

Zero-Emission Appliance Standards: Driving Market Transformation to Equitably Electrify Buildings

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ABSTRACT

To meet health and climate targets, we must quickly and equitably electrify America's new and existing buildings. This paper argues that the best strategy for overcoming market barriers to electrification is by enacting zero-emission appliance standards that are designed to guide and support further market transformation programs and interventions.

Specifically, this paper argues that air quality agencies like the Environmental Protection Agency (EPA) should enact appliance emission standards that require a phaseout of new fossil fuel appliance sales by 2030. This ambitious timeline reflects the pace of electrification needed to meet America's decarbonization commitments. Well-designed zero-emission standards can accelerate equitable electrification by incentivizing and focusing investments, market interventions, and complementary policies.

Zero-emission standards have several advantages that make them the best policy to play this role. They can rule out ineffective building decarbonization strategies like renewable natural gas, align efforts across a wide range of market areas, and scale from local to national scope. To best support further interventions to bring down costs and equitably electrify, standards should incorporate collaborative planning, carefully considered requirements and phase-in schedules, and equity-focused interim reviews.

I. Introduction

To meet health and climate targets, we must rapidly and equitably electrify America's new and existing buildings. Fossil fuel burning appliances like gas furnaces, water heaters, boilers, and stoves contribute significantly to emissions of greenhouse gases (GHGs) and health-harming pollution. But there are serious market barriers to equitable electrification, most notably its costs. This paper argues that the best way to overcome these barriers is through a combination of overarching regulatory signals and targeted market interventions.

Specifically, this paper argues that air quality agencies like the Environmental Protection Agency (EPA) and state equivalents should enact zero-emission appliance standards requiring a phaseout of new fossil fuel appliance sales by 2030. This ambitious timeline is directly aligned with America's decarbonization commitments. Incorporating it into standards would send a clear signal that can align incentives and guide market interventions to advance equitable electrification.

Section II.A describes the need to quickly and equitably electrify new appliances and the market barriers to achieving this. **Section II.B** describes two approaches to overcoming market barriers—regulatory signals and market transformation—and argues that a combination of these approaches is the best strategy for fast, equitable electrification. In this hybrid approach,

standards provide clear, shared, enforceable targets that guide the development and implementation of market transformation strategies by far-flung market actors and coalitions.

Part III argues that zero-emission appliance standards are the best policy to provide the regulatory signal in this hybrid approach. **Section III.A** outlines the basics of zero-emission appliance standards, air agencies' authority to enact them, how they differ from appliance efficiency standards. **Section III.B** describes the advantages that make them better able to guide market transformation efforts for equitable electrification than alternative policies. Specifically, they can focus strategies and interventions by taking bad options off the table, align efforts across a wide range of market areas under a single unifying policy, and build momentum by scaling from local to national scope. **Section III.C** discusses methods of designing standards to effectively guide efforts for equitable market transformation. These methods include collaborative planning, requirements that encourage cost-reducing market interventions, timelines that allow those interventions to occur, and equity-focused interim reviews. **Part IV** concludes with some reflections on combining regulatory signals with market transformation to address challenges beyond electrification.

II. The Need to Electrify, and Two Ways to Get There

Expert analyses have shown that electrifying all new appliance sales nationwide by 2030 can be an effective way to align America's buildings sector with its decarbonization commitments and help avoid the worst impacts of climate change. To equitably achieve this ambitious goal, we must overcome significant market barriers—most notably electrification costs. One approach to overcoming these barriers, called market transformation, is to apply a series of interventions aimed at overcoming specific market barriers. A second approach is to provide an overarching regulatory signal by setting standards that require electrification. I propose that electrification is most likely to succeed through a combination of these two approaches: use standards to set a clear timeline for electrification that guides market transformation efforts.

A. The Need to Electrify Every Building Quickly and Equitably

Burning fossil fuels in America's homes and buildings contributes significantly to climate change, air pollution, health harms, and racial and socioeconomic inequities. These impacts include roughly 10% of U.S. GHG emissions, 425,000 tons of nitrogen oxide pollution (NO_x), and 6,000 premature deaths from pollution exposure each year (Dennison, Louis-Préscott, and Gruenwald 2021).

Many researchers, advocates, and government entities have proposed electrification as a primary strategy for decarbonizing the buildings sector (e.g. Aas et al. 2020, iii; Farbes, Kwok, and Jones 2020, 22; Mass. EEA 2020, 44; NJBPU 2019, 160). To fully eliminate building-related emissions, electrification must be accompanied by continued efforts to decarbonize the electric sector and address issues like growth in electric load (see Specian, Cohn, and York 2021). But several analyses have found that electrification can already reduce overall lifecycle GHG emissions across most of the country under current or projected grid conditions (Pistochini et al. 2022; Murphy et al. 2021, xii-xiii; McKenna, Shah, and Silberg 2020; Hong and Howarth 2016). While alternative decarbonization strategies like the use of low-carbon fuels have been

proposed, many experts remain skeptical that they can play a significant role in decarbonizing buildings, due to factors like high cost, limited current and future availability, GHG leaks throughout the supply chain, and health and environmental impacts (Von Wald et al. 2022; Krasner and Gottlieb 2022; Prieto and Henchen 2022; Saadat, Vespa, and Kresowik 2021; Borgeson 2020; Grubert 2020). And while energy efficiency measures will continue to play a critical role, they must be combined with strategies that can fully eliminate building emissions, because “you can’t efficiency your way to zero” (Griffith 2021, 30). Thus, while there remains some debate about the details of the building decarbonization transition, it is widely recognized that electrification will play a major role.

Furthermore, this transition must happen fast if we are to meet America’s commitments under the Paris Accord and avoid the worst impacts of climate change. Several analyses have concluded that to meet these targets, most or all of America’s newly-installed appliances must be electric by roughly 2030 (Orvis and Mahajan 2021; NAS 2021, 73; IEA 2021, 99, 146; Williams et al. 2021, 1, 14). Crucially, this target includes new appliances installed in existing buildings when old appliances burn out; electrifying in new construction will not be enough. In light of these findings, this paper begins with the widely- though not universally-accepted target of electrifying all or nearly all new appliances sold by 2030, and proposes a policy pathway to help meet it.

Building electrification will likely impact our housing system more directly and significantly than any other climate policy, which means it presents the greatest risks—but also the greatest opportunities—related to housing equity. An equitable transition must be inclusive, which among other things requires making electrification affordable for low-income residents and supporting them in making pre-electrification upgrades like weatherization and electrical panel upgrades where they are needed (Norton et al. 2021). The transition must also protect renters against displacement when landowners make upgrades and property values increase.

To equitably achieve this major shift to all-electric new appliances, we must overcome significant market barriers, such as cost premiums for electric equipment and retrofits, consumers’ and contractors’ lack of familiarity with electric technologies, split incentives, utility rate structures that don’t align with electrification, the externalities of fossil fuel appliances’ GHG and NOx emissions, and others.

B. Two Ways to Get There: Market Transformation and Regulatory Signals

Two of the main approaches that have been used to overcome market barriers to new technology adoption are market transformation and regulatory signals. I propose that our best chance to successfully and equitably electrify America’s buildings is by combining these two approaches.

1. Market Transformation. The market transformation paradigm was developed to overcome barriers to adopting energy efficiency technologies (York et al. 2017; NEEA 2022). Under this approach, market actors and coalitions develop strategies to apply different interventions and programs over the course of a technology’s adoption to address whatever the main market barrier is at each stage. Market actors can include energy efficiency organizations, community-based housing groups, utilities, government agencies, manufacturers, and many other stakeholders. Market interventions can include utility programs, consumer education, contractor training,

rebates and incentives, product efficiency labels, and more. These market interventions are often understood to culminate with incorporation of the technology into codes and standards, whose role is to lock in the technology adoption so it can be sustained without further interventions.

2. Regulatory Signals. An alternative approach is to use standards earlier in the transition to drive technology adoption, rather than locking it in after the fact. This approach has often been applied to reduce air pollution through emission standards. By providing regulatory certainty that there will be demand for pollution-reducing technologies, emission standards encourage the investments and innovation needed to scale production of those technologies and push their costs down the learning curve. The standards overcome market barriers like the externalities and collective action problems that prevent these investments. As examples of this dynamic, emission standards have driven adoption of catalytic converters, low-VOC paints, and alternatives to ozone-depleting CFCs, often much faster and at much lower cost than industry and government had anticipated (EPA 2022a; Andersen, Halberstadt, and Borgford-Parnell 2013, 617).

3. A Hybrid Approach: Guiding Market Transformation with Regulatory Signals. This paper argues that the best building electrification strategy is a hybrid approach, in which regulatory signals and market transformation play complementary roles. In this hybrid approach, standards are designed to motivate and coordinate market transformation efforts by establishing a clear timeline for phasing out new fossil fuel appliances. The standards chart a course and get everyone on board, then market interventions help navigate around specific barriers along the way. Coalitions of market actors still develop and execute market transformation strategies, but the shared vision expressed by the standards makes it much easier to build coalitions and develop these strategies, and for strategies developed by different groups to align with each other.

A primary example of this hybrid approach is the strategy to electrify vehicles. California's Zero-Emission Vehicle (ZEV) standards have been the primary force driving manufacturers to develop electric vehicles, bring down their costs, and expand the range of available models (McConnell, Leard, and Kardos 2019, 1). And by firmly establishing shared targets and timelines for electrification, the standards have also helped bring market actors and stakeholders together to develop and implement critical market interventions. These include rebate and incentive programs, marketing campaigns, charging infrastructure development, and other complementary policies. In this way, the standards have provided the right incentives to both those acting within the market and those acting to transform it.

A version of this hybrid approach has also been applied to heat pump adoption in new construction in Seattle. An architect of the city's strategy has described it as "move forward confidently with the most impactful code provisions available and then scramble to help all the affected parties make the transition" (Jonlin 2021). He emphasized the importance of proactive code measures in moving the whole city toward electrification together, which quickly reduces costs through scale, standardization, and experience. And he described the successful scramble to develop market interventions that helped achieve the ambitious code provisions, such as a standard specification for central heat pump water heating systems, a free online tool for sizing these systems, and a utility-sponsored series of heat pump webinars.

To meet the nation's broader building decarbonization targets, this hybrid strategy must be scaled up and applied to both new and existing buildings. We must work toward a national

standard that requires 100% of new appliances to be zero-emitting by 2030. This ambitious standard would directly align with what's needed to meet our decarbonization commitments. And it would help give market actors the clear unifying vision needed to come together and develop the market interventions we'll need along the way, even though we don't yet know what all of those interventions will be.

This coordinating role will be especially important, because equitable electrification will require alignment between such a wide range of market actors working at different scales and in different market and policy sectors. Although close collaboration between many of these actors will be key, the unprecedented scope of issues involved in electrification will make it impossible for every actor to coordinate directly as they apply thousands of market interventions. The shared vision established by zero-emission appliance standards will help align these interventions and focus them in the areas where they can have the greatest impact.

This paper doesn't attempt to detail the specific market interventions needed to achieve equitable electrification. Instead, it describes why zero-emission appliance standards are the best policy to coordinate these interventions and drive the transformation, and how standards can be designed to play this role most effectively.

III. The Role of Zero-Emission Standards: Guiding Market Transformation

Part II argued that the best way to equitably electrify America's buildings is by setting standards that establish a clear target and help coordinate the market interventions needed to reach it. This Part argues that the best policy to establish this target is a zero-emission appliance standard. **Section III.A** outlines the basics of zero-emission appliance standards. **Section III.B** describes the advantages that make zero-emission standards better able to drive market transformation than alternative policies. **Section III.C** discusses how to design standards to play this role most effectively.

A. Background on Zero-Emission Appliance Standards

This section defines zero-emission appliance standards, describes air agencies' legal authority to enact them, gives examples of existing and proposed standards, and distinguishes emission standards from efficiency standards.

Appliance emission standards are requirements enacted by air quality agencies such as EPA, state environmental agencies, and local air quality districts, that set a limit on the amount of pollution that new residential and commercial appliances may directly emit. Zero-emission appliance standards set this limit at zero for some or all new appliance sales, effectively requiring fossil fuel appliances to be phased out. They can be designed either as zero-GHG or zero-NOx requirements, since electrification eliminates direct emissions of both pollutants. They do not set requirements for existing appliances, so electrification is only required when old appliances are replaced with new ones at the end of their useful life (which is one of the lowest-cost opportunities to electrify).

EPA is authorized to set emission standards for a wide range of pollution sources under Section 111 of the Clean Air Act (Lienke et al. 2021). State and local air agencies are often granted similar authority to set emission standards under state law, and the Clean Air Act expressly provides that EPA standards do not preempt states from setting more protective

standards for the same source type (with the exception of vehicles). When designing appliance emission standards, air agencies will have fairly broad discretion to determine things like which appliance types are covered, whether there are any exemptions, when the standards will take effect, and whether they will be phased in over time.

Emission standards for fossil fuel appliances and similar pollution sources have been around for decades. Low-NO_x standards for gas appliances have been in effect for years in California, Utah, and Texas (Dennison, Louis-Prescott, and Gruenwald 2021, 18). And EPA has set pollution standards for residential wood stoves since 1988 (EPA 1988).

No zero-emission appliance standards have been enacted yet, but several are under development. Two regional air districts in California are considering enacting zero-NO_x standards, while California's statewide Air Resources Board and agencies in New Jersey and New York are considering zero-GHG standards (Dennison, Louis-Prescott, and Gruenwald 2021; NJDEP 2021).

It's important to distinguish appliance pollution standards from appliance efficiency standards. Pollution standards address appliances' NO_x or GHG emissions, and as noted above, federal pollution standards do not preempt state or local standards. Because fuel-burning appliances produce emissions and electric appliances do not, pollution standards can be used to require electrification. By contrast, efficiency standards focus on appliances' energy consumption, and for most appliances, the Department of Energy's federal efficiency standards preempt state and local standards. Further, DOE cannot enact standards that are likely to result in the unavailability of any product types, which likely prevents efficiency standards from being used to phase out fossil fuel appliances (Sallee 2022).

B. Zero-Emission Appliance Standards Are the Most Effective Policy to Guide Market Transformation Efforts

This section describes three advantages that make zero-emission standards more effective than alternative policies at guiding market transformation efforts toward equitable electrification: (1) they can directly align regulatory requirements with America's decarbonization commitments by setting an enforceable timeline for phasing out combustion appliances, (2) they can apply to all new appliances installed both new and existing buildings, and (3) they can be pursued at the local, state, and federal levels in parallel.

1. Enforceable Phaseout. Zero-emission standards can directly require the permanent phaseout of new fossil fuel appliances. This distinguishes them from appliance efficiency standards, which likely can't require fuel switching (see Section III.A), as well as policies and market interventions that may not be permanent and that only encourage, rather than ensure electrification (for example, by providing electrification funding that could run out or require reapproval). By giving market actors long-term regulatory certainty that fossil fuel appliances will be phased out, zero-emission standards can focus interventions where they are most needed for a successful, affordable, and equitable transition.

Here are three examples: **First**, with zero-emission standards in place, incentive funding can focus on making electrification affordable for those who need the most assistance, rather

than making it more attractive for those who already have the means to pursue it.¹ **Second**, many of the funds and programs that currently support the installation of gas equipment can be redirected to support electrification and the managed winddown of the gas system. Examples include gas line extension allowances, government and utility incentives for more efficient gas equipment, and programs to reduce air pollution by replacing wood stoves with gas furnaces. **Third**, attention can be redirected from risky, expensive proposals for low-carbon fuel appliances (which would still produce combustion emissions and therefore be precluded by a zero-emission standard), to viable building decarbonization solutions like electrification.

2. Application to All Buildings. Zero-emission appliance standards can apply to all new appliances, whether they are installed in new or existing buildings of any type. This distinguishes them from municipal bans on gas hookups, which have only been applied to new construction, building codes, which typically apply only to new construction and major retrofits, and building performance standards, which have only been applied to commercial and multifamily buildings.

By reaching the entire new appliance market with a single policy, zero-emission standards can efficiently motivate every market participant and guide the full range of market interventions needed to meet decarbonization goals. A uniform appliance standard can also be cheaper and more efficient to administer and enforce than alternatives like building codes, because air agencies only need to perform testing and certification once for each model line, rather than conduct inspections for each construction project or installation. Noncompliance with zero-emission appliance standards can be harder to get away with and easier to detect, because there are far fewer manufacturers to monitor than installers, because standardized manufacturing practices and specifications are more difficult than individual installations to change in ways that would evade the standards, and because compliance with a *zero-emission* standard is especially easy to verify (does the appliance involve combustion or any other process that could emit pollution?).

Standards that reach all building types can also make electrification more inclusive, because they apply equally whether a building is new or existing, rented or owner-occupied. This can help ensure that no one is left behind in the transition, including tenants and low-income residents. An inclusive transition will allow everyone to share in the benefits of electrification, from improved indoor air quality to access to cooling. And it will avoid saddling those least able to electrify with the costs of maintaining a leaky and aging gas grid as others disconnect. It can also help encourage governments and market actors to develop policies and programs that will make the transition affordable for everyone.

However, a universal zero-emission standard also risks requiring low-income residents to electrify at costs they are unable to bear. As discussed further in Section III.C, zero-emission standards should be designed to minimize this risk by incorporating affordability assessments between enactment and implementation, and by delaying or modifying the standards if an

¹ There is also mixed evidence on the efficacy of rebates in influencing consumer behavior (Sallee 2021). This suggests that society's investments may see greater returns if they focus on making electrification *affordable* than if they focus on making it *happen* at all (a role better served by emission standards). Moreover, it would take a massive investment for rebates to play the role of driving market transformation. Rewiring America and the Center for American Progress estimate that a consumer rebate program for electrification would require up to \$26.5 billion of federal investment each year for a decade (Higgins et al. 2021, 2). For comparison, the 2021 Infrastructure Bill contains \$5 billion for energy efficiency in buildings (Berg 2021).

assessment shows that electrification is unlikely to be affordable after applying available incentives, assistance programs, and financing.

3. Availability at Local, State, and Federal Levels. As noted in Section III.A, zero-emission standards can be enacted by EPA, state air agencies, and local air districts (in states like California that have established local air districts). And federal standards do not preempt state or local standards. This distinguishes zero-emission standards from state and local policies with no federal equivalents, such as building codes and building performance standards, as well as appliance efficiency standards, which are subject to federal preemption (see Section III.A).

Ultimately, a federal standard will provide the strongest signal to guide transformation of the entire national appliance market. But this doesn't mean appliance standards must wait until EPA is ready to act. Because state agencies can enact their own standards, the strategy can be pursued first in leading states like California, New York, and New Jersey (which all have some version of standards under development), then brought to the national stage as momentum and support build. And if EPA enacts a standard whose ambition fails to match the urgency to electrify, states can continue moving the ball forward. This dynamic helps maximize the chance of quickly developing strong zero-emission standards that can play the role of guiding market transformation efforts.

C. Designing Zero-Emission Appliance Standards to Guide Market Transformation

As discussed in Section II.B.3, zero-emission appliance standards should be designed to guide and accelerate the wide range of market interventions and complementary policies needed for equitable electrification. Well-designed standards will send the right signals about what interventions are needed, allow time to apply these interventions, and have some flexibility in case adjustments are needed to support additional interventions. Because the costs of electrification are one of the main barriers to an equitable and successful transition, standards should especially encourage market interventions that bring those costs down or direct resources to helping low-income and energy burdened residents electrify.

This section describes three design features that can help zero-emission standards effectively guide market transformation toward equitable electrification: (1) conduct an inclusive planning process, (2) design timelines and requirements to encourage key market interventions, and (3) review progress toward equitable market transformation and make needed adjustments. For additional information on appliance standard design, see Dennison, Louis-Prescott, and Gruenwald (2021, 16-19).

1. Conduct an Inclusive Planning Process. Air agencies should develop standards through a collaborative, inclusive planning process that brings together impacted communities, market actors, and other government agencies. This will help achieve buy-in and coordination among these actors, and most importantly, give air agencies critical input as they identify key market interventions and design standards to encourage them.

2. Design Timelines and Requirements to Encourage Key Market Interventions. Zero-emission standards should send a strong signal about the market interventions needed to quickly and equitably electrify, but give enough lead time to implement those interventions. Air agencies

can achieve this balance by setting standards that require fossil fuel appliances to be phased out in roughly 5 to 10 years, as agencies in California and New York have proposed (Dennison, Louis-Prescott, and Gruenwald 2021, 19).

On the way to full market transformation, air agencies can design standards to encourage market interventions that reduce electrification costs, especially for low-income residents. For example, standards could require an increasing percentage of each manufacturer's appliance sales to be zero-emitting. And they could give additional credits for appliances that fall below a certain cost threshold, are installed in affordable housing, or are sold with an income-qualified rebate. This would incentivize market interventions that result in a greater number of affordable sales to low-income residents. Any penalties that manufacturers pay for failing to meet the standards could also be used to fund low-income electrification programs directly.

3. Review Progress and Make Needed Adjustments. Finally, air agencies should work with impacted communities to identify conditions for equitable electrification when developing standards, and commit to evaluating whether those conditions are satisfied before the standards are fully phased in. If a pre-implementation review indicates that we are not on track to meeting the standards equitably, air agencies would make any needed adjustments to the standards and their implementation timelines.

California has used similar interim evaluations to ensure that implementing its ZEV standards remained feasible (CARB 2017). And Seattle delayed the implementation date for its building code provisions requiring heat pumps to allow for successful implementation (Jonlin 2021). Interim evaluations for appliance standards should build on these examples, but they should focus explicitly on equity, affordability, and inclusion as much as possible.²

Interim equity reviews can serve three key functions: First, they can provide a backstop to ensure that standards don't require electrification before market interventions succeed in making it affordable for low-income residents. Second, they can produce reports that tell market actors how they are doing and where they should apply additional equity-focused interventions (whether or not the standards need to be adjusted in response). These "report cards" should include accessible, actionable summaries that are shared widely among market actors. Third, interim reviews can make it more likely that equity-focused interventions will occur in the first place, by signaling from the outset that progress under the standards be evaluated using specific equity criteria. It's like telling all the market actors upfront that equity questions will be on the test—you can be sure they'll get studied.

IV. Conclusion

Electrifying America's buildings equitably and quickly will require a market transformation of enormous scope and ambition. Zero-emission appliance standards can

² Interim evaluations should focus on avoiding an inequitable or exclusionary transition because this is one of the greatest risks associated with electrification, as equity-focused and community-based organizations have repeatedly explained (e.g., Norton et al. 2021; Emerald Cities 2020; Greenlining 2019). Drawing on these explanations, Dennison, Louis-Prescott, and Gruenwald (2021) have proposed four criteria for equitable electrification that air agencies could evaluate in interim reviews. These proposed criteria are: (1) affordable upfront costs, (2) affordable energy costs, (3) anti-displacement and renter protections, and (4) provision for necessary pre-electrification housing upgrades.

motivate, accelerate and focus this transformation by establishing clear, enforceable targets that align a wide range of incentives and market interventions, from financing and efficiency programs to contractor training and consumer education. And they can rule out expensive, unhelpful actions like gas system expansion and use of low-carbon fuels in buildings, freeing up resources and energy for more productive solutions.

Zero-emission appliance standards can play this coordinating role more effectively than other policies because they can align directly with our climate commitments, which require that we phase out new fossil fuel appliances by 2030. And they can be designed to encourage key market interventions using features like strategic phase-in timelines, tailored requirements and credits, and interim equity reviews.

The key to the building electrification strategy presented in this paper is to combine two approaches to technology adoption: regulatory signals and market transformation. There are likely many other areas where these approaches could be or already are being combined effectively. Vehicle electrification is one good example.

But it is surprisingly uncommon to hear the two approaches described as complementary elements of a unified strategy. Regulatory requirements are often seen as absolute, leaving no choice in the market and no room to shape it through interventions. Indeed, the market transformation paradigm sometimes relegates standards to the role of locking in technology adoption after there are no more market interventions to apply.

As illustrated in this paper, standards can be used in ways that leave room for, encourage, and benefit from complementary market interventions. This is especially true when the bodies enacting standards are granted flexible authority and apply it creatively. Hopefully, this paper serves as a reminder that regulators and other market actors can and should collaborate to develop equitable solutions to major challenges like building electrification.

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