

# Setting California's Clean Appliance Timeline

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Why we need to transition to zero-emission home appliances much sooner than we think

## Acknowledgments

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The findings and recommendations of this report are SPUR's and do not necessarily reflect the views of those listed below. Any errors are the authors' alone.

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# Driving the Adoption of Zero-Emission Appliances

Big changes are coming to California's energy system now that the state has set out to be carbon-neutral by 2045.<sup>1</sup> Meeting this goal will require all buildings in the state to eliminate the use of fossil fuels and fully rely on electric appliances, rather than gas-burning ones, in less than 25 years.<sup>2 3</sup> Prioritizing the transition to zero-emission home appliances is vital for the environment and for the health of Californians.

Transitioning to zero-emission appliances only when existing natural gas appliances reach the end of their useful life will not be sufficient to meet the state's target or to reduce significant emissions from home appliances. Many gas furnaces, water heaters and boilers last far longer than expected; in order to eliminate emissions from these appliances by 2045, California would have needed to stop installing certain kinds of appliances as early as 1959. Any postponement in phasing out gas appliances in residential buildings will further delay the state in meeting its climate targets and lock in decades of pollution — along with its associated health harms. Driving the adoption of zero-emission appliances *before* today's gas appliances stop working will take strong public policy and significant local and state incentives.

How long do gas appliances really last, and when should air districts require property owners to transition? To help answer this question, SPUR analyzed the existing estimates for how long gas appliances last and identified a need for more nuanced modeling. We then modeled the number of gas water heaters, furnaces and boilers that will still be fully functional in California in 2045 if the entire state were to adopt the timeline proposed by the Bay Area Air Quality Management District for phasing out these appliances. We found that up to 71% of some types of gas appliances will still be in use in 2045 even if zero-pollution requirements start in 2027, as proposed in the Bay Area.



Some gas appliances far outlast their average life expectancy. This central furnace has heated a single-family home in Alameda, California, for more than 100 years.

Photo by Tom Kabat

1 "California's Electricity System of the Future," Governor Gavin Newsom, July 2021, <https://www.gov.ca.gov/wp-content/uploads/2021/07/Electricity-System-of-the-Future-7.30.21.pdf>.

2 California Air Resources Board, "2022 Scoping Plan Update - Building Decarbonization Workshop," <https://ww2.arb.ca.gov/our-work/programs/building-decarbonization> (accessed on November 16, 2021).

3 This paper focuses specifically on gas appliances rather than all fossil fuel-burning appliances because gas appliances make up about 80 percent of fossil fuel appliances and therefore contribute the majority of appliance pollution. See: RMI, Sierra Club, "Factsheet: Why EPA Must Address Appliance Pollution," [https://rmi.org/wp-content/uploads/2021/04/rmi\\_factsheet\\_appliance\\_pollution.pdf](https://rmi.org/wp-content/uploads/2021/04/rmi_factsheet_appliance_pollution.pdf) (accessed on February 17, 2022).

# Home Energy Use and California's Climate Goals

The State of California aims to reduce greenhouse gas emissions by 40% below 1990 levels by 2030, 80% below 1990 levels by 2050<sup>4</sup> and achieve carbon neutrality by 2045.<sup>5</sup> Decarbonizing buildings (replacing all fossil fuel use) is a core component of California's climate action plan given that commercial and residential buildings are responsible for approximately 25% of California's greenhouse gas emissions.<sup>6</sup> The first step in decarbonizing buildings is to switch appliance energy use from fossil fuels to electricity to eliminate on-site emissions. But to eliminate all the emissions that buildings create, the electricity they use for daily operations must be generated from non-fossil fuel sources such as wind and solar power. In California, the emissions from electricity generation are already trending downward, with the state planning for the electrical grid to be carbon-free by 2045.<sup>7</sup> In the Bay Area, community choice aggregation (CCA) energy programs offer nearly every Bay Area business and residence the option to use electricity 100% generated from renewable sources through their existing utility provider.

It is generally easier and more cost-effective to electrify new buildings than to retrofit existing ones.<sup>8</sup> Measures already in place in many California cities and counties require all new buildings to be fully electric. From 2019 to 2022, 54 jurisdictions adopted "reach codes" that go beyond statewide building codes in setting electrification requirements.<sup>9</sup> However, most of these mandates only apply to new buildings, and many include exceptions for some types of buildings or appliances. Because new buildings make up a small percentage of the state's housing, reach codes for new construction are insufficient to meet California's climate goals. Solutions are also needed for existing homes, including incentives to replace existing gas appliances with electric ones or halting the sale of gas appliances altogether.

Gas appliances are commonly used in California homes for cooking, space heating and water heating.<sup>10</sup> They can operate for decades, so it could take a very long time to replace all of them with electric appliances. The gas appliances that emit the most carbon are water heaters, furnaces (which provide space heating) and boilers (which heat space and, in some cases, water). For each

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4 Bay Area Air Quality Management District (BAAQMD), *Spare the Air, Cool the Climate: A Blueprint for Clean Air and Climate Protection in the Bay Area*, 2017, <https://www.baaqmd.gov/plans-and-climate/air-quality-plans/plans-under-development>.

5 Executive Order B-55-18, <https://www.ca.gov/archive/gov39/2018/09/10/governor-brown-signs-100-percent-clean-electricity-bill-issues-order-setting-new-carbon-neutrality-goal/index.html> (accessed on October 13, 2021).

6 The 25% figure includes emissions from fossil fuels combusted onsite, emissions from fossil fuels used to generate electricity, and refrigerants used in cooling systems. "Building Decarbonization | California Air Resources Board," <https://ww2.arb.ca.gov/our-work/programs/building-decarbonization> (accessed on November 16, 2021).

7 California Energy Commission California Public Utilities, California Air Resources Board and California Public Utilities Commission, "Achieving 100% Clean Electricity in California," California Energy Commission, <https://www.energy.ca.gov/news/2021-03/california-releases-report-charting-path-100-percent-clean-electricity>.

8 Laura Feinstein, "Bold Moves on Building Electrification in the San Francisco Bay Area," SPUR, December 9, 2020, <https://www.spur.org/news/2020-12-09/bold-moves-building-electrification-san-francisco-bay-area>.

9 Matt Gough, "California's Cities Lead the Way to a Gas-Free Future," Sierra Club, July 22, 2021, <https://www.sierraclub.org/articles/2021/07/californias-cities-lead-way-gas-free-future>.

10 "Achieving Carbon Neutrality in California," Energy + Environmental Economics, October 2020, <https://ww2.arb.ca.gov/resources/documents/achieving-carbon-neutrality-california-final-report-e3>.

of these appliances, electric equivalents already exist on the market. The electric alternatives include both electric resistance devices (which use electricity to generate heat directly) and electric heat pumps (which use electricity to move heat from one place to another). Electric resistance devices cost less than electric heat pumps. However, because heat pumps use electricity to move heat rather than make heat, they are two to three times more efficient than gas-burning alternatives or even electric resistance appliances.<sup>11</sup>

## Natural Gas Appliances

**Gas water heater**



**Gas furnace**



**Gas boiler**



Gas water heaters, furnaces and boilers can be replaced with zero-emission alternatives including heat pump water heaters, central heat pumps or mini-split heat pumps (ductless heating and cooling appliances) for space heating and cooling.

## Electric Appliances

**Heat pump water heater**



**Central heat pump**



**Mini-split heat pump**



Sources: Mini split heat pump courtesy flickr user National Renewable Energy Lab, central heat pump courtesy flickr user Nordique, gas water heater courtesy flickr user Tony Alter, gas boiler courtesy NTI Boilers

<sup>11</sup> Laura Tam and Sarah Jo Szambelan, "Fossil-Free Bay Area," SPUR, September 2016, <https://www.spur.org/publications/spur-report/2016-09-21/fossil-free-bay-area>.

Reducing the prevalence of gas burning appliances will make the air both inside and outside of homes healthier to breathe. Gas cooktops and ovens in particular release large amounts of nitrogen oxide inside a home, which contributes to myriad health problems. A 2013 study showed that children living in homes with gas cooking appliances have a 42% higher chance of having asthma.<sup>12</sup> Home gas appliances also contribute to outdoor air pollution due to nitrogen oxides emissions.<sup>13</sup> In combination, indoor and outdoor air pollution disproportionately impact low-income communities — the same communities who face the greatest cumulative environmental health burden.<sup>14</sup> Eliminating the use of gas-burning space and water heaters would eliminate more nitrogen oxide pollution than taking all of the gas-burning passenger vehicles off the road in the Bay Area.<sup>15</sup>

Eliminating the use of gas-burning space and water heaters would eliminate more nitrogen oxide pollution than taking all of the gas-burning passenger vehicles off the road in the Bay Area.

The most cost-effective time to make the switch from a gas appliance to an electric one is when an old appliance is no longer functional. This timeline prevents the unnecessary financial and environmental cost of discarding a working appliance. Enacting all-electric requirements would ensure that any new appliance purchased would be electric. Today, new electric appliances for space and water heating can often be more expensive than their gas counterparts. However, as sales of electric appliances increase, the cost is expected to go down significantly.<sup>16</sup>

In conjunction with zero-emissions rules, financial incentives or rebate programs will help expedite the transition to electric appliances in the state. Jurisdictions, CCAs and utility companies currently offer a variety of programs at the local, regional or state level.<sup>17</sup> The TECH Clean California incentives are one major opportunity, offering rebate programs for electric appliances in select regions in the state.<sup>18</sup> The program — established by Senate Bill 1477 (Stern) in 2018 and brought to life by the California Public Utilities Commission<sup>19</sup> — became available at the end of 2021 and includes \$120 million for electric space and water heating units. These incentives provide a template for further support of an equitable transition to electric appliances.

12 Lin, Weiwei, Bert Brunekreef and Ulrike Gehring, "Meta-Analysis of the Effects of Indoor Nitrogen Dioxide and Gas Cooking on Asthma and Wheeze in Children," *International Journal of Epidemiology* 42, no. 6 (December 1, 2013): 1724–37. <https://doi.org/10.1093/ije/dyt150>.

13 See note 8.

14 Brady Seals and Andee Krasner, "Health Effects From Gas Stoves," RMI, Mothers Out Front, Physicians for Social Responsibility, Sierra Club, <https://rmi.org/insight/gas-stoves-pollution-health/> (accessed on March 7, 2022).

15 Jennifer Elwell, "Workshop Report: Draft Amendments to Building Appliance Rules," Bay Area Air Quality Management District, September 2021, <https://www.baaqmd.gov/rules-and-compliance/rule-development/building-appliances>.

16 Sherri Billimoria, Leia Guccione and Leah Louis Prescott, "The Economics of Electrifying Buildings," RMI, <https://rmi.org/insight/the-economics-of-electrifying-buildings/> (accessed March 7, 2022).

17 "Make the Switch to an All-Electric Home | The Switch Is On," <https://switchison.org/incentives> (accessed on February 17, 2022).

18 "TECH Clean California Incentives," <https://energy-solution.com/tech-incentives/> (accessed on February 17, 2022).

19 Kiki Velez and Merrian Borgeson, "TECH Clean California: \$120M in Good News for the Climate," NRDC (blog), February 16, 2022, <https://www.nrdc.org/experts/kiki-velez/tech-clean-california-120m-good-news-climate>.

Providing gas service will also become more expensive as more people transition to all-electric energy, which poses a significant equity concern for low-income communities, who would face the heaviest financial burden if they maintain gas service after most others have made the transition to all-electric. The costs of operating and maintaining the gas grid are mostly fixed. As this fixed cost of maintaining the gas grid is shared by fewer ratepayers, the rate per household will increase, which will most adversely impact low-income gas ratepayers.<sup>20</sup>

## The Bay Area's Proposed Requirement for Zero-Emission Appliances

The Bay Area Air Quality Management District (BAAQMD) is considering a zero-emission requirement for the sale of new residential and commercial water heaters, furnaces and boilers in its jurisdiction, which includes the nine Bay Area counties except for parts of Solano and Sonoma counties.<sup>21 22</sup> This requirement would start in 2027 for small water heaters, 2029 for furnaces and 2031 for large water heaters and boilers. This will effectively end the sale of these gas-powered appliances, so after the compliance dates, only zero-emission versions will be available to purchase in the Bay Area.

By ending the sale of some polluting appliances, this proposal has the potential to significantly improve air quality in the coming decades. But there are some questions that remain unanswered. How long do gas appliances actually last? If gas appliances are replaced only at the end of life, will the proposed requirement be enough to ensure the state meets its climate goals?

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<sup>20</sup> "California's Gas System in Transition: Equitable, Affordable, Decarbonized and Smaller," Gridworks, <https://gridworks.org/initiatives/cagas-system-transition/> (accessed on February 8, 2022).

<sup>21</sup> Bay Area Air Quality Management District (BAAQMD), "Rules 9-4 and 9-6 Building Appliances," <https://www.baaqmd.gov/rules-and-compliance/rule-development/building-appliances> (accessed on November 9, 2021).

<sup>22</sup> There is currently no proposed ruling that includes fossil fuel-burning cooktops.



# Estimating Appliance Lifespans: Overview of Methods

*For a detailed explanation of the methods used, please refer to the Appendix on page 14.*

A number of studies have attempted to gauge the lifespan of gas appliances. These studies generally conclude that appliances have a lifespan of 10 to 25 years, depending on the appliance. The Energy Information Agency (EIA) estimates a mean lifespan of 13 years for gas-fired storage water heaters, 22 years for gas furnaces and 25 years for residential gas-fired boilers.<sup>23</sup> These studies are often cited in models that try to estimate how long it will take for gas appliances to phase out of homes and buildings.

These models use average lifespan as a proxy to identify how long it will take for a new appliance requirement to penetrate the market and assume that 100% of appliances will fail at the year of average lifespan. SPUR used the Weibull distribution, a probability distribution function, to model appliance life expectancy and incorporated findings from the prominent research study *Using National Survey Data to Estimate Lifetimes of Residential Appliances*.<sup>24</sup> (See the Appendix on page 14 for details on our methods.)

We modeled the replacement rate of gas water heaters, furnaces and boilers over time, which more accurately indicates when appliances will stop working and shows how many will remain in a given year. For each appliance type, we examined the percentage of appliances that would still be functional in 2045 by comparing two years of installation: the current year and the year in which BAAQMD has proposed a zero-pollution requirement for that appliance. We focused specifically on water heaters, boilers and furnaces because they're responsible for the majority of fossil fuel emissions from existing buildings and because they're the subject of BAAQMD's proposed requirement.

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<sup>23</sup> Navigant Consulting, Appendix A: EIA, Technology Forecast Updates – Residential and Commercial Building Technologies – Reference Case, US Energy Information Administration, 2018, <https://www.eia.gov/analysis/studies/buildings/equipcosts/>.

<sup>24</sup> James D. Lutz, Asa Hopkins, Virginie Letschert, Victor H. Franco and Andy Sturges, "Using National Survey Data to Estimate Lifetimes of Residential Appliances," Ernest Orlando Lawrence Berkeley National Laboratory, October 2011, <https://www.osti.gov/servlets/purl/1182737>.

# Estimating Appliance Lifespans: Results

There is a mix of gas appliances and zero-emission appliances installed in residential buildings in the Bay Area. This will continue to be the case for many years to come. On its own, BAAQMD's proposed requirement stands to flip the ratio of gas to electric appliances in homes throughout the Bay Area: In 2019, about 75% to 85% of appliances in California homes burned gas.<sup>25</sup> With the adoption of these requirements, about 90% of homes would be using zero-emission appliances by 2045.

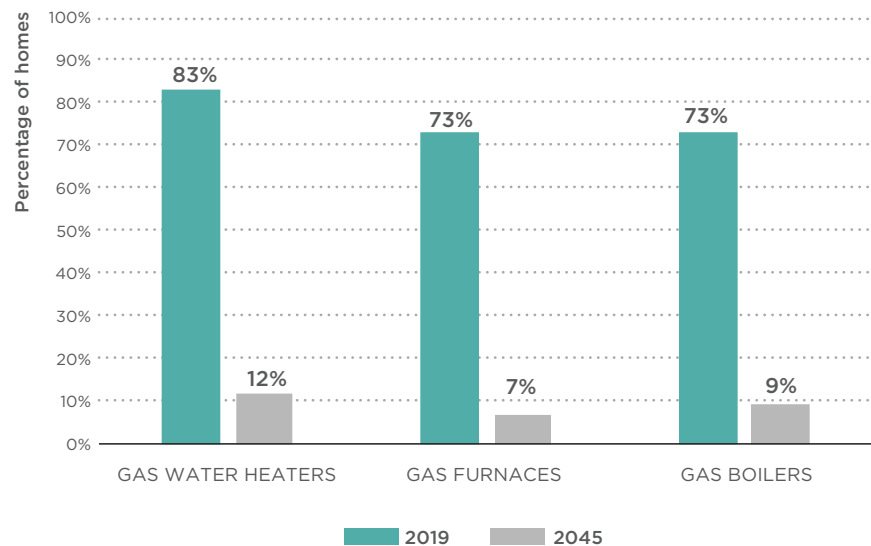
With the adoption of new requirements proposed for the Bay Area, about 90% of homes could be using zero-emission appliances by 2045.

**FIGURE 1**  
**How Much Can Natural Gas Use in Homes Change by 2045?**

Percentage of California homes using gas versions of appliances in 2019 vs. 2045

In 2019, most homes relied on gas-powered versions of water heaters, furnaces and boilers to heat the space and water in the building. If BAAQMD's proposed zero-emission requirements were to be applied across the state, gas appliance usage is projected to decrease dramatically by 2045 as people replace appliances at their end of life with zero-emission versions.

Source: SPUR analysis using methods and turnover data from Lutz et al., 2011.



Mean lifespan represents the average lifespan for an appliance, but it's often misused to predict the failure rate for a group of appliances. For example, it is common to see rough estimates that water heaters and furnaces last 15-20 years, based on their mean lifespan even though many live

<sup>25</sup> California Energy Commission, "2019 California Residential Appliance Saturation Study (RASS) Executive Summary," July 2021. Figure ES-8. [https://webtools.dnv.com/CA\\_RASS/Uploads/CEC-200-2021-005-ES.pdf](https://webtools.dnv.com/CA_RASS/Uploads/CEC-200-2021-005-ES.pdf).

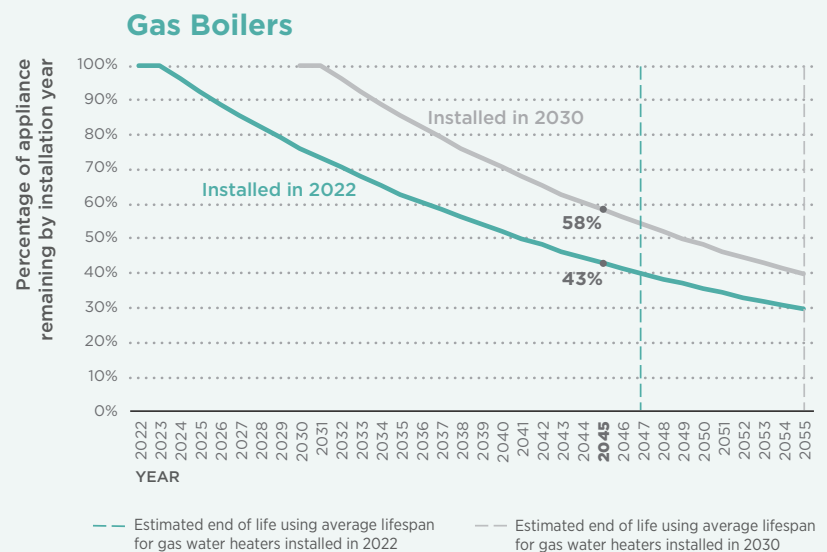
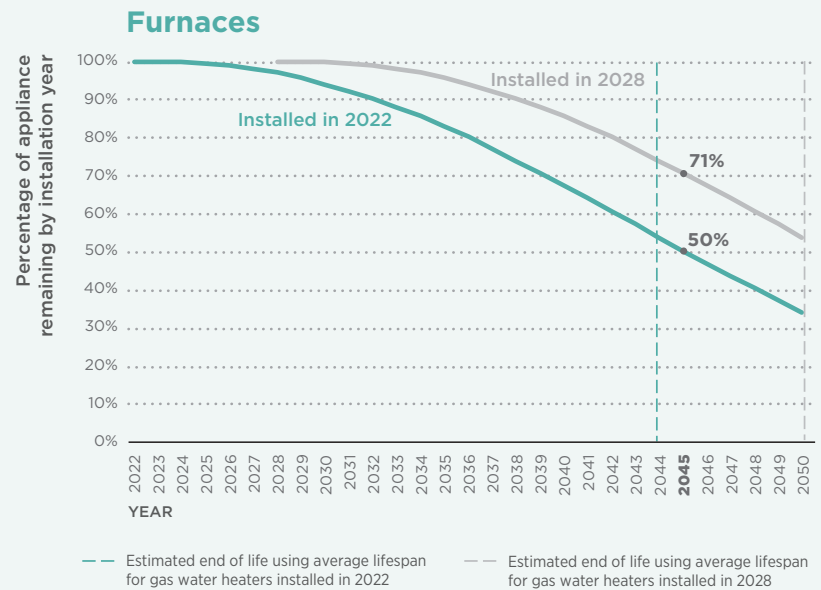
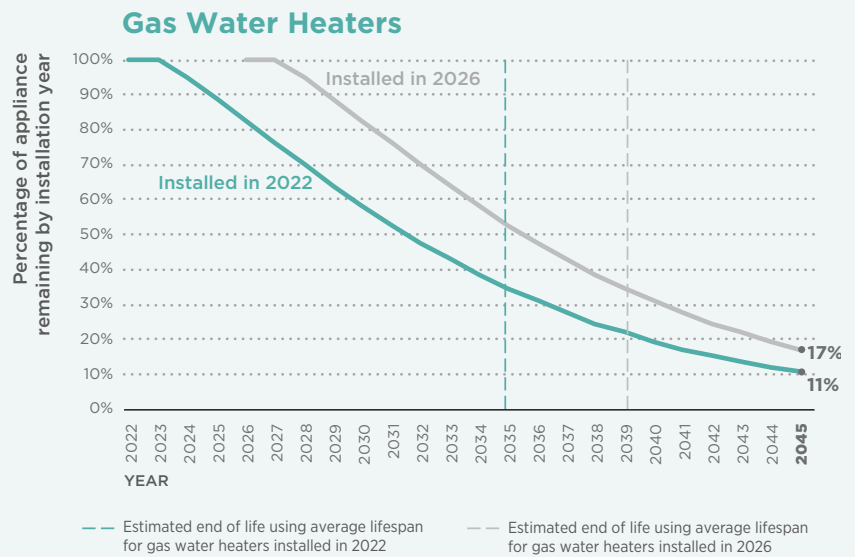
FIGURE 2

### What Percentage of Gas Appliances Will Still Be Working in 2045?

Percentage of gas water heaters, furnaces and boilers remaining by year according to the Weibull model compared to the EIA average lifespan

For each gas appliance, we compared the appliances installed this year to those installed in either 2026, 2028 or 2030, the final year before BAAQMD's proposed zero-emission requirement would go into effect for that appliance.

Source: SPUR analysis using methods and turnover data from Lutz et al., 2011.



Between 11% and 50% of gas appliances installed in 2022 will still be functional in 2045.

much longer (Figure 3).

Continuing to install gas appliances will hinder the state in meeting its climate targets and will result in more appliances needing to be replaced before the end of their useful lives. Even if gas appliances were no longer sold as of January 2022, there would still be units operating in homes in 2045. Of the three types of gas appliances included in the study:

- 11% of water heaters installed in 2022 and 17% installed in 2026 will still be functional in 2045
- 50% of furnaces installed in 2022 and 71% installed in 2028 will still be functional in 2045
- 43% of boilers installed in 2022 and 58% in 2030 will still be functional in 2045

## Conclusion

Even if California were to stop selling gas appliances in 2022, 11% of gas water heaters, 50% of gas furnaces and 43% of gas boilers installed in 2022 would still be functioning in 2045. This means we have already passed the point where the state's proposed zero-pollution requirements for gas appliances would be sufficient to ensure carbon neutrality by 2045. Through incentives and regulations, California will need to drive the replacement of gas appliances with electric ones well before their end of life.

Given how long gas appliances can linger in operation, and given that the transition to electrification is well underway, the time to take action is now. BAAQMD should adopt the proposed requirements without delay, and the state should use them as a model for other jurisdictions. BAAQMD's zero-pollution requirements can be an important step in efficiently electrifying all Bay Area buildings in the next three decades and helping the state reach climate-neutrality by 2045. These requirements should also be paired with additional rebates for people to transition their appliances to electric ones. Combined, these efforts will ensure that Californians are not locked into a gas system once electrification has happened. Ending the sale of gas appliances now will ensure that the burden of replacing appliances before their useful life ends is lessened. This is particularly important for low-income residents and communities of color throughout the state. Reaching climate neutrality by 2045 will only be possible if California takes action now and uses a variety of creative approaches to reduce the legacy of gas-burning appliances.

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## Appendix: Detailed Methods

We created a model for the replacement rate of certain household gas appliances as a way to determine what percentage of natural gas appliances purchased in a given year would still be installed in 2045, the year California is aiming to reach carbon neutrality. The Weibull probability distribution is commonly used to model the replacement rate of an appliance over time because it allows for more precision rather than simply using the average useful life of an appliance to determine when an appliance might fail. The average useful life provides an overly simplistic understanding of an appliance's lifespan, because many appliances live far longer than the average useful life.

We incorporated findings from a prominent research study into our Weibull distribution model. The study was conducted by James D. Lutz, Asa Hopkins, Virginie Letschert, Victor H. Franco and Andy Sturges at the Lawrence Berkeley National Laboratory.<sup>26</sup> The researchers used national survey data to estimate the replacement rates for a large sample of residential appliances, resulting in specific findings about the shape and scale of the Weibull distribution for each appliance they studied.

The Lutz et al. approach to modeling appliance lifespans used a larger dataset than other studies, and rather than simply estimating mean lifespan, they estimated the replacement rate per year. They found that failure rates tend to be very low in the beginning, pick up around mean lifespan, then show a long tapering off period. A few hardy specimens can last a decade or two longer than the mean lifespan.

The replacement rate model indicates what percentage of the original cohort of appliances is still remaining in a given year. We used this to determine what percentage of appliances purchased between 2022 and 2045 will still be installed in the year 2045. Specifically, to figure out what percentage of appliances purchased in 2022 are still remaining in 2045, we looked for the percentage of the original cohort of appliances that are still remaining 23 years after purchase. This tells us what percentage of appliances purchased in 2022 are still installed 23 years later, in the year 2045. We followed this same step for each year between 2022 and 2045.

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<sup>26</sup> See note 23.



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