_App_A.pdf

An assessment published in 2022 on the EPA's Energy Star website used typical or average values to compare the installation and operation costs of electric heat pump water heaters, electric resistance storage water heaters, gas storage water heaters and gas tankless water heaters. The results are summarized in Table 6.[57]

Table 6: Typical installation and operation costs for different water heating technologies

	Heat pump	Resistance	Gas storage	Gas tankless
Installed cost	$1400–$3000	$450–$1200	$500–$1500	$800–$2000
Annual fuel cost	$104–$160	$400–$500+	$200–$300	$175–$225

Data source: Energy Star, 2022.

Taken in combination, and assuming a 14-year average lifespan for water heaters, the cost data above suggest that lifetime costs of ownership for heat pump water heaters and gas storage water heaters may not be very different. The heat pump option could cost more or less, depending on local circumstances like retail electricity prices or labor costs. Lifetime costs for electric resistance water heaters may be $2,700–$3,000 greater than for gas storage water heaters.

Furthermore, this rough explanation of incremental costs after 2035 obscures the fact that an assessment based on today's costs of ownership could be radically different than what we should expect the costs of ownership to be in 2035. Electric heat pumps are still a relatively new and improving technology for water heating. As is the case for most new technologies, the costs are expected to decline as demand grows and product innovations develop. We lack the expertise and tools to forecast those trends but note here that it is possible — some would say likely — that the zero-emissions standards that take effect in 2035 may not impose any incremental costs on consumers at all. It is also possible that innovations in heat pumps will address the air exchange issues that make installation impossible or impractical in some buildings, making electric resistance water heaters largely obsolete.

Finally, we note the passage of the Inflation Reduction Act of 2022, which is expected to provide consumer rebates for electric heat pump water heaters that will lower upfront purchase and installation costs, including costs to upgrade buildings to allow for heat pump installation. These rebates could, in the short term, erase any incremental costs associated with electric heat pump water heating. We don't expect such rebates to be available in 2035, but their availability in the coming few years could accelerate a market transformation in water heating.

[57] Energy Star. (2022, October). *Ask the Experts: Is a Heat Pump Water Heater Right for Your Home?* https://www.energystar.gov/products/ask-the-experts/is-a-heat-pump-water-heater-right-for-your-home. Solar water heating costs were not assessed, nor were propane or oil water heaters.

Cost-Effectiveness of Model Rule Compared to Other NO_x Reduction Strategies

In addition to thinking about consumer costs, state officials may be interested in a comparison of the different regulatory options for reducing ozone. A thorough analysis of this type is beyond our expertise and capacity, but we note that air agencies in California have conducted such assessments. SCAQMD assessed the cost-effectiveness of its ultra-low- NO_x emissions standards for large water heaters (akin to the initial emissions limit for our Category 2) at $26,500 per ton of NO_x reduced. This was not the least expensive of the ozone-reduction measures recently taken by SCAQMD, but it cost only a little more than half as much as some of the other measures adopted, as shown in Table 7.[58]

Table 7. Cost-effectiveness for recently adopted South Coast AQMD rules

Rule Adoption/Amendment*	Rule Adoption/ Amendment Year	Cost-Effectiveness ($/ton)**
1150.3 – Emissions of Oxides of Nitrogen from Combustion Equipment at Landfills	2021	$27,200
1147.1 – NOx Reductions from Aggregate Dryers	2021	$46,000
1109.1 – Emissions of Oxides of Nitrogen from Petroleum Refineries and Related Operations	2021	$11,000 to $50,500
1117 – Emissions from Container Glass Melting and Sodium Silicate Furnaces	2020	$22,700
1179.1 – Emission Reductions from Combustion Equipment at Publicly Owned Treatment Works Facilities	2020	$50,000
1118.1 – Control of Emissions from Refinery Flares	2019	$45,000
1134 – Emissions of Oxides of Nitrogen from Stationary Gas Turbines	2019	$4,900 to $11,500
1110.2 – Emissions from Gaseous- and Liquid-Fueled Engines	2019	$41,000
1135 – Emissions of Oxides of Nitrogen from Electricity Generating Facilities	2018	$5,630 to $23,000
1146 – Emissions of Oxides of Nitrogen from Industrial, Institutional and Commercial Boilers, Steam Generators, and Process Heaters/1146.1 – Emissions of Oxides of Nitrogen from Small Industrial, Institutional, and Commercial Boilers, Steam Generators, and Process Heaters/1146.2 – Emissions of Oxides of Nitrogen from Large Water Heaters and Small Boilers and Process Heaters	2018	$26,500
1168 – Adhesive and Sealant Applications	2017	$12,400

* Rules only shown if they required a cost-effectiveness calculation in the socioeconomic analysis.
** Cost-effectiveness is for NOx, except for Rule 1168 which is for VOC.

As previously noted, the 2022 draft SIP released by the California Air Resources Board assesses the costs of a potential statewide zero-emissions rule for water heaters. The draft SIP indicates that such a rule would reduce NO_x emissions in 2037 by 13.5 tons per day, at a total net incremental cost through 2037 of $10 billion (amortized in 2021 dollars).

[58] SCAQMD. (2022, December 2). *2022 Air Quality Management Plan*. http://www.aqmd.gov/docs/default-source/clean-air-plans/air-quality-management-plans/2022-air-quality-management-plan/revised-draft-2022-aqmp/revised-draft-2022-aqmp.pdf?sfvrsn=4

Key Implementation Considerations

Affordability and Equity Concerns

As noted earlier, market transformation of the water heater market to low- NO_x and no-NO_x models will not be possible without concerted effort to enable all consumers to benefit from these models and to reap the benefits of lower or none emitting and more efficient technologies.

Environmental agencies will want to work with their colleagues in energy, housing and other departments with access to funds that can be used to provide information and access to new technologies for low-income, environmental justice and frontline communities. This could mean, for example, using energy efficiency rebates to lower the upfront costs for purchasing an electric heat pump water heater and looking at rate structures that would reward off-peak use so that customers are better able to manage and minimize their electricity bills by shifting their energy use to off-peak hours (along with offsetting the costs of no longer using gas, propane or oil).

We believe that as the grid gets cleaner in the next 10–15 years, the use of electric resistance water heaters where electric heat pump water heaters cannot be installed will also benefit consumers with improved air quality inside and outside their homes. We are aware of concerns about the increase in electric load that will come from electrification of appliances, from a grid and individual consumer perspective. We believe that those increases in electricity use can be moderated through design of electric utility rate structures and incentives to dissuade peak-time use, either through individual homeowner action or third-party aggregations using internet-enabled technologies.

Opportunities to Support Other State Policies

Implementation of a low- NO_x water heater rule may also align with other jurisdictional policies that are encouraging adoption of these technologies for other outcomes. Closely aligned goals include 1) energy efficiency, 2) electrification/fuel switching and GHG reduction and 3) grid flexibility.

Utility programs provide customer rebates or incentive payments to lessen the incremental first cost of the more efficient appliance option than the baseline unit. This encourages reduced energy use (and lower costs) over the life of the investment. During the transition period, utility programs may support electric heat pump water heaters with zero- NO_x emissions, further accelerating the electrification transition. Examples of complementary utility and state energy efficiency incentives for electric heat pump water heaters can be explored through the database of state incentives for renewables and efficiency managed by North Carolina's Clean Energy Technology Center.[59] Additional rebates for electric heat pump water heaters will become available through state energy office implementation of the Federal Inflation Reduction Act rebates.[60]

State electrification goals are typically driven by GHG reduction targets. Efforts to

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[59] Database of State Incentives for Renewables and Efficiency (DSIRE). https://www.dsireusa.org/

[60] The White House. (2023, January). *Building a Clean Energy Economy: A Guidebook to the Inflation Reduction Act's Investments in Clean Energy and Climate Action*. https://www.whitehouse.gov/cleanenergy/inflation-reduction-act-guidebook/

encourage switching to electric heat pump water heaters would allow alignment of criteria-pollutant- and GHG-reduction rules, creating another source of potential market leverage for implementation of this rule.[61]

As more renewable-generation resources are added to the grid to replace dispatchable fossil-fueled resources (gas- and coal- fired generation), the variable nature of wind and solar production is driving the need for more flexible-grid resources, such as storage and flexible demand. While replacing gas-, propane- or oil-fired with electric-fueled water heaters increases demand for electricity in total, it creates potential for using the heaters as "flexible demand." Electric water heaters can be aggregated and controlled to shift heating demand off of peak system hours without consumer impact.[62] Electric utilities or third-party aggregators can benefit the grid by managing the units through preheating storage tanks ahead of the peak or directly cycling heating loads during the peak hours.

Outreach and Stakeholder Engagement Conducted/Expected

The model rule (and this document) was reviewed by states in the OTC and the NESCAUM's Zero Emission Buildings Task Force. We presented on the model rule over 10 times in the past year to the Northeast Energy Efficiency Partnership (NEEP) states, their appliance workgroup and a broad group of stakeholders, including manufacturers. We received many helpful comments that shaped the final version.

We plan to continue our efforts to reach the regulated community to gather their input, and we expect to work with NESCAUM, NEEP and the OTC states to reach community groups about the impact of the rule and other electrification efforts to ensure the rule and its implementation are informed by underrepresented communities and environmental justice groups.

We view the model rule as a tool for environmental and energy offices to work together to promote improved air quality, climate mitigation and building electrification to improve efficiency and lower consumer costs. State agencies will want to coordinate efforts in energy efficiency programs so that market transformation of appliances is available for all communities at an affordable price and the benefits of low- NO_x and no- NO_x appliances are widespread. In addition, other state energy-related issues should be considered with this model rule. This includes electric and gas rate design, time-of-use rates to lower consumer costs and avoid peak-time use of appliances (which is usually detrimental to air quality) and use of appliances as distributed resources that can be managed during peak times to limit usage and improve grid reliability.

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[61] Yim. E. (2022, August 23). *Three States Enact Integrated Plans to Decarbonize Buildings* [Blog post]. American Council for an Energy-Efficient Economy (ACEEE). https://www.aceee.org/blog-post/2022/08/three-states-enact-integrated-plans-decarbonize-buildings

[62] Hale. E. (2022, March 22). *Physically Realistic Estimates of Electric Water Heater Demand Response Resource* [Presentation to ACEEE Hot Water Forum]. National Renewable Energy Laboratory. https://www.nrel.gov/docs/fy22osti/82082.pdf

Questions for Public Hearings: Areas That May Warrant Seeking Public Comment

State agencies use their public hearing process to seek public comment on areas of particular interest (in addition to overall comments on the design and impact of the proposed rule). The areas that were discussed most in the development of the model rule were:

- Categories and exemptions — how many categories of water heaters should be in the rule; whether the size differentiation is appropriate; which fuels should be covered.
- Emissions limits — was using the existing limits from other jurisdictions a good starting point; are the interim limits useful or necessary; should zero be the final limit; whether oil and propane units should have initial and interim standards in addition to a zero limit and phase-out date.
- Timing — is two years after issuance of the final rule a good starting date; what subsequent dates (e.g., 2030 and 2035) work for other environmental objectives in the states (e.g., criteria pollutant goals and GHG targets).
- Costs — what additional incremental cost data will be needed by states; can manufacturers or others help provide those values.

These may be areas where states will continue to gather input as they proceed to a rulemaking process.

Conclusion

Fossil-fuel fired water heaters represent an unregulated source of NO_x emissions in most of the United States, but technologies exist to dramatically cut these emissions, as well as reducing greenhouse gases. Our model rule builds on the existing rules in place in several states and districts, demonstrating how other states could establish limits to address the negative health and environmental impacts of NO_x pollution. Regulating this pollution source represents an opportunity for environmental regulators to help their state meet public health and clean energy goals, and drive an affordable transition toward lower-emission water heating.

The model rule's design offers options for jurisdictions to design a rule that fits within their existing regulations and authority, and to establish their own timeline for reducing NO_x emissions. RAP is prepared to offer advice and technical assistance to any agency that is interested in adapting the model rule for use in a formal regulatory proceeding.

Appendix: Existing Emissions Limits

The table below includes all the emissions limits in effect for water heaters sold in the listed jurisdictions as of August 1, 2022. The categories to which each emissions limit applies are specified in the table. Note that the categories in these existing rules do not match the categories in our model rule. Also note that the form of the emissions limit in the source rule is not always expressed in nanograms per Joule (ng/J) of heat output. Where other units are specified in the source rule, we have converted the values to a comparable value in nanograms per Joule of heat output. The limits used as the basis for the initial emissions limits in the model rule are highlighted in green.

Table A-1. Emissions limits for water heaters

Fuel	Category	Size (rated heat input capacity in BTU)	Emissions limit on heat OUTPUT basis	Jurisdiction
Gas	RV	All	EXEMPT	All but UT
Gas	RV	All	Not specified but not specifically exempted	UT
Gas	Mobile home	<2,000,000	40 ng/J	BAAQMD
Gas	Mobile home	All	40 ng/J	UT
Gas	Mobile home	<75,000	40 ng/J	SCAQMD, SJVAPCD, VCAPCD
Gas	Mobile home	75,000 to 2,000,000	Not specified but not specifically exempted	SCAQMD
Gas	Mobile home	<2,000,000	Not specified but not specifically exempted	TX
Gas	Pool/spa	<400,000	EXEMPT	BAAQMD
Gas	Pool/spa	400,000 to 2,000,000	14 ng/J	BAAQMD and UT
Gas	Pool/spa	<400,000	40 ng/J	UT
Gas	Pool/spa	<75,000	EXEMPT	TX
Gas	Pool/spa	75,000 to 2,000,000 (single-family residence)	EXEMPT	TX

Gas	Pool/spa	75,000 to 2,000,000 (elsewhere)	Not specified but not specifically exempted	TX
Gas	Pool/spa	<75,000	Not specified but not specifically exempted	SCAQMD
Gas	Pool/spa	75,000 to 400,000	40 ng/J	SCAQMD
Gas	Pool/spa	400,000 to 2,000,000	Not specified but not specifically exempted	SCAQMD
Gas	Pool/spa	<75,000	40 ng/J	SJVAPCD
Gas	Instantaneous	<2,000,000	Not specified but not specifically exempted	All but BAAQMD and SJVAPCD
Gas	Instantaneous	<75,000	EXEMPT	BAAQMD
Gas	Instantaneous	75,000 to 2,000,000	14 ng/J	BAAQMD
Gas	Instantaneous	<75,000	14 ng/J	SJVAPCD
Gas	Storage	<75,000	10 ng/J	All but TX
Gas	Storage	75,000 to 2,000,000	14 ng/J	All but TX
Gas	Storage	<400,000	40 ng/J	TX
Gas	Storage	400,000 to 2,000,000	15.9 ng/J	TX
Gaseous fuels not produced from biomass: includes NG, LNG, LPG, propane	Conventional	<1,364,857	19.5 ng/J	EU
Liquid fuels not produced from biomass	Conventional	<1,364,857	41.7 ng/J	EU
Gaseous fuels not produced from biomass: includes NG, LNG, LPG, propane	Electric heat pump w/external combustion	<1,364,857	24.3 ng/J	EU

Gaseous fuels not produced from biomass: includes NG, LNG, LPG, propane	Solar w/combustion	<1,364,857	24.3 ng/J	EU
Liquid fuels not produced from biomass	Electric heat pump w/external combustion	<1,364,857	41.7 ng/J	EU
Liquid fuels not produced from biomass	Solar w/combustion	<1,364,857	41.7 ng/J	EU
Gaseous fuels not produced from biomass: includes NG, LNG, LPG, propane	Electric heat pump w/internal combustion	<1,364,857	83.3 ng/J	EU
Liquid fuels not produced from biomass	Electric heat pump w/internal combustion	<1,364,857	145.8 ng/J	EU
Indicative Benchmark (best performing at rule adoption) for gaseous fuels	Conventional	<1,364,857	12.2 ng/J	EU

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