

NO_x, NO_x – Who’s There? Decarbonizing Buildings through Nitrogen Oxides Emissions Standards

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ABSTRACT

Reducing emissions of nitrogen oxides (NO_x) is key to attaining a variety of Clean Air Act standards that remain elusive; for example, more than 125 million Americans are affected by summer smog each year. An innovative approach to regulating a particular source of NO_x emissions — fossil-fueled water heaters — could help drive widespread adoption of cleaner and more energy-efficient heat pump models.

Regulation could limit NO_x emissions from gas-fired water heaters by capping emissions for these appliances at a level proportional to the emissions associated with powering a typical electric heat pump appliance. As the power grid becomes cleaner, the emissions associated with the heat pump will decline. Thus, emissions standards will become more stringent over time. Fossil-fueled appliances will eventually *not* be able to meet the standards and will no longer be sold.

RAP is developing a model rule that would cap appliance NO_x emissions in this manner; this paper will describe how the rule would work to phase out gas-fired water heaters. The standards would become tighter over time *without requiring new rules* — an innovation over existing water heater regulations, which have a static emissions limit that can only be changed through new rulemaking. We will address affordability and equity through provisions that ensure that lifetime costs to consumers will not increase. We see linkages between emissions standards and efficiency incentive programs as critical to ensuring that upfront costs of heat pump appliances are not a barrier to the transition, and incentives for fossil-fueled appliances would be phased out.

Introduction

The Regulatory Assistance Project (RAP)¹ is developing a model rule² for nitrogen oxide (NO_x) emission standards for water heaters that will be designed for use by U.S. state air quality regulators.³ This paper describes why water heaters are an important source of air pollution, why NO_x emission standards are an excellent tool for reducing the environmental impact of water

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 As of June 1, 2022, a draft of the model rule has been discussed with states in the Ozone Transport Commission. We await their comments and have not updated information about the standards proposed in this version of the paper.

heaters and how those standards can promote electrification and market transformation of appliances.

We chose to focus on water heaters and NO_x standards for reasons discussed in the paper — primarily due to the prevalence of water heaters, the feasibility of establishing and updating NO_x standards, and the limited number of sizes and scenarios of water heater appliances to consider (a contrast from the more complex market landscape for space heating). We are preparing a model rule that builds on existing rules in California, Texas, and Utah and a model rule for water heating standards developed by the Ozone Transport Commission (OTC) states⁴ 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 model rules. 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. We hope this would eventually lead the U.S. Environmental Protection Agency (EPA) to take on development of a national water heater rule. A 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 (in air quality parlance, consumer products), 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 wood stove emissions standard in over 20 years, two regional air quality groups, the Northeast States for Coordinated Air Use Management (NESCAUM) and the Western States Air Resource Council (WESTAR),⁶ started a multi-state process that ultimately led to a new federal standard in 2020 (Johnson and Marin 2012; NESCAUM 2020).

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 is combusted. Figure 1 demonstrates how NO_x is a key component in forming summer ozone, or smog, which affects over 125 million Americans each summer (U.S. EPA 2022). NO_x is also a fine particle,⁷ and fine particle pollution leads to premature mortality of around 100,000 Americans each year (Goodkind et al 2019). Finally, NO_x contributes to visibility impairment (U.S. EPA 2022a), acid rain (U.S. EPA 2021a), and water eutrophication (U.S. EPA 2021b). Truly a pollutant that warrants attention.

⁴ The Ozone Transport Commission 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 (OTC 2001).

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 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 (U.S. EPA 2021).

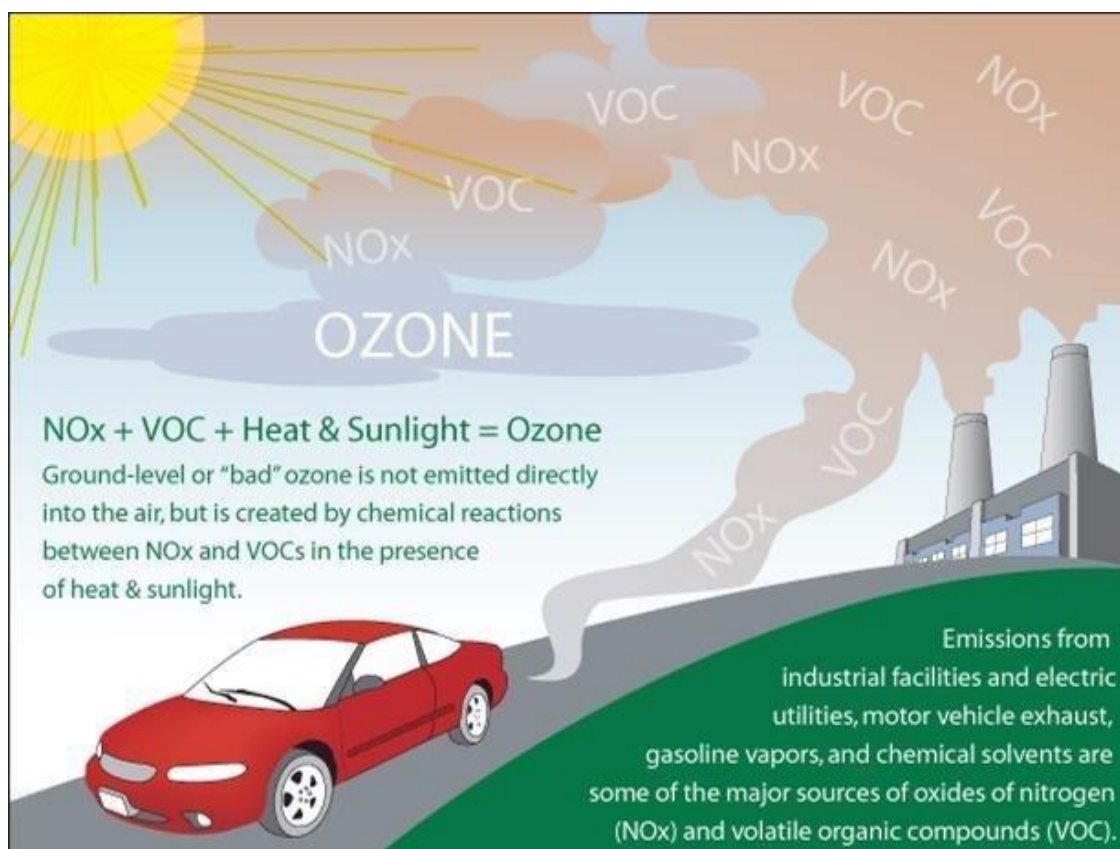


Figure 1. Process of ozone formation. Source: U.S. EPA 2021c.

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 $\text{PM}_{2.5}$ 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 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 (U.S. EPA, 2022a).

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 diminishes, air quality agencies have also 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 . They warrant a closer look, particularly if emissions reductions can be gained cost-effectively compared to other available options.

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 greenhouse gas (GHG) emissions, and another 10 have targets set through executive action (Center for Climate and Energy Solutions). For example, in Utah and Texas, NO_x reductions are necessary to meet federal public health standards, but no authority to regulate GHG exists. RAP chose to focus our model rule on limiting NO_x emissions rather than carbon dioxide (CO₂) or other GHG emissions, but any reduction in fossil fuel combustion to meet a more stringent NO_x standard will drive down GHG emissions as a co-benefit.

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 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 GHG.

Background and Purpose

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 (RMI 2021). The RMI researchers examined detailed emission inventory data submitted by air quality agencies to the EPA and then separated the relevant categories of fuel usage that are most likely to include appliances. RMI found that NO_x emissions from all appliances total more than twice the emissions of power plants, and that emissions of PM_{2.5} from appliances equal about 25% of power plant PM_{2.5} emissions. Since power plant emissions have been regulated for decades, this data supports examining the potential for regulating NO_x from water heaters. States can examine their emissions inventories compared to their options for NO_x reductions to meet state and federal deadlines, to ensure that the expected emissions reductions from water heaters warrant proceeding.

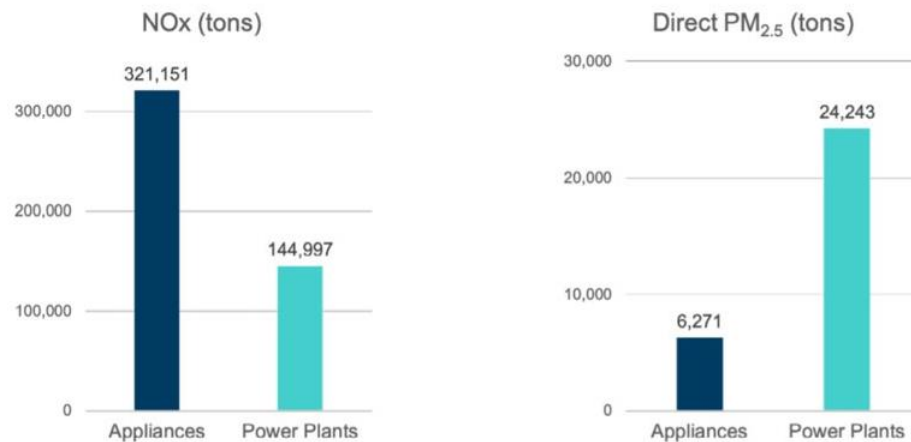


Figure 2. US gas appliance pollution rivals or exceeds gas power plant pollution. *Source: RMI 2021.*

We compared RMI's figures to work done by the Bay Area Air Quality Management District (AQMD). The AQMD 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 (Bay Area AQMD 2021).

At the same time, we noted that multiple jurisdictions have already adopted NO_x emissions limits for 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.⁸ Those rules date back five to 15 years ago. (Utah Administrative Code 2015; Texas Administrative Code 2007). These regulations generally cover the same sizes of water heaters with the standards split in two to three categories based on heat input ratings. These are discussed in the next section.

Importantly and recently, the Bay Area AQMD has proposed a water heater NO_x emissions standard that will decline to zero by 2027 to 2031 depending on the size of the water heater (Bay Area AQMD 2021). If finalized, this would be a first for appliance standards.

Knowing that not all agencies would share the Bay Area's interest in a rule that establishes a zero emissions standard in less than a decade, we chose to write our model with an important twist. Our model will 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: where the 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 emission standard by 90–95%, an agency does not have to re-propose a rule to lower the emissions standards in future years, and

⁸ In California and some other states, the state has delegated some aspects of air pollution regulatory authority to local air quality districts.

manufacturers get advanced notice and can plan accordingly for the standards between now and 2035. Our calculations showing how these limits would compare are discussed in the next section.

Design of the Model Rule

Three crucial design questions will be addressed in the model rule that are critical to implementing NO_x limits for water heaters. First, we must decide which water heaters will be subject to emissions limits and group them into **categories**. RAP will seek input from industry experts on this design question. Second, we must decide how to create a **mechanism** whereby water heater emissions decline over time without the need for a rule rewrite. The model rule will present two options: a *schedule* option and a *formula* option. And third, we must decide on the **stringency** of the emissions limits. The model rule will propose emissions limits based on a combination of what's possible with existing commercially available low-NO_x technologies and how the emissions associated with powering electric water heaters are projected to decline over time.

Categories: In designing the model rule we first examined the current regulations for water heater NO_x emissions in California, Texas, and Utah. In every case, those regulations group water heaters into categories based on type or size, as shown in Figure 3. The rules then specify different emissions limits applicable to each category. In the case of our model rule, we could, for example, include all storage water heaters with a heat input rating of 75,000 BTU/hour or less in “Category 1” and all other water heaters up to 2 million BTU/hour in “Category 2,” with appropriate emissions limits for each.

Figure 3 shows the types and general sizes of the water heaters currently regulated.



Types of water heaters

- Storage
- Tankless/instantaneous
- Mobile home
- Pool/spa heater



Sizes of water heaters

- ≤ 75,000 BTU/hour
- 75,000 – 400,000 BTU/hour
- 400,000 – 2,000,000 BTU/hour

Figure 3. Emissions vary based on type and size of water heater. *Source:* RAP.

Mechanism: The model rule will propose two possible mechanisms to drive down emissions, from which air pollution regulators can choose: emission standards based on a *schedule*, and emission standards based on a *formula*.

The emissions limits in Table 1 illustrate how an emissions limit *schedule* would work. (RAP has not yet determined what years or emissions limits we will propose in the model rule — the values shown in Table 1 are illustrative).

Table 1. Illustrative declining NO_x standard

Year	Category 1 emissions limit (ng/J heat output)	Category 2 emissions limit (ng/J heat output)
2025	10.0	14.0
2030	5.0	7.0
2035	1.0	1.0

Alternatively, we will propose an emissions limit based on a formula where the limit is a function of an initial emissions limit and the actual rate of change in NO_x emissions from the power sector. This approach would guarantee that fossil-fueled water heaters reduce their emissions at the same pace that the emissions attributable to electric water heaters will decline. Unlike the emissions limit schedule option, this option would be based not on projections but on actual NO_x emissions in the power sector, with a new emissions limit possible every year, though revising the standard every year is not likely in a regulatory scheme. Figure 4 illustrates how the emissions limit might continually decline, as contrasted to the static standards that exist in Texas, Utah and California today. The green dotted line indicates how the standard is lowered as grid NO_x emissions lower.

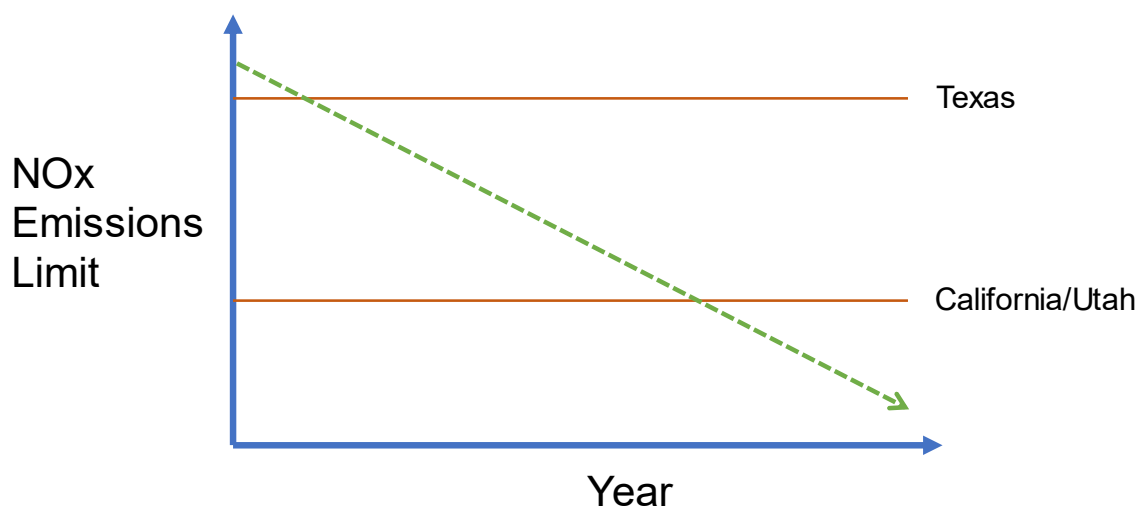


Figure 4. Formula method for emission standards – stricter standards over time. *Source:* RAP.

Stringency: For both methods we will propose a starting standard based on the current standards in California or Utah, because manufacturers are already producing water heaters that can comply with those emissions limits.⁹

Emissions limits after the starting date will be based on projections of power sector NO_x emissions (in the case of the emissions limit schedule option) or actual reductions in power sector NO_x emissions (in the case of the formula option).

For the emissions limit schedule option, the final standard in the model rule will likely be a 90–95% reduction from the starting standard as soon as 2035. While achieving zero NO_x emissions may not be technically feasible using fossil fuels, at some point the amount of renewable energy on the grid will mean that any electric water heater will in essence be close to a zero-emitting appliance (on an annual basis). We believe that the Clean Air Act allows for states to set a zero standard for purposes of public health (given their need to attain the ozone or PM_{2.5} health standards), assuming as is true in this case that there are technologies that can meet the needs of consumers.

In setting the emissions limit there are important grid implications, and those will vary depending on regional variations in the United States. Certain parts of the U.S. grid are using up to 50% renewables at certain times of day already (e.g., California in midday, Texas at night). In other areas (e.g., New England or PJM) renewables make up 10–20% of the grid in some hours. Some areas of the United States burn coal around 25% of the time (e.g., PJM). Despite these regional variations in power sector emissions, appliance manufacturers will likely prefer a rule that includes identical emissions limits across jurisdictions. In addition, to reduce demand during peak hours, controls have been developed for grid-enabled water heaters that can heat water when electric demand and emissions tend to be lowest and minimize water heating when demand and emissions are highest.

Affordability and Equity

An important consideration for the model rule is how we can ensure that all consumers can afford a low-emitting water heater. Electric resistance water heaters have lower upfront costs, but typically use more energy, have shorter lifespans, and may produce higher emissions than gas appliances, particularly in cases where an electric resistance water heater would replace a low-NO_x gas-fired water heater in an area where the grid has limited renewable energy or still includes a sizable amount of coal-fired generation. Electric heat pump water heaters, in contrast, tend to have higher upfront costs than fossil-fueled water heaters but often have lower operating costs. Customers in older homes may also have to upgrade their electrical wiring to accommodate heat pumps, which adds to upfront costs.¹⁰ We know that incentives from energy efficiency programs help lower upfront costs of purchase and installation, but these programs have not focused on lifetime costs, so purchase incentives may not be helpful if annual energy

⁹ For example, the current standards in place at the Bay Area AQMD are 10 nanograms/Joule of heat output for smaller water heaters (< 75,000 Btu/hour) and 14 nanograms/Joule for larger water heaters (Bay Area AQMD 2007).

¹⁰ Innovations are coming to enable the installation of heat pump water heaters in buildings with older electric panels that only accommodate 120 volts of service. One example is the “Retrofit Ready” program being developed as part of the Advanced Water Heater Initiative (AWHI 2021).

bills will be higher for water heaters that comply with the model rule. We want all consumers to be able to afford technology-leading heat pump water heaters with lower emissions, if appropriate to their housing situation, particularly as the grid gets cleaner. We also want to assist in the phase-out of gas appliances while ensuring that emissions do not increase.

We will be working with energy offices in the Northeast to examine issues that can ensure equitable access to low NO_x appliances and examine whether other aspects of energy efficiency programs can be used to assist with implementation of a water heater regulation and in meeting state energy efficiency and climate goals. We expect to work with the Northeast Energy Efficiency Partnership (NEEP). They have a workgroup on appliance standards and are interested in establishing links for appliance emission standards to implementation of state energy efficiency/distributed energy resource (DER) programs. For example, if low emitting water heaters can include an interoperability standard (which could be regulated by the state energy office under their authority) that would enable inclusion of low-emitting water heaters in DER programs. That could assist with achieving electrification goals, lowering costs to consumers through peak time reductions, and achieving emission and GHG goals.

We propose that air quality agencies work with their energy counterparts to develop programs that promote heat pump water heaters wherever possible, particularly to lower-income households and rental properties. This will likely involve different incentives in considering how to offset lifetime costs including costs of potential electric panel upgrades and may involve new retail rate designs that offer lower rates for using electricity at times when power system demand and costs (and typically, emissions) are lowest. There may be homes where a heat pump water heater cannot be installed (e.g., apartments, mobile homes, or other dwellings without basements or a utility room space large enough for proper ventilation to ensure the unit can operate). In such cases, electric resistance water heaters may someday be the only option that would comply with our model rule. For that reason, we want to ensure that any electric resistance water heaters that continue to be sold are high-efficiency and affordable based on upfront and lifetime costs.

We will be seeking stakeholder input on all the issues raised in this section. First, we propose to discuss our draft with state air quality and energy offices. We will also seek input from advocates at energy nongovernmental organizations, water heater manufacturers, and the EPA and U.S. Department of Energy, particularly those setting water heater standards or promoting electrification (e.g., Energy Star). Based on our discussion with state agencies, we will involve other stakeholders in their states to ensure an equitable design to the rule.

Certification and Manufacturer Input

Implementing the model rule will require a certification process for demonstrating that appliances meet the emission standards. Currently, the California air districts in the Bay Area and South Coast (covering Los Angeles County) require manufacturers to demonstrate compliance using an independent testing laboratory. The manufacturer submits an application to the air district based on required testing procedures and using timing and information required ahead of the regulation dates for meeting a new emission standard. Certifications are valid for three years in the Bay Area, and the two districts allow for reciprocity.

The Bay Area requires that the testing be completed using a South Coast procedure (South Coast Air Quality Management District 1995) or their own, similar to the South Coast.

These procedures use EPA test methods and an ANSI standard.^{11,12} Finally, the water heaters carry a label documenting the testing on the rating plate.

We believe these procedures will suffice for our model rule.

We will also need input from manufacturers. Some of the important issues to discuss with them include: their review of our emission standards methodology; their views on the viability of the interim and zero or near-zero emission standards; and their thoughts on certification and enforcement of the standards, including whether improvements or revisions can be made to the methods employed in California.

Air pollution regulators would have several ways to enforce the certification requirements, including random testing of certified water heaters, auditing of manufacturer testing results, and inspections of retail outlets to ensure that older models that don't achieve the standards have been pulled. Random inspections by environmental agencies at retail outlets (e.g., "big box" stores) have been used in other successful emission programs for consumer items like paints. Manufacturers' certification of emission standards through random testing is used in many industries; auto manufacturers are a prominent example of this.

Conclusion: Next steps

As of May 2022, RAP has a model rule being reviewed by state agencies and we will be presenting an updated draft rule to other stakeholders over the summer. We expect robust discussions with state agencies on our emissions limit proposals and assumptions about the availability of renewables on the grid. We also look forward to discussions with energy offices, REEOs, and manufacturers on technology feasibility and other relevant energy programs that should be aligned with emission standard implementation — like energy efficiency performance standards, how the gas transition is being viewed for building electrification, implementation of DER programs, etc. By the time of summer study in August we plan to have a final model rule that could be discussed at the conference.

A model rule for NO_x emission standards for water heaters can set an important precedent in the evolution of building electrification and gas transition efforts in states and local areas with emission and GHG targets. It provides a handy starting point for jurisdictions interested in offering consumers a healthier alternative to fossil-fueled appliances, a way to contribute to clean air in their neighborhood, a way to contribute to climate mitigation, and if implemented in conjunction with DERs, a way to lower bills, reduce peak electricity use and emissions at the same time. We believe this idea can be extended to regulation of emissions from space heating appliances (boilers and furnaces) once we have successfully deployed our model rule, which we hope will occur in 2023–2024 as states look to move it through their rule-making procedures.

¹¹ "Each tested water heater shall be operated in accordance with Section 2.4 of American National Standards ANSI Z21.10.1-1990 at normal test pressure, input rates, and with a five-foot exhaust stack installed during the nitrogen oxides emissions tests." (Bay Area AQMD). The Bay Area regulation also includes the procedure for calculating NO_x emissions.

¹² The Utah rule defers to the California district procedures.

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