Zero-Emission Heating Equipment Standards: A New Tool in the Policy Toolbox

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ABSTRACT

Under state environmental statutes and the federal Clean Air Act, states have the authority to set zero-emission heating equipment standards (ZEHES) limiting pollution from buildings. Under this policy, only space and water heating equipment with zero onsite emissions of greenhouse gases and air pollutants such as nitrogen oxides can be sold and installed after a certain date. These standards do not require early replacement of functioning equipment in buildings, but ensure that polluting equipment will be replaced with zero-emission alternatives, such as high-efficiency heat pumps, at the end of their useful life.

ZEHES is a nascent policy to address pollution from buildings but is gaining momentum. In March 2023, to help attain federal ozone standards, the Bay Area Air Quality Management District in California became the first jurisdiction in the nation to promulgate zero-NOx standards for furnaces and water heaters. The California Air Resources Board included a similar zero-greenhouse gas focused measure in its 2022 Strategy for the State Implementation Plan and the Maryland Department of the Environment committed to pursue a ZEHES rulemaking in its Climate Pollution Reduction Plan, released in December 2023. Other states are exploring this policy to transform the market by setting a clear end date for the sale of polluting HVAC and water heating equipment. This paper discusses policy design options and equity considerations, reviews progress and lessons learned to date, and discusses the outlook for ZEHES.

Introduction

Pollution from buildings is a significant source of both greenhouse gas (GHG) and criteria air pollutant emissions, contributing to the climate crisis and a variety of negative health outcomes. Seventy million homes and businesses across the country burn fossil fuels such as gas, oil, or propane onsite (RMI 2019), mostly for space and water heating (EIA 2023). This fossil fuel combustion releases pollutants that harm air quality and human health, including nitrogen oxides (NOx) and fine particulates (PM2.5). NOx contributes to increased inflammation of the airways, worsened cough and wheezing, reduced lung function, and increased asthma attacks (ALA 2024a). NOx also reacts in the atmosphere with volatile organic compounds (VOCs) and sunlight to form ozone (smog). Ground-level ozone harms the human respiratory system and can cause serious health problems to those who inhale it (ALA 2024b).

Because heating, ventilation, and air conditioning (HVAC) systems and water heaters vent directly outdoors, these harmful pollutants are released directly into communities, contributing to outdoor air pollution. According to the American Lung Association (2023), “nearly 120 million people in the U.S., or more than one in three, live in counties that had unhealthy levels of ozone or particle pollution.” Nationally, hundreds of counties are designated to be in “non-attainment” with the National Ambient Air Quality Standards (NAAQS) for criteria pollutants such as ozone and particulate matter (EPA 2024a).

Buildings are also a significant contributor to the climate crisis: direct GHG emissions from fossil fuel combustion and refrigerant leaks in residential and commercial buildings made up 13% of total U.S. emissions in 2022; with indirect emissions from electricity generation included, this percentage rises to 31% (EPA 2024b). States are setting increasingly ambitious goals to reduce GHG emissions, generate electricity with clean and renewable sources, and achieve economy-wide decarbonization by 2050. As of September 2023, 23 states and the District of Columbia had adopted economy-wide greenhouse gas emissions targets (C2ES 2023).

To reach both climate and air quality goals, states recognize that they need to redouble their efforts to tackle pollution from the building sector. To date, state policies to address buildings have centered on energy efficiency and weatherization programs, rooftop solar incentives, and building energy codes. Efficiency, weatherization, and solar programs provide incentives and other assistance to help residents and businesses make energy upgrades to their buildings. However, participation in these programs is voluntary and they typically only reach a small percentage of the potential market. Building energy codes are widely adopted, but mainly apply to new construction and major alterations, leaving most emissions from existing buildings untouched. Because of these limitations, these long-standing building-sector policies have proved insufficient to decarbonize buildings at the pace and scale necessary.

States that have modeled pathways to decarbonize the building sector have identified electrification as a primary strategy, coupled with efficiency (Dyson et al. 2020). Electric equipment does not release any onsite pollution and heat pumps are the most efficient electric technology for space and water heating, achieving 2-4 times greater efficiency than fossil fuel heating systems (McKenna, Shah, and Silberg 2020). Heat pumps also provide both heating and cooling in a single device, so they can offer cooling benefits to homes that do not yet have air conditioning and increase resilience during heat waves. Even with the current electricity generation mix, heat pumps already result in lower GHG emissions than gas furnaces in all 48 continental states, and this advantage will only grow as the electricity grid gets cleaner (Tan and Teener 2023). To achieve economy-wide decarbonization by 2050, given the long lifespan of heating equipment – 10-15 years for water heaters and 15-20 years for space heaters – most newly installed equipment will need to be electric by 2035 at the latest.

In 2022, several papers (Seidman and Shenot 2022; Dennison 2022) published in these proceedings proposed a new policy to address air and climate pollution from buildings: zero-emission standards for appliances such as water heaters. Dennison argued that zero-emission standards have three advantages that make them "more effective than alternative policies at guiding market transformation efforts toward equitable electrification: (1) they can directly align regulatory requirements with decarbonization commitments by setting an enforceable timeline for phasing out combustion appliances, (2) they can apply to all new appliances installed in both new and existing buildings, and (3) they can be pursued at the local, state, and federal levels in parallel" (2022). Since 2022, this policy, now known as zero-emission heating equipment standards (ZEHES), has gained momentum.

In 2023, the Bay Area Air Quality Management District (BAAQMD) adopted the nation's first zero-NOx standards for furnaces and water heaters (Elwell and Lara 2023), and other jurisdictions are now considering similar policies to decarbonize buildings and reduce air pollution. This paper reviews how zero-emission standards can address pollution from buildings, identifies policy design options, reviews ZEHES progress to date, and recommends strategies to support equitable and effective ZEHES implementation.

Zero-Emission Heating Equipment Standards

ZEHES are an emerging policy option to address pollution from combustion equipment in buildings by using air agency regulatory authority to limit NOx and GHG emissions. ZEHES establish emission limits in nanograms per joule (ng/J) of heat output for NOx and/or carbon dioxide equivalent (CO2e) from GHG emissions emitted during operation of heating equipment such as furnaces and water heaters, based on the equipment type and size, as measured in rated heat input capacity (Btu/hour). Zero-emission standards take a proven regulatory model that has reduced air pollution and GHG emissions from other sectors, such as mobile sources and industry, and apply it to smaller-scale combustion equipment in buildings.

States are making progress tackling air pollution from other sectors, such as mobile sources and large stationary sources (e.g., coal-fired power plants and industrial facilities). For example, more than a dozen states have adopted or taken action to adopt California's Advanced Clean Cars (ACC) II and Advanced Clean Trucks (ACT) regulations, which require manufacturers to sell an increasing share of zero-emission vehicles (ZEV) over time. Under ACC II, the sales percentage ramps up to 100% ZEVs by 2035 (CARB 2024a). In contrast to the progress in other sectors, pollution from the building sector remains largely uncontrolled. In aggregate, gas combustion equipment in buildings emits twice as much NOx pollution (356,000 tons) as gas power plants (178,000 tons) per year, despite using only two-thirds of the gas – because power plants have pollution scrubbers while buildings do not (Wilson 2024).

Regulating emissions from heating equipment can effectively eliminate a large portion of building sector pollution and support a transition to zero-emission equipment like heat pumps. The U.S. Environmental Protection Agency (EPA) is authorized to set emission standards for a wide range of pollution sources under Section 111 of the Clean Air Act, though it has not yet set national standards for heating equipment. In 2022, the Sierra Club and 25 other environmental and public health organizations formally petitioned EPA to initiate rulemaking proceedings to list heating appliances such as furnaces and water heaters as a source category and promulgate performance standards for new sources within the category (Sierra Club et al. 2022).

State air agencies and local air districts are granted similar authority to set emission standards under state law, and – unlike for mobile sources – the Clean Air Act expressly grants state and local governments the ability to enact more stringent pollution regulations for stationary sources than the federal standards (Lienke et al. 2021). States have broad discretion to determine which pollution control measures to pursue to improve air quality (Dadashi, Horowitz, and Stein 2022). States also have a legal obligation to demonstrate their compliance with the NAAQS for pollutants including ozone and PM2.5. ZEHES can be a measure to support state compliance (Dennison, Louis-Prescott, and Gruenwald 2021). States that are in attainment of NAAQS can still pursue zero-emission standards; the Clean Air Act requires states to continue monitoring their pollution and demonstrate ongoing maintenance of the NAAQS (Dadashi 2023).

Regulation of NOx emissions from heating equipment is not new. Texas, Utah, and air districts in California have long regulated pollution from space and water heaters, including residential-scale equipment, requiring that all water heaters and furnaces sold and installed be certified to have NOx emissions below a threshold level (typically in the range of 10-14 ng/J). Many states also regulate NOx emissions from heating equipment, but to date have chosen to focus on larger-scale equipment such as industrial boilers. ZEHES extends this proven regulatory approach by setting a limit of zero NOx and GHG emissions from new equipment after a certain date, eliminating onsite emissions.

ZEHES does not require early replacement of functioning equipment in buildings, but ensures that polluting equipment will be replaced with zero-emission alternatives, such as heat pumps, at the end of useful life. These standards can be designed to target either GHG or NOx emissions, or both, since equipment with zero onsite GHG emissions also typically has zero NOx emissions. Fundamentally, ZEHES follows a similar model to ACC II and ACT for vehicles, by requiring that all new purchases must be zero-emissions after a certain future date. By setting dates well in the future, typically in the 2027-2033 range, both policies provide a strong signal to the market and clarify the pace and scope of the transition to zero-emission options.

BAAQMD in California recently passed the nation's first zero-emission requirement for furnaces and water heaters, demonstrating a new policy pathway to phase out fossil fuel combustion equipment in buildings over time. The statewide California Air Resources Board (CARB) and South Coast Air Quality Management District (SCAQMD) in the Los Angeles region are also in the process of developing ZEHES rules. These California agencies demonstrate how state and regional policies can work together, as the state pursues a zero-GHG standard with NOx co-benefits and the regional agencies pursue zero-NOx standards with GHG co-benefits.[1] Each of these agencies' regulations can be included in the State Implementation Plan (SIP) that California must submit to EPA to demonstrate its efforts to improve air quality and achieve the NAAQS. Beyond California, other states, including Maryland (Maryland EO 2024), are also now considering ZEHES.

Design Options for Zero-Emission Standards

When developing standards, agencies need to determine a general rule framework, scope of applicable equipment, implementation timing, and design elements. Below we explore each of these elements and provide examples that agencies may consider; the next section discusses equity considerations for ZEHES. While some of the examples are not specific to building equipment, they draw on regulations that operate in a similar manner, such as ZEV rules.

The rule framework determines the high-level compliance structure for regulated entities, primarily original equipment manufacturers (OEMs). Table 1 lays out options and examples of regulations that have adopted similar frameworks.

Table 1. ZEHES framework options

Framework	Examples of Regulations with this Framework
Blanket rule: all new sales and installations of covered products are zero-emission by a specified date	-BAAQMD's Rules 9-4 and 9-6 require all new sales and installations of furnaces and water heaters be zero-emission by specific dates -CARB zero-emission off-road engine rules require most newly manufactured small road engines be zero-emission starting in 2028
Percentage of sales: requires an increasing percentage of an OEM's product fleet in a given year to be zero-emission	-CARB ZEV regulation requires 4.5% of a manufacturer's fleet to be zero-emission by 2018, 7% by 2019, etc.

[1] Many Western and Midwestern states have local and regional air districts and agencies, like California, while most Eastern states only have statewide air pollution control agencies.

Scope refers to the equipment categories that are covered by a given standard. Table 2 lays out different options for how an agency could define the scope for ZEHES in terms of the equipment types, sizes, and installation scenarios covered.

Table 2. ZEHES scope of applicable equipment and applications

Scope	Examples
Equipment size: covers equipment that meets a specified rated heat input capacity	-BAAQMD Rules 9-4 and 9-6, SCAQMD Rule 1146.2, CARB zero-emission rule proposal, and Utah Rule 307-230 cover equipment of specified rated heat input capacity
Equipment type: defines the type of equipment being regulated (e.g., water heaters, furnaces)	-BAAQMD Rules 9-4, 9-6 regulates water heaters and furnaces -SCAQMD Rule 1146.2 regulates specific types of water heaters and pool heaters -CARB zero-emission rule proposal regulates water heaters and furnaces
New construction: applies to equipment installed in new buildings and exempts replacement equipment in existing buildings	-SCAQMD Rule 1146.2 sets earlier dates for new construction than existing retrofits
Retrofit: applies to new equipment installed in existing buildings	-SCAQMD Rule 1146.2 sets later dates for existing retrofits than new construction

Implementation timing indicates when the rules take effect. Table 3 lays out different options for how an agency could consider implementation timing. The California agencies developing zero-emission standards are favoring the staggered approach.

Table 3. ZEHES implementation timing options

Implementation timing	Examples
Staggered dates: varying implementation dates for different scopes (e.g., different equipment types, applications, or sizes) to reach zero emissions	-BAAQMD Rules 9-4 and 9-6, SCAQMD Rule 1146.2, and CARB zero-emission rule proposal set different dates for different equipment types based on market readiness
Ramp up targets: under a percentage of sales or fleetwide average framework, different dates signal a ramp up of sales or ramp down of emissions over time	-CARB ZEV regulation sets different dates that have varying sales targets
Phased emissions levels: Ultra-low-NOx standards followed by zero-NOx standards	-BAAQMD Rule 9-6 requires ultra-low-NOx furnaces in 2023 and zero-NOx furnaces in 2029 -RAP Model Rule includes a near-term ultra-low-NOx step, followed by a zero-NOx requirement in 2035

Equity Considerations for ZEHES

ZEHES is a leading policy to address pollution from building equipment, but should be considered as part of a suite of policies as opposed to a standalone solution. Historic and ongoing inequities, such as redlining and housing segregation, have burdened low-income residents and communities of color, and new policies should do no further harm to these communities. Policymakers should approach the transition to zero-emission buildings with extra care to ensure that all households and communities reap the benefits of electrification. Specifically, air and environmental regulators should coordinate closely with other state agencies to ensure that policies and funding are in place to deliver the following outcomes before ZEHES takes effect:

- **Affordable upfront costs**: Electric appliances, especially high-efficiency heat pumps, often cost more money upfront today relative to fossil fuel equipment. Financial incentives, such as the Inflation Reduction Act's Home Energy Rebates, utility rebates, tax credits, and inclusive financing can help homeowners afford electrification upgrades.
- **Affordable energy bills**: The high efficiency of heat pumps can help lower utility bills for many homes, but states may need to reform electricity and gas utility rates and expand bill protection measures to ensure all buildings see lower energy bills after electrification.
- **Tenant protections**: When a landlord electrifies building equipment, tenants should not face displacement, eviction, or pass-through costs. States should adopt and enforce tenant protections to prevent these adverse impacts.
- **Health and safety upgrades**: Some buildings have more urgent maintenance needs than equipment replacement, or need enabling upgrades such new panels and wiring, or even utility line extensions, to enable electrification. Health and safety hazards, such as mold and lead, should also be addressed to protect residents. Dedicated program funding is needed to address these upgrades.

ZEHES can also include design elements that support equitable implementation, as shown in Table 4. Many of these elements support inclusive processes to ensure communities that will be affected by policies are at the table from the start (Greenlining Institute and Energy Efficiency for All 2019; Emerald Cities Collaborative and PODER 2020).

Table 4. Equity design elements for ZEHES

Design Elements	Examples
Lead time: sets a future implementation date for 100% zero-emission new equipment requirement, allowing time to adopt equity-focused policies first	-Under BAAQMD Rules 9-4 and 9-6 and CARB's zero-emission rule proposal, zero-emission standards take effect in 2027-2031, allowing time to ready the market -MD climate plan aims for zero-emission standards to take effect by 2030 and notes that significant rebates for LMI households will be available starting in 2024
Interim reporting: requires progress assessment of technology readiness and equitable and affordable implementation before standards take effect	-BAAQMD Rules 9-4 and 9-6 and SCAQMD Rule 1146.2 incorporate a technology assessment prior to rules taking effect

Design Elements	Examples
Multi-agency coordination: organized effort to coordinate with other state and local agencies on complementary equity policies and funding	-CARB's zero-emission rule proposal in its 2022 ozone SIP illustrates how zero-emission standards coordinate with other state policies, as shown in Figure 1
Multi-stakeholder coordination: organized effort to coordinate on equitable implementation with various stakeholders	-BAAQMD Rules 9-4 and 9-6 and CARB zero-emission rule proposal include stakeholder engagement activities described in the case studies below

While it is too early to tell how well these equity design elements will work in practice, we do know that even a well-designed ZEHES cannot stand alone. States must take a holistic approach to electrification, where ZEHES is one part of a suite of equity-centered policies.

ZEHES Case Studies and Models

The following case studies discuss how several jurisdictions have moved forward with developing and implementing zero-emission standards since 2022.

Bay Area Air Quality Management District

In March 2023, BAAQMD became the first jurisdiction in the nation to adopt zero-NOx standards for furnaces and water heaters. The agency had already established low-NOx regulations for gas-fired water heaters (Rule 9-6) and gas-fired furnaces (Rule 9-4), so the agency opened a single rulemaking to amend these two rules and set new limits for zero-NOx (Elwell and Lara 2023). BAAQMD's framework is a blanket rule with staggered implementation dates based on the equipment size. Small storage water heaters (mainly used in residential applications) have the earliest implementation date of 2027, followed by residential and small commercial sized furnaces in 2029, and finally, larger residential and commercial water heaters in 2031. BAAQMD includes phased emissions levels for its furnace rule to achieve near-term emissions with an ultra-low-NOx requirement while preparing to move to zero-NOx five years later. Implementation dates were informed by the agency's technology and market assessment. Table 5 summarizes the rule sizes, applicability, and key dates.

The rules include three key equity design elements: lead time, interim reporting, and multi-stakeholder coordination. From the time of rule adoption, there are four to eight years of lead time before any rule takes effect, "allowing for further technology development, market saturation of zero-NOx appliances and development of funding mechanisms such as those provided through the Inflation Reduction Act" (Elwell and Lara 2023). To ensure the market develops at the anticipated pace, BAAQMD committed to an interim reporting process whereby staff brings a report on the accessibility of zero-NOx appliances to the Board of Directors two years prior to each rule's implementation date. Further, staff began convening an Implementation Working Group (IWG) of diverse state and local stakeholders (e.g., manufacturers, contractors, environmental justice organizations) following rule adoption to support implementation and inform the reports. The combination of these thoughtful design elements helped earn the nearly unanimous support of the Board, who voted to adopt the rules 20-0 in March 2023. In June, the Board approved the submission of these rules to California's ozone SIP, so they will be included as a strategy for the state to attain the NAAQS for ozone.

Table 5. Summary of BAAQMD Rules 9-4 and 9-6 (Elwell and Lara 2023)

Rule	Covered Equipment	Size	NOx Limit	Effective Date	Interim Report Deadline
9-4	Natural gas-fired fan type central furnaces	Heat input rate less than 175,000 Btu/hr	14 ng/J	Jan. 1, 2024	N/A
9-6	Small water heaters and boilers	Heat input rate less than 75,000 Btu/hr	0 ng/J	Jan. 1, 2027	Jan. 1, 2025
9-4	All gas-fired furnaces	Heat input rate less than 175,000 Btu/hr	0 ng/J	Jan. 1, 2029	Jan. 1, 2027
9-6	Large water heaters and boilers	Heat input rate 75,001-2,000,000 Btu/hr	0 ng/J	Jan. 1, 2031	Jan. 1, 2029

Since rule adoption, BAAQMD staff have been running the IWG and working with contractors to produce targeted research to help inform the interim report. The ongoing IWG is facilitated by a neutral third-party and meets publicly once a quarter. Between quarterly meetings, three IWG subcommittees meet: a technical subcommittee, an equity subcommittee, and a steering committee. These subgroups dive deeper into specific topics of interest and expertise to explore the current landscape and innovative solutions to support equitable implementation. Meanwhile, contractors are providing unique insights, such as a cost analysis for zero-NOx water heaters in the Bay Area. These two efforts will help inform the first interim report on small water heaters, which will be brought to the Board by January 1, 2025. Though it is too early to tell how these efforts will impact rollout of the rule, it is notable that this rulemaking has engaged a broader group of stakeholders than other agency rules.

California Air Resources Board

CARB is the first statewide agency to pursue a zero-emission space and water heater standard. CARB's first step was to propose development of zero-GHG emission standards for heating equipment as part of its 2022 State SIP Strategy for the 2015 8-hour ozone standard. The standards are also part of California's climate strategy as laid out in the 2022 Scoping Plan (CARB 2022b). CARB is currently conducting its pre-rulemaking process and anticipates bringing a proposed rule to its Board for potential adoption in 2025. Like BAAQMD, CARB is undertaking a single rulemaking that will address multiple types of building equipment. The 2022 State SIP Strategy envisioned rules potentially taking effect in 2030 and applying to residential and commercial space and water heaters, with the possibility to expand to other end-uses (CARB 2022a). At their May 29, 2024, public workshop, CARB solicited public feedback on a draft proposal with staggered implementation dates that apply based on equipment type and equipment size (CARB 2024c).

Notably, CARB took a unique approach to ensure an equitable rulemaking process by contracting a neutral third-party, Sacramento State University, to develop a community engagement process recommendation. The rulemaking started with Sacramento State conducting stakeholder interviews with interested parties to collect their feedback and perspectives on

community engagement considerations for this zero-emission standards rulemaking. Sacramento State then published a summary of their findings and advised on CARB's outreach and engagement plan (California State University Sacramento 2023; CARB 2023).

CARB has also opened a solicitation for Public Experts, defined as "California-based individuals or organizations possessing expertise that is relevant to staff analysis, engagement, and/or implementation needs for potential zero-emission appliance standards" (CARB 2023). CARB is seeking experts not only to inform the technical elements of the rule, but also to host listening sessions with their communities to help CARB engage with hard-to-reach individuals that may not otherwise be able to participate in the rulemaking. CARB is providing compensation to stakeholders with a demonstrated need and offering simultaneous Spanish translation for public meetings and workshops. Though CARB's rulemaking is still underway, it demonstrates a thoughtful adaptation to their rulemaking process to improve inclusivity and hear from more diverse stakeholders.

South Coast Air Quality Management District

SCAQMD in Southern California committed to develop zero-emission equipment standards in its 2022 Air Quality Management Plan. Given that the Los Angeles basin has the worst ozone air quality in the country, SCAQMD intends for all of its zero-emission rules for building equipment to meet or exceed the zero-emission equipment categories regulated by BAAQMD. SCAQMD recently passed the first zero-emission rule (Rule 1146.2) for commercial water heaters and boilers, instantaneous water heaters, and pool heaters (SCAQMD 2024).

SCAQMD adopted a blanket rule framework with staggered implementation dates based on equipment type and size (SCAQMD 2024). Notably, SCAQMD set earlier compliance dates for zero-emission equipment installed in new construction than in existing buildings, since it is easier and less expensive to install zero-emission equipment in new construction. For existing commercial and industrial buildings, SCAQMD is requiring replacement of existing water heaters with zero-emission alternatives at the end of "unit age" or lifespan (15-25 years, depending on the type of equipment), rather than when the equipment burns out. Like BAAQMD, SCAQMD will conduct a technology assessment prior to the rules taking effect. The assessment will assess technology and market readiness, capital and utility costs, and equity issues for all equipment categories (SCAQMD 2024). SCAQMD is also working on rules for smaller water heaters and furnaces, targeting adoption by the end of 2024.

Maryland Department of the Environment

Maryland committed to adopt zero-emission standards for heating equipment in its December 2023 Climate Pollution Reduction Plan, becoming the first jurisdiction outside of California to begin a ZEHES rulemaking process (MDE 2023). In 2022, the Maryland legislature passed the Climate Solutions Now Act, which set a new goal to reduce GHG emissions 60% by 2031. To meet this goal, building sector emissions will have to decline 6% per year on average between 2024 and 2031. Maryland is pursuing several new policies to drive higher levels of GHG reduction: a statewide Building Energy Performance Standard (BEPS), Clean Heat Standard (CHS), and ZEHES. Maryland sees ZEHES as filling a policy gap by setting a clear end date for new installations of polluting heating equipment and addressing emissions from small residential, multifamily, and commercial buildings that are below the BEPS size threshold.

Maryland is early in its regulatory process, but intends to leverage the model rules being developed by the Northeast States for Coordinated Air Use Management (NESCAUM) and the Regulatory Assistance Project (RAP), two organizations that provide technical assistance to state policymakers. These model rules are described below.

ZEHES Model Rules

State air quality agencies have a long track record of using model rules as the starting point for regulations. Model rules provide sample language that states can use or adapt within their own rulemaking process. This can streamline states' regulatory process while providing valuable consistency to regulated entities like manufacturers that may be subject to similar rules in multiple states. Since 2022, RAP and NESCAUM have been working to develop model ZEHES. These model rules draw extensively on the statewide and air district rulemaking efforts underway in California, while adapting the standards to meet the needs of other states.

In February 2023, RAP published a model rule to assist U.S. state and local air quality regulators in regulating water heater emissions (Seidman et al. 2023). RAP's water heater model rule establishes categories of water heaters based on their size and fuel use, and a date by which any water heater sold or installed must meet the stated emission limit. Initially the RAP model rule lowers emissions to match the "low-NOx" standards established in California with their earlier regulations. It also establishes a date of January 1, 2035 when water heater NOx emissions must be zero. The rule covers water heaters up to 2 MMBtu/hour heat input and regulates natural gas, oil, and propane water heaters. The water heater model rule was informed by input from stakeholders such as water heater manufacturers and environmental advocates. RAP also published a technical support document for states that may use the model rule.

In September 2023, ten states (CA, CT, HI, MA, MD, NY, OR, PA, RI, WA) that are members of the U.S. Climate Alliance committed to "explore the adoption of zero-emission standards for space and water heating equipment" as part of a broader commitment to quadruple heat pump installations by 2030 (USCA 2023). These states, and other interested states, are participating in an Equipment Emission Standards Cohort (EESC) co-convened by NESCAUM and the U.S. Climate Alliance. The EESC is developing model rules and compiling research to support states that are exploring zero-emission standards for HVAC and water heating equipment. NESCAUM has also established an Environmental Justice (EJ) Advisory Group with representatives of EJ and community-based organizations to guide the EESC's work.

In 2023 and 2024, NESCAUM and RAP have been working to update the RAP water heater model rule based on additional input from states participating in the EESC, as well as manufacturers and EJ organizations. In 2024, NESCAUM and the EESC also began developing a model rule regulating NOx and GHG emissions emitted during operation of space and water heating equipment such as furnaces and boilers. Both model rules are leveraging insights from zero-emission standards under development in California to inform policy design. The updated water heater model rule and the HVAC model rule are expected to be finalized in fall 2024. The covered equipment and compliance dates are being determined, but the model rules are expected to focus initially on equipment sized for use in residential and small commercial buildings.

ZEHES Lessons Learned

ZEHES is a nascent policy option to tackle emissions from the building sector; model rules are still under development and states and air districts are in the initial stages of rulemaking

and implementation. However, these early efforts are already yielding lessons learned that can inform states and air districts considering similar policies.

Manufacturer Feedback

Manufacturers of air-source heat pumps and heat pump water heaters, as well as fossil fuel heating systems, have provided valuable input to guide zero-emission rulemakings in California, as well as model rule development. While manufacturer perspectives vary, a key takeaway is that manufacturers and other market actors benefit from regulatory certainty on the pace and scope of the transition to zero-emission buildings. Policies like ZEHES that establish enforceable timelines for sales of zero-emission equipment can give manufacturers the confidence to scale up heat pump production, invest in new heat pump product lines, and shift production away from fossil fuel equipment. Standards also send a strong signal to equipment distributors, retailers, and installers to increase stocking, sales, and training for heat pumps. A coalition of heat pump manufacturers and the Building Decarbonization Coalition (BDC) recently released a joint vision for a decarbonized marketplace that includes the following statement: "Regulation is essential. The marketplace will not scale without clear regulatory requirements— not just incentives. Regulations must be simple and transparent enough to send an unmistakable signal to the marketplace, but they must avoid arbitrarily stifling the technological innovations that will help to set the hardest-to-decarbonize installations on a path to net-zero by 2050" (BDC 2024).

While manufacturers generally appreciate having a clear regulatory signal, they also flagged ZEHES design elements of potential concern. First, they are attuned to the market readiness and "degree of difficulty" associated with transitioning from fossil fuel heating equipment to heat pumps in different market segments. Manufacturers are more supportive of ZEHES for equipment types and sizes for which market-ready heat pump solutions are already available. For example, they are more comfortable with earlier phase-in dates for zero-emission standards for residential-scale equipment, since air-source heat pumps and heat pump water heaters are already widely available for nearly all common applications. Manufacturers are more concerned about setting zero-emission standards for larger commercial and industrial applications. They noted that the commercial heat pump technology for some applications, such as high-temperature uses, is not yet fully market-ready, and that electrification may require expensive custom systems to overcome size and siting constraints.

Manufacturers also recommend that ZEHES be designed to align with other market drivers, such as federal energy efficiency standards for water heaters and furnaces and hydrofluorocarbon (HFC) regulations. For example, DOE's recently adopted efficiency standards for consumer water heaters will transition a significant share of electric storage water heaters to high-efficiency heat pump technology starting in 2029 (DOE 2023). Manufacturers suggest taking these standards and other factors influencing the broader heat pump market into consideration when determining equipment categories and phase-in dates for ZEHES, to streamline the number of regulations they must comply with in any given year.

Coordination with Other Building Decarbonization Policies

Policymakers and stakeholders recognize that ZEHES policies cannot be implemented in a vacuum; they must be accompanied by other policies to support the market transition to zero-emission buildings. Dennison (2022) notes that "the standards chart a course and get everyone on

board, then market interventions help navigate around specific barriers along the way." A 2024 policy brief (NEEP 2024) describes a comprehensive, state-based approach to building decarbonization, focusing on four policy areas:

- Equity and workforce investments address housing and workforce inequities by empowering historically marginalized communities and ensuring that the energy transition is just and inclusive.
- Carbon reduction obligations set performance requirements for obligated parties, such as energy providers, to reduce carbon emissions or install clean heating systems.
- Codes and standards like ZEHES establish a clear timetable for improving the energy performance of buildings and equipment, spurring changes in the market.
- Utility planning and regulation sets mandates and frameworks to ensure that utility investment, rates, and programs align with building decarbonization goals.

CARB's stakeholder engagement materials highlight how zero-emission standards are just one component of a comprehensive policy framework for building decarbonization in California. Figure 1 illustrates the wide range of policies being advanced across multiple agencies, including the California Energy Commission and Public Utilities Commission, in addition to CARB. These complementary policies all play an essential role. For example, rate design and elimination of gas subsidies are enabling mechanisms for electrification, while incentive programs help households afford the upfront costs of heat pump equipment. Further, many of California's building decarbonization incentive programs are funded, in whole or part, by revenue from the state's cap-and-invest program, a type of carbon reduction obligation.

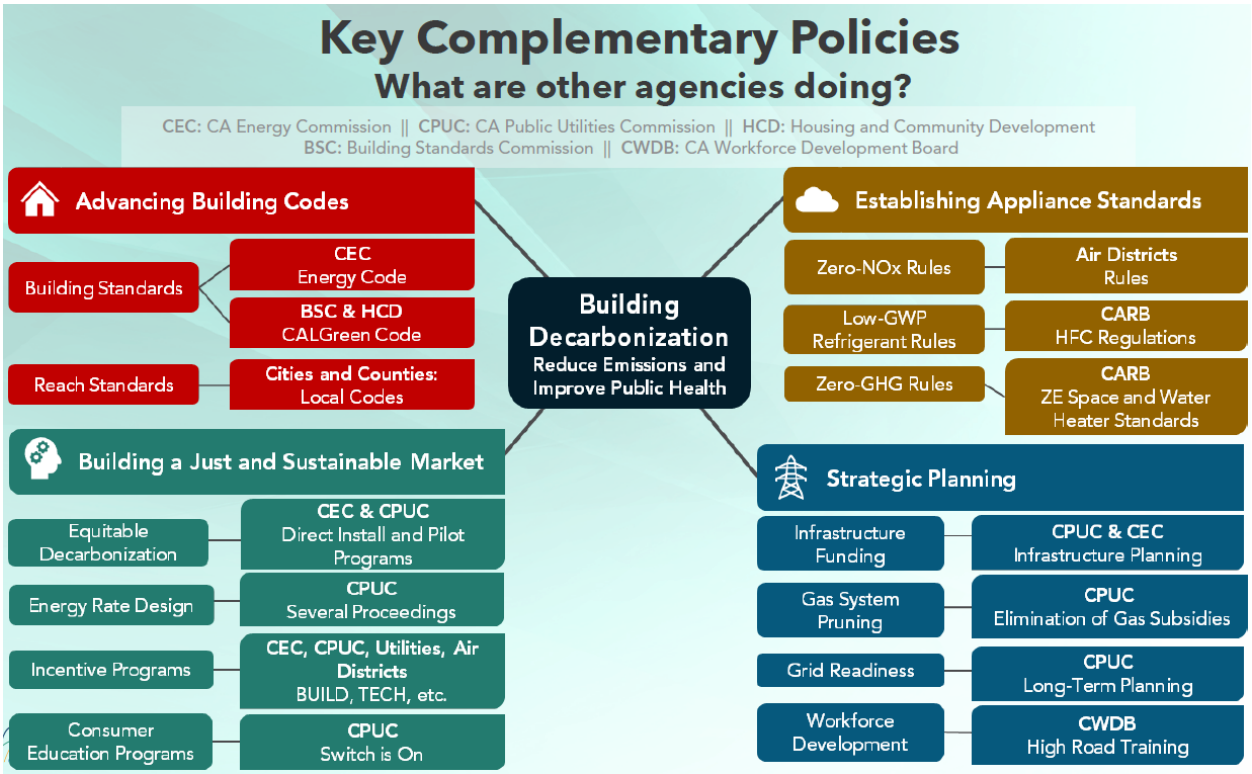

Figure 1. Building decarbonization policies in California. *Source*: CARB 2024b.

Outlook for Zero-Emission Standards

Berkeley Lawsuit and Federal Preemption

While not directly related to emission-based standards, a recent legal decision has garnered attention. The city of Berkeley, CA pursued a municipal building ordinance to restrict gas infrastructure in new buildings. The ordinance was struck down by the 9th Circuit Court as being preempted by the federal Energy Policy and Conservation Act (EPCA) because it would disallow the use of gas-powered appliances that meet federal energy efficiency standards (PHLC 2024). The court's decision specifically applies to building codes.

Emission-based standards like ZEHES are not building codes and are supported by clear authority under the Clean Air Act. Moreover, some states have had NOx standards for furnaces, boilers, and water heaters in place for decades. Emission standards may be on particularly strong legal footing if incorporated into a SIP to help a state attain or maintain attainment with the national air quality standards for ozone, PM, or regional haze.

Potential for Federal Action on Building Pollution

State and local action to adopt zero-emission standards for heating equipment could ultimately lead EPA to develop national standards. As Seidman and Shenot note (2022), "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." While EPA has not yet officially responded to the Sierra Club petition to establish new source-performance standards for heating appliances, the growing number of states pursuing ZEHES will continue to put pressure on EPA to develop a coordinated national approach. State actions also create an opportunity to support market readiness and solve implementation challenges, which over time should increase EPA's comfort with adopting national standards.

Future State Action on Zero-Emission Standards

States interested in learning more about zero-emission standards for heating equipment can join the Equipment Emission Standards Cohort and leverage the ZEHES model rules. They can also benefit from California's leading efforts to design equitable and effective standards, informed by robust stakeholder engagement and substantial research on the emissions, public health, cost, and equity impacts of zero-emission standards. By working together, states can share learnings, align efforts to provide consistency to the market, and accelerate the equitable transition to zero-emission buildings.

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