APPENDIX F
BUILDING DECARBONIZATION

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1. Introduction

Buildings are a large source of greenhouse gases (GHG), and as included in the Draft Scoping Plan, decarbonization of California's buildings must be accelerated to achieve mid-century climate targets and avoid the worst impacts of climate change. Building decarbonization refers to the umbrella of strategies to reduce residential and commercial building emissions, which include maximizing energy efficiency, use of low- and zero-carbon electricity, demand flexibility, energy storage, use of very low- or no-GWP refrigerants and refrigerant emission reduction, and eliminating fuel combustion by electrifying appliances and equipment, among other actions. Building electrification—in new and existing buildings—provides the most technologically feasible path to reduce building-related emissions.[1] [2] [3] [4] Therefore, building electrification is the focus of this appendix, including a range of potential actions that could support these goals and would be considered through future public processes.

The Draft Scoping Plan evaluated four scenarios to achieve climate targets. The Proposed Preferred Scenario, identified as Alternative 3, establishes three main goals for buildings to reduce emissions for both GHGs and air pollution: 1) energy efficiency aligned with the mid-high (electric) and mid-mid (gas) scenarios from the 2019 Integrated Energy Policy Report;[5] 2) new construction would be zero-emission starting in 2026 for residential buildings and 2029 for commercial buildings through alignment of state and local authorities; and 3) all new appliances sold in California would be zero-emission by 2035 for installation in homes and by 2045 for installation in commercial buildings. These goals are not intended to be additive,

[1] Kenney, M., N. Janusch, I. Neumann, and M. Jaske. 2021. "California Building Decarbonization Assessment." *California Energy Commission.* Publication Number: CEC-400-2021-006-CMF. Available at: https://www.energy.ca.gov/publications/2021/california-building-decarbonization-assessment.

[2] Energy Futures Initiative. 2019. *Optionality, Flexibility, and Innovation: Pathways for Deep Decarbonization in California.* Available at: https://www.ourenergypolicy.org/resources/optionality-flexibility-innovation-pathways-for-deep-decarbonization-in-california-2/.

[3] Mahone, A., Z. Subin, G. Mantegna, R. Loken, C. Kolster, and N. Lintmeijer. 2020. "Achieving Carbon Neutrality in California: PATHWAYS Scenarios Developed for the California Air Resources Board." *Energy and Environmental Economics, Inc.* Available at: https://ww2.arb.ca.gov/sites/default/files/2020-10/e3_cn_final_report_oct2020_0.pdf.

[4] Raghavan, S. V., M. Wei, and D. Kammen. 2017. "Scenarios to Decarbonize Residential Water Heating in California." *Energy Policy* Volume 109, pp. 441-451. Available at: https://energy.lbl.gov/publications/scenarios-decarbonize-residential?msclkid=075a26aac73711ec81703993891e80a1.

[5] California Energy Commission staff. 2020. "Final 2019 Integrated Energy Policy Report." *California Energy Commission.* Publication Number: CEC-100-2019-001-CMF. Available at: https://www.energy.ca.gov/data-reports/reports/integrated-energy-policy-report/2019-integrated-energy-policy-report.

stand-alone measures, but are complementary in achieving GHG emission reductions from buildings.

For purposes of this Scoping Plan, zero-emission buildings refer to buildings that have no combustion-based equipment or appliances installed. For example, a zero-emission building would only have equipment and appliances that are all-electric. Similarly, within this document, zero-emission appliances are those that do not directly utilize combustion.

To decarbonize buildings, California will need to replace natural gas energy with zero-carbon electricity especially in existing buildings, expand construction of zero-emission buildings, and increase production and use of highly efficient and flexible, zero-emission appliances. To enable successful building decarbonization, actions are needed to help build a consumer-friendly market by increasing affordability and accessibility, such as through expanding incentive programs and ensuring utility rates are supportive of electrification, developing the workforce, and increasing consumer education. In each of these efforts, it will be important to ensure the needs of frontline communities are prioritized and current inequities are not reinforced or exacerbated.

The first section of this appendix focuses on why building decarbonization is one of several key priorities for California by summarizing its important benefits. The second section discusses the technical feasibility of electric appliances, costs and cost-savings, and consumer adoption and awareness. The final section outlines a number of potential actions that would support a successful transition to building decarbonization.

2. Building Decarbonization is a Priority for California

In addition to reducing GHG emissions, building decarbonization can deliver multiple benefits. These include improved air quality and health—as discussed below.

a) Air Quality and Health Impacts

Combustion of natural gas for space and water heating, cooking, clothes drying, and other end uses in residential and commercial buildings contributes about five percent of statewide oxides of nitrogen (NOx) emissions, and produces carbon monoxide (CO), ultrafine particles (UFPs, particles with diameters smaller than 0.1 micron) and fine particulate matter (PM2.5, particles with diameters smaller than 2.5 micron), and formaldehyde, which are harmful to human health and the environment.[6] Some of the emissions occur indoors and thus

[6] Zhu, Y., R. Connolly, T. Mathews, and Z. Wang. 2020. "Effects of Residential Gas Appliances on Indoor and Outdoor Air Quality and Public Health in California." *UCLA Fielding School of Public Health Department of Environmental Health Sciences.* Available at: https://ucla.app.box.com/s/xyzt8jc1ixnetiv0269qe704wu0ihif7.

deteriorate indoor air quality, while most emissions are eventually released to the ambient air and increase air pollution levels. Emissions from gas appliances have been linked to various acute and chronic health effects, including respiratory illness, cardiovascular disease, and premature death. If all residential natural gas appliances in California (in 2018) were replaced with electric ones instantaneously, one study estimated the emission benefits to result in 354 fewer premature deaths annually.[7] A similar study that looked at both residential and commercial buildings across California (in 2035) predicted that the emission reductions would avoid 818 premature deaths per year.[8] In addition to these avoided premature deaths, these studies suggest building electrification also reduces acute and chronic health effects.

i. Indoor Air Quality

Of all building end uses, cooking with natural gas has the largest impact on indoor air quality because the kitchen range is the only combustion appliance whose emissions may not be directly vented outdoors. Some homes have cooking rangehoods that vent kitchen exhausts, but these are not always used by occupants or ducted to outside. Homes with a gas stove have higher NOx and CO levels compared to those with an electric stove.[9] [10] An estimated 12 million Californians with gas stoves are exposed routinely to indoor NOx levels that exceed both federal and California ambient (outdoor) air quality standards.[11] While electric and gas stoves produce similar levels of PM2.5 during cooking,[12] UFP are higher in homes with gas

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[7] Ibid.

[8] Mantegna, G., A. Burdick, S. Price, A. Olson, M. Mac Kinnon, and S. Samuelsen. 2022. "Quantifying the Air Quality Impacts of Decarbonization and Distributed Energy Programs in California." Available at: *https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/integrated-resource-plan-and-long-term-procurement-plan-irp-ltpp/2019-2020-irp-events-and-materials/quantifying-air-quality-impacts.pdf*.

[9] Seals, B., A. Kasner, R. Golden, B. Gottlieb, and B. Nilles. 2020. "*Health Effects from Gas Stove Pollution.*" *Rocky Mountain Institute*, Available at: *https://rmi.org/insight/gas-stoves-pollution-health*.

[10] Mullen, N. A., J. Li, M.L. Russell, M. Spears, B.D. Less, and B.C. Singer. 2016. "Results of the California Healthy Homes Indoor Air Quality Study of 2011–2013: Impact of Natural Gas Appliances on Air Pollutant Concentrations." *Indoor Air* Volume 26, pp. 231-245. Available at: *https://onlinelibrary.wiley.com/doi/10.1111/ina.12190*.

[11] Logue, J. M., N. E. Klepeis, A.B. Lobscheid, and B.C. Singer. 2014. "Pollutant Exposures from Natural Gas Cooking Burners: a Simulation-Based Assessment for Southern California." *Environmental Health Perspectives* Volume 122, pp. 43-50. Available at: *https://ehp.niehs.nih.gov/doi/10.1289/ehp.1306673*.

[12] Singer, B. C., W.W. Delp, D.M. Lorenzetti, and R.L. Maddalena. 2016. "Pollutant Concentrations and Emission Rates from Scripted Natural Gas Cooking Burner Use in Nine Northern California Homes." *Lawrence Berkeley National Laboratory, U.S. Department of Energy*. Available at: *https://www.osti.gov/servlets/purl/1420274*.

stoves due to the combustion of gas.[13] [14] [15] Due to their smaller size and larger total surface area, UFPs have been linked with many respiratory, cardiovascular, and central nervous system health effects.[16] Study findings indicate that children living in a house with gas stove cooking have a 42 percent increase in risk for current asthma and 24 percent increased risk for lifetime asthma.[17] The health risk of exposure to emissions from a gas stove is higher for children living in multifamily housing, including the higher likelihood of wheezing, shortness of breath, and chest tightness.[18]

While ventilation can reduce the impacts of indoor pollutants, electrification provides a more comprehensive solution. Research shows that newer homes that utilize mechanical ventilation systems have lower pollutant concentrations than older homes.[19] However, kitchen ventilation, where it exists, is only used while cooking in 36 percent of homes and 28 percent of low-income apartments.[20] In addition, electrification may be more beneficial for mitigating exposure to cooking pollution for lower-income households that are more likely to have elevated cumulative exposure from outdoor pollution sources, such as traffic and industry. Households in under-resourced communities also tend to live in smaller units with higher

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[13] Bhangar, S., N.A. Mullen, S.V. Hering, N.M. Kreisberg, and W.W. Nazaroff. 2011."Ultrafine Particle Concentrations and Exposures in Seven Residences in Northern California."*Indoor Air* Volume 21, pp. 132-144. Available at: *https://onlinelibrary.wiley.com/doi/10.1111/j.1600-0668.2010.00689.x*.

[14] Buonanno, G., L. Stabile, and L. Morawska. 2014. *"Personal Exposure to Ultrafine Particles: The Influence of Time-Activity Patterns." Science of the Total Environment* Volume 468-469, pp. 903-907. Available at: *https://www.sciencedirect.com/science/article/abs/pii/S0048969713010449*.

[15] Dennekamp, M., S. Howarth, C. A. J. Dick, J. W. Cherrie, K. Donaldson, and A. Seaton. 2001. "Ultrafine Particles and Nitrogen Oxides Generated By Gas and Electric Cooking." *Occupational and Environmental Medicine* Volume 58, pp. 511-516. Available at: *https://oem.bmj.com/content/oemed/58/8/511.full.pdf*.

[16] Schraufnagel, D. E. 2020. "The Health Effects of Ultrafine Particles." *Experimental and Molecular Medicine* Volume 52, pp. 311-317. Available at: *https://www.nature.com/articles/s12276-020-0403-3*.

[17] Lin, W., B. Brunekreef, and U. Gehring. 2013. "Meta-Analysis of the Effects of Indoor Nitrogen Dioxide and Gas Cooking on Asthma and Wheeze in Children." I*nternational Journal of Epidemiology* Volume 42, 6, pp. 1724-1737. Available at: *https://pubmed.ncbi.nlm.nih.gov/23962958/*.

[18] Belanger, K., J. F. Gent, E. W. Triche, M.B. Bracken, and B. P. Leaderer. 2006. "Association of Indoor Nitrogen Dioxide Exposure with Respiratory Symptoms in Children with Asthma" *American Journal of Respiratory and Critical Care Medicine* Volume 173, 3, pp. 297-303. Available at: *https://pubmed.ncbi.nlm.nih.gov/16254270/*.

[19] Singer, B. C., W. R. Chan, Y. Kim, F. J. Offermann, and I. S. Walker. 2020. "Indoor Air Quality in California Homes with Code-Required Mechanical Ventilation." *Indoor Air*. Available at: *https://onlinelibrary.wiley.com/doi/abs/10.1111/ina.12676*.

[20] Zhao, H., W. R. Chan, W. W. Delp, H. Tang, I. S. Walker, and B.C. Singer. 2020. "Factors Impacting Range Hood Use in California Houses and Low-Income Apartments." *International Journal of Environmental and Public Health* Volume 17, 23. Available at: *https://www.mdpi.com/1660-4601/17/23/8870*.

occupant density, have insufficient ventilation or ventilation systems that do not meet operational performance requirements, and may use gas ovens as heating sources, all of which can lead to very high pollutant concentrations.[21] [22] [23]

ii. Outdoor Air Quality

Building decarbonization can help California meet air quality standards. In California, the ambient air quality in 40 out of 58 counties does not meet federal air quality standards for safe levels of PM2.5 and ozone.[24] Combustion of natural gas in residential and commercial buildings in California is projected to contribute to 66.3 tons of NOx per day in 2022, about four times the emissions from power plants and nearly two-thirds those from petroleum-fueled light-duty vehicles.[25] In addition, natural gas burned in residential and commercial buildings is projected to contribute to 55.1 and 7.7 tons of CO and PM2.5 per day in 2022, respectively.[26]

3. Feasibility

This section summarizes critical factors of building decarbonization feasibility—technical feasibility, costs and cost-savings, and consumer adoption and awareness—in order to identify barriers and opportunities to help accelerate the decarbonization of buildings.

a) Technical Feasibility

Electric alternatives to natural gas appliances are technically ready to deploy in several applications but there are some technologies that need further development to address

[21] Zhao, H., W. R. Chan, S. Cohn, W. W. Delp, I. S. Walker, and B. C. Singer. 2021."Indoor Air Quality in New and Renovated Low-Income Apartments with Mechanical Ventilation and Natural Gas Cooking in California." *Indoor Air* Volume 31, pp. 717-729. Available at: *https://pubmed.ncbi.nlm.nih.gov/33070378/*.

[22] Seals, B., A. Kasner, R. Golden, B. Gottlieb, and B. Nilles. 2020. "*Health Effects from Gas Stove Pollution.*" *Rocky Mountain Institute*, Available at: *https://rmi.org/insight/gas-stoves-pollution-health*.

[23] Lebel, E. D., C. J. Finnegan, Z. Ouyang, and R. B. Jackson. 2021. "Methane and NOx Emissions from Natural Gas Stoves, Cooktops, and Ovens in Residential Homes." *Environmental Science & Technology*, p. 11. Available at: *https://pubs.acs.org/doi/10.1021/acs.est.1c04707*.

[24] US EPA. 2021. *Current Nonattainment Counties for All Criteria Pollutants*. Available at: *https://www3.epa.gov/airquality/greenbook/ancl.html*.

[25] CARB. 2022. *CARB Criteria Emission Inventory CEPAM 2022 v1.01 - Standard Emission Tool.* Available at: *https://www.arb.ca.gov/app/emsinv/fcemssumcat/fcemssumcat2016.php*.

[26] Ibid.

barriers to adoption. Table 1-5 summarize the current technical readiness of different technologies by end-use and application.

Technology continues to evolve to address market barriers, especially with respect to heat pump appliances. For example, manufacturers are developing lower voltage heat pump appliances—without a backup electric resistance unit so it relies solely on the heat pump—that can run on lower amperage circuits to reduce the need for upgrading electric service panels, which is a barrier for electrification of multiple end-uses in some existing buildings. [27] Combination space and water heating technologies are emerging and suitable for many building types. Additionally, manufacturers are making technological advancements to improve heat pump efficiency in cold climates since early models had difficulty operating in sub-freezing temperatures.[28] Heat pump manufacturers are also investigating alternatives to typically used high-global warming potential (GWP) refrigerants since replacing natural gas appliances with heat pump technologies could cause emissions from high-GWP refrigerants to grow in ways that offset some of the climate benefits of electrification. For instance, manufacturers have developed commercially available heat pump water heaters that utilize carbon dioxide[29] as the refrigerant, and these systems perform very well in cold ambient conditions without the need for backup supplemental heating.

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[27] Sathe, A., K. Maoz, J. Aquino, A. Pande, and F. Keneipp. 2020. "Fuel Substitution Forecasting Tools: Methods Supporting Senate Bill 350 Analysis." *California Energy Commission*. Publication Number: CEC-200-2020-001. Available at: *https://efiling.energy.ca.gov/GetDocument.aspx?tn=233241&DocumentContentId=65725*.

[28] Gartman, M., and A. Shah. 2020. "Heat Pumps: A Practical Solution for Cold Climates." *RMI*. Available at: *https://rmi.org/heat-pumps-a-practical-solution-for-cold-climates/*.

[29] Carbon dioxide is a refrigerant which has a very low global warming potential of one.

Table 1 Technical readiness of zero-emission space conditioners[30] [31] [32] [33]

Technology	*Building Types**	*Status*	*Challenges*
Air Source Heat Pumps	SF, MF, SC, LC, SI	Fully ready and widely available. Three to five times more energy efficient than traditional gas heating and electric resistance air conditioning systems.	Risk of operating in energy-intensive electric resistance mode in colder climates. Split-systems may require ductwork replacement in retrofits. Packaged terminal systems may have difficulty conditioning the interior core of larger buildings. Roof area may be limited for packaged rooftop units.
Heat Recovery Chiller	LC, SI	Fully ready and widely available.	Requires simultaneous heating and cooling loads. Potential siting barriers for retrofits.
Variable Refrigerant Flow	MF, SC, LC, SI	Fully ready and widely available.	Low-GWP refrigerant options are not available. Long refrigerant lines can result in significant refrigerant leakage.
Geothermal Heat Pump	SF, MF, SC, LC, SI	Fully ready; performs well in colder climates.	Lack of consumer awareness and experienced designers and installers.
Electric Resistance Boiler	SF, MF, SC, LC, SI	Decades old and widely available.	More energy-intensive than heat pump systems.
Combination Systems	SF, MF, SC, LC, SI	Emerging; not widely available.	Product availability is main barrier.

*SF: single family home; MF: multifamily home; SC: small commercial; LC: large commercial; SI: schools and institutions

[30] U.S. DOE. Accessed on 11 January 2022. "Heat Pump Systems." *Energy Saver*. Available at: https://www.energy.gov/energysaver/heat-pump-systems.

[31] Redwood Energy. 2021. "A Pocket Guide to All-Electric Retrofits of Single-Family Homes." *Menlo Spark*. Available at: https://redwoodenergy.net/wp-content/uploads/2021/02/Pocket-Guide-to-All-Electric-Retrofits-of-Single-Family-Homes.pdf.

[32] Sathe, A., K. Maoz, J. Aquino, A. Pande, and F. Keneipp. 2020. "Fuel Substitution Forecasting Tools: Methods Supporting Senate Bill 350 Analysis." *California Energy Commission*. Publication Number: CEC-200-2020-001. Available at: https://efiling.energy.ca.gov/GetDocument.aspx?tn=233241&DocumentContentId=65725.

[33] Miller, A., and C. Higgins. 2021. "The Building Electrification Technology Roadmap." *New Buildings Institute*. Available at: https://newbuildings.org/resource/building-electrification-technology-roadmap/

Table 2 Technical readiness of zero-emission building water heaters[34] [35] [36]

Technology	***Building Types****	***Status***	***Challenges***
Heat Pump Water Heater	SF, MF, SC, LC, SI	Fully ready and widely available. Two to four times more energy efficient than traditional gas and electric resistance heaters. Emerging products are available with low-GWP refrigerants.	Require significant manufacturing increases to meet expected demand.
On-Demand Electric Resistance	SF, MF	Widely available and reliable for space-constrained installations.	Energy-intensive making them a lower priority for building decarbonization.

*SF: single family home; MF: multifamily home; SC: small commercial; LC: large commercial; SI: schools and institutions

Table 3 Technical readiness of zero-emission swimming pool water heaters[37] [38]

Technology	***Building Types****	***Status***	***Challenges***
Heat Pump Pool Heater	SF, MF, SI	Widely available. Provides heating year-round. Reduces energy use by using ambient heat in the air.	Heat pump pool heaters only work efficiently when the outside temperature remains above 45-50˚F.
Solar Thermal	SF, MF, SI	Reduces energy use by heating water directly from the sun.	Limited to providing heating 5 to 8 months out of the year.

*SF: single family home; MF: multifamily home; SC: small commercial; LC: large commercial; SI: schools and institutions

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[34] Sathe, A., K. Maoz, J. Aquino, A. Pande, and F. Keneipp. 2020. "Fuel Substitution Forecasting Tools: Methods Supporting Senate Bill 350 Analysis." *California Energy Commission*. Publication Number: CEC-200-2020-001. Available at: *https://efiling.energy.ca.gov/GetDocument.aspx?tn=233241&DocumentContentId=65725*.

[35] Miller, A., and C. Higgins. 2021. "The Building Electrification Technology Roadmap." *New Buildings Institute*. Available at: *https://newbuildings.org/resource/building-electrification-technology-roadmap/*.

[36] U.S. DOE. Accessed on 11 January 2022. "Heat Pump Systems." *Energy Saver*. Available at: *https://www.energy.gov/energysaver/heat-pump-systems*.

[37] Ibid.

[38] Redwood Energy. 2021. "A Pocket Guide to All-Electric Retrofits of Single-Family Homes." *Menlo Spark*. Available at: *https://redwoodenergy.net/wp-content/uploads/2021/02/Pocket-Guide-to-All-Electric-Retrofits-of-Single-Family-Homes.pdf*.

Table 4 Technical readiness of zero-emission cooking equipment[39] [40]

Technology	***Building Types****	***Status***	***Challenges***
Radiant	SF, MF, SC, LC, SI	Decades old and widely available.	Poor responsiveness, long cool-down time after cooking, and lower efficiency. Not recommended from emissions perspective.
Induction	SF, MF, SC, LC, SI	Readily available off-the-shelf. Units are more efficient than radiant electric ranges.	Lack of knowledge about the performance and safety benefits are limiting uptake.
Electric Foodservice Appliances	SC, LC, SI	Electric ovens, fryers, griddles, broilers, and food warmers are widely available.	May require retraining or cooking changes as performance characteristics can differ from gas equipment.

*SF: single family home; MF: multifamily home; SC: small commercial; LC: large commercial; SI: schools and institutions

[39] Sathe, A., K. Maoz, J. Aquino, A. Pande, and F. Keneipp. 2020. "Fuel Substitution Forecasting Tools: Methods Supporting Senate Bill 350 Analysis." *California Energy Commission*. Publication Number: CEC-200-2020-001. Available at: *https://efiling.energy.ca.gov/GetDocument.aspx?tn=233241&DocumentContentId=65725*.

[40] Miller, A., and C. Higgins. 2021. "The Building Electrification Technology Roadmap." *New Buildings Institute*. Available at: *https://newbuildings.org/resource/building-electrification-technology-roadmap/*.

Table 5 Technical readiness of zero-emission clothes dryers[41]

Technology	***Building Types****	***Status***	***Challenges***
Combination Washer and Dryer	SF, MF, SC	Readily available, but uncommon in U.S. Offers a space-saving advantage. Condensing units cut energy use in half compared to electric resistance.	Water usage of condensing units is higher than standard washers. Available with a heat pump dryer, but they are rare.
Heat Pump Clothes Dryer	SF, MF	Technically ready. Use 60 percent less energy than electric resistance and 30-40 percent less energy than ENERGY STAR rated electric resistance.	Smaller capacities and longer run times that have hindered their adoption rates nationally.
Electric Resistance Clothes Dryer	SF, MF, SC, LC, SI	Decades old and widely available. ENERGY STAR options use 20 percent less energy.	Requires venting to the outdoors.

*SF: single family home; MF: multifamily home; SC: small commercial; LC: large commercial; SI: schools and institutions

[41] Ibid.

b) Costs and Cost-Savings of Building Decarbonization

This section identifies near-term opportunities for cost-savings, cost barriers with potential solutions, and considerations of how building decarbonization may impact low-income households. The costs and potential cost-savings of building decarbonization vary by end use and by whether decarbonization is undertaken in new construction or in existing buildings.

i. Appliance and Equipment Capital Costs

Electric alternatives to natural gas appliances and equipment are becoming increasingly cost-competitive.[42] [43] [44] [45] Heat pump space conditioners—which provide both heating and cooling—are less expensive to purchase than furnace and air conditioning systems combined but may cost more when compared solely with a furnace.[46] [47] [48] [49] With respect to water heaters, heat pump water heaters are similarly priced as tankless gas water heaters and more expensive than traditional gas storage water heaters, but in some cases can provide lifetime

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[42] Allied Market Research. 2020. "Heat Pump Market by Type (Air-to-Air, Water Source, and Geothermal) and Application (Residential, Industrial, and Commercial): Global Opportunity Analysis and Industry Forecast, 2019-2026." Available at: *https://www.alliedmarketresearch.com/heat-pump-market*.

[43] Future Market Insights. 2021. *Heat Pumps Market.* Available at: *https://www.futuremarketinsights.com/reports/heat-pumps-market*.

[44] Markets and Markets. 2021 "Heat Pump Market by Type (Air-to-Air and Air-to-Water), Rated Capacity (Up to 10 kW, 10–20 kW, 20–30 kW, and Above 30 kW), End-User (Residential, Commercial, and Industrial), and Region (North America, Europe, APAC, and RoW) - Global Forecast to 2023." Available at: *https://www.marketresearch.com/MarketsandMarkets-v3719/Heat-Pump-Type-Air-Water-30880276/*.

[45] Technavio. 2021. $11 BN Growth Expected in Heat Pump Market Between 2021 and 2025. Cision PRNewswire. Available at: *https://www.prnewswire.com/news-releases/-11-bn-growth-expected-in-heat-pump-market-between-2021-and-2025--analysing-growth-in-industrial-machinery-industry--17-000-technavio-research-reports-301391224.html*.

[46] Mahone, A., C. Li, Z. Subin, M. Sontag, G. Mantegna, A. Karolides, A. German, and P. Morris. 2019. "Residential Building Electrification in California: Consumer Economics, Greenhouse Gases, and Grid Impacts." *Energy and Environmental Economics, Inc.* Available at: *https://www.ethree.com/wp-content/uploads/2019/04/E3_Residential_Building_Electrification_in_California_April_2019.pdf*.

[47] Billimoria, S., L. Guccione, M. Henchen, L. Louise-Prescott. 2018. "The Economics of Electrifying Buildings: How Electric Space and Water Heating Supports Decarbonization of Residential Buildings." *RMI.* Available at: *https://rmi.org/insight/the-economics-of-electrifying-buildings/*.

[48] Deason, J., M. Wei, G. Leventis, S. J. Smith, and L. C. Schwartz. 2018. "*Electrification of Buildings and Industry in the United States: Drivers, Barriers, Prospects, and Policy Approaches." Ernest Orlando Lawrence Berkeley National Laboratory.* Available at: *https://emp.lbl.gov/publications/electrification-buildings-and*.

[49] TRC. 2016."Palo Alto Electrification Final Report." *City of Palo Alto.* Available at: *https://www.cityofpaloalto.org/files/assets/public/development-services/advisory-groups/electrification-task-force/palo-alto-electrification-study-11162016.pdf*

bill savings.[50] [51] The cost of natural gas stoves is comparable to electric resistance stoves, but induction stoves are more expensive and may require purchasing new cookware.[52] However, induction stoves are a more energy efficient option for cooking and provide a better user experience.[53] [54] Finally, the cost of electric resistance clothes dryers is comparable to natural gas clothes dryers, but heat pump clothes dryers cost more.[55] Statewide actions focused on increased funding for incentive programs would help to overcome barriers of added upfront costs allowing installation of the most energy-efficient electric appliances possible to meet the State's GHG reduction goals.[56]

ii. Energy Costs

Energy costs are a critical determinant of the long-run cost of decarbonization.[57] However, these costs depend on the characteristics of the appliances and buildings, as well as different usage and preferences by consumers. Furthermore, annual energy bills vary by region due to climate variation and differing utility rates, although gas rates tend to be lower than electricity

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[50] Navigant Consulting, Inc. 2018. "Impacts of Residential Appliance Electrification". *California Building Industry Association*. Available at: *https://drive.google.com/file/d/14cFig3V_G_scSpSJggrI2RcXFhbgx593/view*.
[51] Mahone, A., C. Li, Z. Subin, M. Sontag, G. Mantegna, A. Karolides, A. German, and P. Morris. 2019. "Residential Building Electrification in California: Consumer Economics, Greenhouse Gases, and Grid Impacts." *Energy and Environmental Economics, Inc.* Available at: *https://www.ethree.com/wp-content/uploads/2019/04/E3_Residential_Building_Electrification_in_California_April_2019.pdf*.
[52] Ibid.
[53] Miller, A., and C. Higgins. 2021. "The Building Electrification Technology Roadmap." *New Buildings Institute*. Available at: *https://newbuildings.org/resource/building-electrification-technology-roadmap/*.
[54] Hope, P. 2021. "Gas or Electric Range: Which Is Better?" *Consumer Reports*. Available at: *https://www.consumerreports.org/ranges/gas-or-electric-range-which-is-better-a1142956590/*.
[55] Mahone, A., C. Li, Z. Subin, M. Sontag, G. Mantegna, A. Karolides, A. German, and P. Morris. 2019. "Residential Building Electrification in California: Consumer Economics, Greenhouse Gases, and Grid Impacts." *Energy and Environmental Economics, Inc.* Available at: *https://www.ethree.com/wp-content/uploads/2019/04/E3_Residential_Building_Electrification_in_California_April_2019.pdf*.
[56] Lamm, T., and E. N. Elkind. 2021. "Building Toward Decarbonization: Policy Solutions to Accelerate Building Electrification in High-Priority Communities." *Berkeley Law Center for Law, Energy & the Environment; UCLA Emmett Institute on Climate Change & the Environment; Climate Change and Business Research Initiative*. Available at: *https://www.ourenergypolicy.org/resources/building-toward-decarbonization-policy-solutions-to-accelerate-building-electrification-in-high-priority-communities/*.
[57] Mahone, A., C. Li, Z. Subin, M. Sontag, G. Mantegna, A. Karolides, A. German, and P. Morris. 2019. "Residential Building Electrification in California: Consumer Economics, Greenhouse Gases, and Grid Impacts." *Energy and Environmental Economics, Inc.* Available at: *https://www.ethree.com/wp-content/uploads/2019/04/E3_Residential_Building_Electrification_in_California_April_2019.pdf*.

rates on a cost per unit energy basis.[58] [59] Even though electric alternatives are more energy efficient than their natural gas counterparts, the relatively high cost of electricity compared to natural gas in investor-owned utility (IOU) territories means that a switch to electric appliances may increase energy bill costs depending on the climate zone, customer use patterns, gas market dynamics and prices, and rate structure. Recent IOU studies submitted to the California Public Utilities Commission (CPUC), which are currently pending review, present a mixed picture in terms of bill impacts resulting from fuel-switching depending on a variety of such factors. The impacts on individual customers can vary depending on user profile. For instance, according to an E3 study, 87% of single-family homes that already have air conditioners and retrofit these to heat pumps are likely to see bill savings.[60] Similarly, some households served by publicly owned utilities (POUs) are expected to experience energy bill savings by switching to electrified end-uses because POU electric rates tend to be lower (per unit energy output) than their natural gas rate.

These trends have a number of implications for supporting the transition to all-electric buildings. Other factors, such as on-site solar energy generation, managing and shifting demand, and energy efficiency, could reduce ongoing energy costs by reducing energy demand.[61] [62] [63] Since the 1970's, building energy efficiency standards in combination with appliance energy efficiency standards have saved California consumers more than $100 billion in utility bills.[64] Additionally, statewide actions focused on ensuring energy rates are designed

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[58] Navigant Consulting, Inc. 2018. "Impacts of Residential Appliance Electrification". *California Building Industry Association*. Available at: *https://drive.google.com/file/d/14cFig3V_G_scSpSJggrI2RcXFhbgx593/view*.

[59] Decarbonization is cost-effective for homes transitioning away from propane or heating oil.

[60] Mahone, A., C. Li, Z. Subin, M. Sontag, G. Mantegna, A. Karolides, A. German, and P. Morris. 2019. "Residential Building Electrification in California: Consumer Economics, Greenhouse Gases, and Grid Impacts." *Energy and Environmental Economics, Inc*. Available at: *https://www.ethree.com/wp-content/uploads/2019/04/E3_Residential_Building_Electrification_in_California_April_2019.pdf*.

[61] Billimoria, S., L. Guccione, M. Henchen, L. Louise-Prescott. 2018. "The Economics of Electrifying Buildings: How Electric Space and Water Heating Supports Decarbonization of Residential Buildings." *RMI.* Available at: *https://rmi.org/insight/the-economics-of-electrifying-buildings/*.

[62] Frontier Energy. 2021. "2019 Cost-Effectiveness Study: Existing Single Family Residential Building Upgrades." Available at: *https://frontierenergy.com/wp-content/uploads/2019-Cost-Effectiveness-Study-Existing-Single-Family-Residential-Building-Upgrades-report.pdf*.

[63] Sathe, A., K. Maoz, J. Aquino, A. Pande, and F. Keneipp. 2020. "Fuel Substitution Forecasting Tools: Methods Supporting Senate Bill 350 Analysis." *California Energy Commission.* Publication Number: CEC-200-2020-001. Available at: *https://efiling.energy.ca.gov/GetDocument.aspx?tn=233241&DocumentContentId=65725*.

[64] CEC. 2019. *Achieving Energy Efficiency.* Available at: *https://www.energy.ca.gov/about/core-responsibility-fact-sheets/achieving-energy-efficiency#:~:text=The%20Energy%20Commission%20established%20targets,benefiting%20from%20energy%20efficiency%20measures*

to support electrification,[65] [66] [67] [68] promoting load management programs, and establishing flexible demand appliance standards would help to lower current energy costs moving forward to support building decarbonization.

iii. New Construction Costs

All-electric new construction is one of the most cost-effective near-term applications for building decarbonization efforts. Several studies estimate that the costs of constructing all-electric homes are lower than constructing mixed-fuel[69] new homes, primarily due to the avoided costs of natural gas infrastructure at the building site, with cost savings in the range

[65] Mahone, A., C. Li, Z. Subin, M. Sontag, G. Mantegna, A. Karolides, A. German, and P. Morris. 2019. "Residential Building Electrification in California: Consumer Economics, Greenhouse Gases, and Grid Impacts." *Energy and Environmental Economics, Inc.* Available at: *https://www.ethree.com/wp-content/uploads/2019/04/E3_Residential_Building_Electrification_in_California_April_2019.pdf*.
[66] Mahone, A., Z. Subin, J. Kahn-Lang, D. Allen, V. Li, G. De Moor, N. Ryan, and S. Price. 2018. "Deep Decarbonization in a High Renewables Future: Updated Results from the California PATHWAYS Model." *California Energy Commission*. Publication Number: CEC-500-2018-012. Available at: *https://www.energy.ca.gov/publications/2018/deep-decarbonization-high-renewables-future-updated-results-california-pathways*.
[67] Deason, J., M. Wei, G. Leventis, S. Smith, and L. Schwartz. 2018. "Electrification of Buildings and Industry in the United States: Drivers, Barriers, Prospects, and Policy Approaches." Lawrence Berkeley National Laboratory, U.S. Department of Energy. Available at: *https://eta-publications.lbl.gov/sites/default/files/electrification_of_buildings_and_industry_final_0.pdf*.
[68] Building Decarbonization Coalition. 2020 "Rapid Building Decarbonization: 10 Policy Recommendations for California's Leadership." Available at: *http://www.buildingdecarb.org/uploads/3/0/7/3/30734489/10_policies_for_rapid_decarbonization_final.pdf*.
[69] Mixed-fuel refers to a building that typically uses natural gas or propane and electricity.

of $2,000 to $10,000 per unit.[70] [71] [72] [73] [74] When factoring in energy costs, all-electric new home construction also reduces costs over the lifetime of appliances when compared to fossil-fueled homes.[75] All-electric new construction of smaller, nonresidential buildings, such as medium office, medium retail, and small hotels, can be cost-effective when combined with energy efficiency measures.[76] Statewide actions focused on strengthening California's state standards and local building requirements to support all-electric new construction provide an important opportunity because it is less costly to build, avoids new pipeline costs to ratepayers, and avoids expensive retrofits later.

iv. Retrofit Costs

Overall, building decarbonization in existing buildings can require new investments related to replacement equipment, installation, and, in certain situations, electrical panel upgrades. Installation costs account for labor, electrical circuits, wiring, ductwork modifications in attics or closet locations and other miscellaneous supplies to make zero-emission equipment fully operational.[77] There may be additional potential costs associated with building retrofits for

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[70] Mahone, A., C. Li, Z. Subin, M. Sontag, G. Mantegna, A. Karolides, A. German, and P. Morris. 2019. "Residential Building Electrification in California: Consumer Economics, Greenhouse Gases, and Grid Impacts." *Energy and Environmental Economics, Inc.* Available at: *https://www.ethree.com/wp-content/uploads/2019/04/E3_Residential_Building_Electrification_in_California_April_2019.pdf*.

[71] Billimoria, S., L. Guccione, M. Henchen, L. Louise-Prescott. 2018. "The Economics of Electrifying Buildings: How Electric Space and Water Heating Supports Decarbonization of Residential Buildings." *RMI.* Available at: *https://rmi.org/insight/the-economics-of-electrifying-buildings/*.

[72] TRC. 2016."Palo Alto Electrification Final Report." *City of Palo Alto*. Available at: *https://www.cityofpaloalto.org/files/assets/public/development-services/advisory-groups/electrification-task-force/palo-alto-electrification-study-11162016.pdf*.

[73] Frontier Energy. 2019. "2019 Cost-effectiveness Study: Low-Rise Residential New Construction". *California Energy Codes and Standards: A Statewide Utility Program*. Available at: *https://localenergycodes.com/download/73/file_path/fieldList/2019%20Res%20NC%20Cost-eff%20Report.pdf*.

[74] TRC. 2018. "City of Palo Alto 2019 Title 24 Energy Reach Code Cost Effectiveness Analysis DRAFT" *City of Palo Alto*. Available at: *https://www.cityofpaloalto.org/files/assets/public/development-services/green-building-files/2019-palo-alto-reach-code-cost-effectiveness-20180914.pdf*.

[75] Billimoria, S., L. Guccione, M. Henchen, L. Louise-Prescott. 2018. "The Economics of Electrifying Buildings: How Electric Space and Water Heating Supports Decarbonization of Residential Buildings." *RMI.* Available at: *https://rmi.org/insight/the-economics-of-electrifying-buildings/*.

[76] TRC. 2019. "2019 Nonresidential New Construction Reach Code Cost Effectiveness Study." *California Energy Codes and Standards.* Available at: *https://localenergycodes.com/download/74/file_path/fieldList/2019%20NR%20NC%20Cost%20Effectiveness%20Report.pdf*.

[77] Mahone, A., C. Li, Z. Subin, M. Sontag, G. Mantegna, A. Karolides, A. German, and P. Morris. 2019. "Residential Building Electrification in California: Consumer Economics, Greenhouse Gases, and Grid Impacts."

space reconfiguration to provide adequate space for the installation of new equipment. Existing homes may not have adequate electric service panel capacity to convert all gas appliances to electric.[78] When existing buildings require electrical infrastructure upgrades, the range of retrofit costs varies depending on building type, end uses, size, age/condition, existing wiring, and local workforce conditions.

Several studies indicate that the greatest near-term cost-savings opportunity for retrofitting existing buildings is replacing space heating and cooling equipment with heat pump space conditioning.[79] [80] [81] [82] [83] To improve the cost-effectiveness of retrofits, low-amperage water heating technologies may help avoid the need for electrical panel upgrades when the building occupant has limited heating needs.[84] [85] [86] Statewide actions focused on increased funding for retrofit incentive programs, as well as developing and increasing production of zero-emission

Energy and Environmental Economics, Inc. Available at: *https://www.ethree.com/wp-content/uploads/2019/04/E3_Residential_Building_Electrification_in_California_April_2019.pdf*.

[78] Frontier Energy. 2021. "2019 Cost-Effectiveness Study: Existing Single Family Residential Building Upgrades." Available at: *https://frontierenergy.com/wp-content/uploads/2019-Cost-Effectiveness-Study-Existing-Single-Family-Residential-Building-Upgrades-report.pdf*.

[79] Mahone, A., C. Li, Z. Subin, M. Sontag, G. Mantegna, A. Karolides, A. German, and P. Morris. 2019. "Residential Building Electrification in California: Consumer Economics, Greenhouse Gases, and Grid Impacts." *Energy and Environmental Economics, Inc.* Available at: *https://www.ethree.com/wp-content/uploads/2019/04/E3_Residential_Building_Electrification_in_California_April_2019.pdf*.

[80] Billimoria, S., L. Guccione, M. Henchen, L. Louise-Prescott. 2018. "The Economics of Electrifying Buildings: How Electric Space and Water Heating Supports Decarbonization of Residential Buildings." *RMI.* Available at: *https://rmi.org/insight/the-economics-of-electrifying-buildings/*.

[81] Deason, J., M. Wei, G. Leventis, S. J. Smith, and L. C. Schwartz. 2018. "*Electrification of Buildings and Industry in the United States: Drivers, Barriers, Prospects, and Policy Approaches.*" *Ernest Orlando Lawrence Berkeley National Laboratory*. Available at: *https://emp.lbl.gov/publications/electrification-buildings-and*.

[82] TRC. 2016."Palo Alto Electrification Final Report." *City of Palo Alto*. Available at: *https://www.cityofpaloalto.org/files/assets/public/development-services/advisory-groups/electrification-task-force/palo-alto-electrification-study-11162016.pdf*.

[83] Nadel, S., and C. Perry. 2020. "Electrifying Space Heating in Existing Commercial Buildings: Opportunities and Challenges." Available at: *https://www.aceee.org/research-report/b2004*.

[84] Kenney, M., N. Janusch, I. Neumann, and M. Jaske. 2021. "California Building Decarbonization Assessment." *California Energy Commission.* Publication Number: CEC-400-2021-006-CMF. Available at: *https://www.energy.ca.gov/publications/2021/california-building-decarbonization-assessment*.

[85] Navigant Consulting, Inc. 2018. "Impacts of Residential Appliance Electrification". *California Building Industry Association.* Available at: *https://drive.google.com/file/d/14cFig3V_G_scSpSJggrI2RcXFhbgx593/view*.

[86] Mahone, A., C. Li, Z. Subin, M. Sontag, G. Mantegna, A. Karolides, A. German, and P. Morris. 2019. "Residential Building Electrification in California: Consumer Economics, Greenhouse Gases, and Grid Impacts." *Energy and Environmental Economics, Inc.* Available at: *https://www.ethree.com/wp-content/uploads/2019/04/E3_Residential_Building_Electrification_in_California_April_2019.pdf*.

appliances that are ready to fit within the existing space and electrical capacity of existing buildings, would help keep retrofit costs down. To achieve the most cost-effective range of benefits for the building occupants, building decarbonization investments could be coupled with other health and habitability improvements (a "whole-building" approach).[87]

v. Implications for Low-Income Households

Building decarbonization efforts are taking place alongside California's ongoing housing affordability and homelessness crisis. One-third of all California households lack sufficient income to cover basic living expenses.[88] This has been exacerbated by the ongoing impacts of the COVID-19 pandemic.[89]

Low-income homeowners are less likely to be able to afford the upfront costs of new electric equipment without extensive support. Because buildings in frontline and low-income communities tend to be older and have more deferred maintenance, the retrofit cost to these homeowners is generally higher than that of higher-income homeowners.[90] [91] To remove cost barriers, statewide actions that prioritize financial support to low-income homeowners, such as the Building Initiative for Low-Emissions Development (BUILD) program,[92] could be expanded to improve access to building decarbonization.

Since landlords are responsible for maintaining and replacing equipment in their properties, renters may not have to pay for the upfront cost to electrify their homes unless costs are passed on through increased rents. Regardless, there is a split-incentive between owners and

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[87] Harwood, M., S. Newlin, K. Velez, M. V. Ralston. 2021. "The Flipside Report: A White Paper on Targeted Geographic Electrification in California's Gas Transition." *Building Decarbonization Coalition*. Available at: *https://www.buildingdecarb.org/uploads/3/0/7/3/30734489/the_flipside_report_-_targeted_electrification_for_gas_transition.pdf*.

[88] Harwood, M., S. Newlin, K. Velez, M. V. Ralston. 2021. "The Flipside Report: A White Paper on Targeted Geographic Electrification in California's Gas Transition." *Building Decarbonization Coalition*. Available at: *https://www.buildingdecarb.org/uploads/3/0/7/3/30734489/the_flipside_report_-_targeted_electrification_for_gas_transition.pdf*.

[89] Samarripas, S., and A. Jarrah. 2021. "A New Lease on Energy: Guidance for Improving Rental Housing Efficiency at the Local Level" *American Council for an Energy-Efficient Economy*. Available at: *https://www.aceee.org/research-report/u2102*.

[90] ARUP. 2021. "Los Angeles Affordable Housing Decarbonization Study Phase 2."Available at: *https://www.nrdc.org/sites/default/files/la-affordable-housing-decarbonization-study-phase2-20211108.pdf*.

[91] Gough, M. 2021. *California's Cities Lead the Way to a Gas-Free Future*. Sierra Club. Available at: *https://www.sierraclub.org/articles/2021/07/californias-cities-lead-way-gas-free-future*.

[92] CEC. Accessed on 19 April 2022. Building Initiative for Low-Emissions Development Program. Available at: *https://www.energy.ca.gov/programs-and-topics/programs/building-initiative-low-emissions-development-program*.

renters when deciding if an energy retrofit should be made to a property.[93] Since building owners typically do not pay energy bills over time, they have little incentive to pay for building retrofits.[94] Incentives to landlords, especially aimed at affordable housing rental units, could help offset the upfront costs of retrofit and could include property tax deduction[95] [96] or grants.[97] However, renovations can heighten housing insecurity, especially if a rent-stabilized unit can be rented at market rate once it is vacated.[98] In some cases, research shows that property owners have used new repair and maintenance requirements as a pretext for displacing tenants or increasing rents.[99] Local jurisdictions could adopt and enforce anti-displacement policies, such as just-cause eviction and tenant right to counsel, and limit or ban the pass-through of decarbonization upgrade costs from building owners to tenants to help ensure that decarbonization policies are not misused in this way.[100] The potential impacts on housing should be considered when designing building decarbonization policies or programs to protect California's most vulnerable populations.

In addition to retrofit costs, electricity rates are often higher than natural gas rates. As a result, higher energy bills due to electrification could burden both low-income homeowners and renters. However, supportive rate structures are beginning to be designed. For example, a recently submitted study by Pacific Gas and Electric Company (PG&E)[101] to the CPUC shows

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[93] Kenney, M., N. Janusch, I. Neumann, and M. Jaske. 2021. "California Building Decarbonization Assessment." *California Energy Commission.* Publication Number: CEC-400-2021-006-CMF. Available at: https://www.energy.ca.gov/publications/2021/california-building-decarbonization-assessment.

[94] Ibid.

[95] Cities throughout California charge a property transfer tax as part of the home buying process. The City of Berkeley provides rebates to home buyers who complete seismic retrofits. In 2021, the City of Berkeley proposed expanding the program to offer rebates to home buyers for building electrification actions.

[96] City of Berkeley. 2021."Existing Buildings Electrification Study." Available at: https://drive.google.com/file/d/10OY_USkF2MeoBkLXuzQEewpW8rAm-WTk/view.

[97] Samarripas, S., and A. Jarrah. 2021. "A New Lease on Energy: Guidance for Improving Rental Housing Efficiency at the Local Level" *American Council for an Energy-Efficient Economy.* Available at: https://www.aceee.org/research-report/u2102.

[98] Harwood, M., S. Newlin, K. Velez, M. V. Ralston. 2021. "The Flipside Report: A White Paper on Targeted Geographic Electrification in California's Gas Transition." *Building Decarbonization Coalition*. Available at: https://www.buildingdecarb.org/uploads/3/0/7/3/30734489/the_flipside_report_-_targeted_electrification_for_gas_transition.pdf.

[99] Nadel, S., and C. Perry. 2020. "Electrifying Space Heating in Existing Commercial Buildings: Opportunities and Challenges." Available at: https://www.aceee.org/research-report/b2004.

[100] Ibid.

[101] PG&E. 2022. "Net Electric and Gas Bill Impact Study for Residential Customers Who Switch from Natural Gas Water Heater to Heat Pump Water Heater, in Compliance with D.21-11-002." *Advice Letter 4571-G/6497-E to Public Utilities Commission of the State of California.* Available at: https://www.pge.com/tariffs/assets/pdf/adviceletter/GAS_4571-G.pdf.

bill savings for a majority of households and nearly all low-income households[102] when switching from gas water heaters to electric heat pump water heaters under the recently approved pro-electrification time-of-use (TOU) rate (E-ELEC).[103][104] This is also because the California Alternate Rates for Energy (CARE) discount for low-income customers for electric service (35%) is higher than for gas service (20%). Southern California Edison's application for a rate adjustment for customers switching from gas water heaters to heat pump systems, and San Diego Gas and Electric's (SDG&E) application for a pro-electrification rate are pending CPUC review. Finally, because some rural and tribal areas within California are not connected to the state's electric grid—nor natural gas infrastructure—but rely instead on propane and wood burning, they need special consideration to ensure they still benefit from building decarbonization policies and programs.[105]

As more households move away from using natural gas, those remaining on the natural gas system are likely to pay an increasingly larger share of systemwide costs,[106] which could further widen the affordability gap between households that are able to decarbonize early and those that are not.

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[102] Here, households on CARE rates are assumed to be low-income.

[103] PG&E's pro-electrification TOU rate (E-ELEC) was approved in CPUC Decision 21-11-016 on November 18, 2021.

[104] CPUC. 2021. "Decision Adopting Marginal Costs, Revenue Allocation, and Rate Designs for Pacific Gas and Electric Company." *California Public Utilities Commission. Decision 21-11-016.* Available at: *https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M424/K378/424378035.PDF*.

[105] Kenney, M., N. Janusch, I. Neumann, and M. Jaske. 2021. "California Building Decarbonization Assessment." *California Energy Commission.* Publication Number: CEC-400-2021-006-CMF. Available at: *https://www.energy.ca.gov/publications/2021/california-building-decarbonization-assessment*.

[106] CARB. 2021. "California Greenhouse Gas Emissions for 2000 to 2019 Trends of Emissions and Other Indicators." Available at: *https://ww3.arb.ca.gov/cc/inventory/pubs/reports/2000_2019/ghg_inventory_trends_00-19.pdf*.

Low-Income Households and Climate Resilience[107]

More frequent extreme weather events from climate change often hit vulnerable and disadvantaged communities hardest and first.[i] More than half (55%) of vulnerable communities in Southern California—those with the lowest levels of air conditioning penetration and affluence—are expected to experience more extreme heat days by the end of the century.[ii] Installation of heat pump space conditioning systems, which provide both efficient heating and cooling, are particularly valuable in frontline communities to improve occupant comfort and increase resilience to heat waves because they are more likely to lack access to air conditioning.[iii]

vi. Implications of Costs and Cost-Savings

Large-scale building decarbonization can assist California with achieving climate and air quality targets, but it has the potential to be very expensive overall. Because of the high cost, it is important to prioritize resources for frontline communities to ensure these communities benefit from building decarbonization. One of the key opportunities to achieve cost-savings is through electrification of new buildings, which is primarily due to the avoided cost of gas infrastructure. To minimize the number of households in existing buildings that may experience increased bill costs, actions that support reduced energy demand—such as weatherization, energy efficiency, and load shifting—along with supportive energy rates would help reduce potential cost burdens to energy customers. Most importantly, low-income households may struggle to afford the transition and risk the potential of displacement. Section 4 will elaborate on potential actions to increase funding for incentives and expand funding to support healthy, whole building retrofits to minimize costs of decarbonization and enable residents to take advantage of the benefits.

[107] References for Low-Income Households and Climate Resilience text box.

[i.] Greenlining Institute. 2021. *Climate Reslience.* Available at: *https://greenlining.org/our-work/environmental-equity/climate-resilience/*.

[ii] Chen, M., G. A. Ban-Weiss, and K. T. Sanders. 2020. "Utilizing Smart-Meter Data to Project Impacts of Urban Warming on Residential Electricity Use for Vulnerable Populations in Southern California." *Environmental Research Letters* Volume 15, 6. Available at: *https://iopscience.iop.org/article/10.1088/1748-9326/ab6fbe*.

[iii] RMI. 2021. *Heat Pumps are the Answer to Heat Waves.* Available at: *https://rmi.org/why-heat-pumps-are-the-answer-to-heat-waves/*.

c) Consumer Adoption and Awareness

Increased consumer adoption of zero-emission appliances and buildings would catalyze the market. Over 70 percent of California's households still rely on natural gas for space heating, water heating, and cooking, and nearly 40 percent rely on gas for clothes drying.[108] [109] Although only 5 percent of California single-family homes use natural gas swimming pool heaters, these appliances consume over six times the energy of natural gas range/ovens on a per unit basis.[110] Consumer preference for appliances they are already familiar with is a major barrier to full-scale electrification.[111] Many utilities offer incentives for high-efficiency heat pump and induction cooking technologies, but adoption has been limited due to the low cost of natural gas prior to 2021, extensive network of natural gas infrastructure in urban areas, and a lack of consumer and contractor awareness.[112] [113] Over half of Californians are not familiar with heat pump or induction technologies, yet they show strong preference for appliances powered by clean, renewable energy rather than fossil fuels.[114] Thus, actions that increase consumer awareness of the zero-emission technologies and their value should help drive demand and lower prices.

Rising electric rates can, in turn, make it less appealing for customers to invest in building decarbonization. Another barrier to consumer adoption is the potential for public safety power shutoffs (PSPS) to mitigate wildfire risk, which can make consumers—especially those in more fire-prone areas—reluctant to switch to all-electric appliances. However, many gas appliances also will not work when there is no electric power, and the price of natural gas has been volatile. While PSPS have increased in the past couple of years, they are not a viable longer-term strategy for dealing with wildfire risk given the significant negative impacts on

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[108] This varies by building type and end use. For instance, in single-family homes, nearly 90 percent of water heaters, 80 percent of space heaters, and 75 percent of cooking stoves are fueled by gas. Multi-family housing tends to have lower natural gas appliance saturation compared to single-family homes.

[109] Palmgren, C., M. Goldberg, B. Ramirez, and C. Williamson. 2021. "2019 California Residential Appliance Saturation Survey (RASS)." *California Energy Commission*. Publication Number: CEC-200-2021-005. Available at: *https://www.energy.ca.gov/publications/2021/2019-california-residential-appliance-saturation-study-rass*.

[110] Ibid.

[111] Miller, A., and C. Higgins. 2021. "The Building Electrification Technology Roadmap." *New Buildings Institute*. Available at: *https://newbuildings.org/resource/building-electrification-technology-roadmap/*.

[112] Ibid.

[113] Mahone, A., C. Li, Z. Subin, M. Sontag, G. Mantegna, A. Karolides, A. German, and P. Morris. 2019. "Residential Building Electrification in California: Consumer Economics, Greenhouse Gases, and Grid Impacts." *Energy and Environmental Economics, Inc.* Available at: *https://www.ethree.com/wp-content/uploads/2019/04/E3_Residential_Building_Electrification_in_California_April_2019.pdf*.

[114] Metz, D., and M. Everitt. 2020. "California Voter Views of Building Decarbonization" *FM3 Research*. Available at: *https://fm3research.com/wp-content/uploads/2020/03/California-Electrification-Survey-Results-Memo.pdf*.

customers, and the CPUC and Office of Energy Infrastructure Safety are working to reduce the frequency of PSPS events. Also, load shifting and on-site solar panels in combination with energy storage can improve resilience to these events and may help to increase consumer adoption of zero-emission appliances and buildings. Therefore, statewide actions aimed at expanding incentives that support whole building retrofits that include energy storage, load shifting, and on-site energy generation could help to improve consumer adoption of zero-emission technologies.

4. Potential Actions to Support a Successful Transition to Building Decarbonization

Achieving the scale of emission reductions necessary from California's building sector requires a holistic approach encompassing many actions that expand construction of zero-emission buildings and increase production and use of zero-emission appliances. Additional actions can help build a sustainable market, including increasing affordability and accessibility and increasing consumer education. Moving forward, harmonization of new and existing actions across all levels of government is needed to send clear, cohesive signals to market actors about the direction of building decarbonization. Additional actions are needed to involve stakeholders early and continuously to ensure frontline communities benefit equitably from building decarbonization. Additional potential actions focused on electric grid capacity and stability and workforce development would also complement the actions included in this appendix. Chapter 4 of the Draft Scoping Plan summarizes the sector transformation needed and the actions that support building decarbonization. This section includes detail on potential actions that would support moving away from natural gas and advancing zero-emission buildings and appliances followed by those that would help to build a sustainable market. All of these actions are identified as potential because they would be evaluated through full public processes, as required and appropriate, before implementation. They are not mandated by this document, but instead are offered as paths forward.

a) Scale Back Natural Gas Infrastructure

Utilities encourage the use of natural gas in buildings through hundreds of millions of ratepayer dollars annually allocated to various incentives including subsidies for new gas line connections and maintenance of the existing system.[115] [116] [117] [118] [119] Redirecting resources away from investments that incentivize gas demand, and toward aligned public investments that accelerate building electrification, will help phase out traditional combustion technologies and associated climate impacts and pollution.[120] Furthermore, new installations of natural gas infrastructure will become financial burdens to customers and utilities as the gas demand and customer base decreases due to decarbonization, and utilities will likely pass the maintenance and stranded costs to the remaining customer base through rate increases.[121]

To help address this, in November 2021, the CPUC released a Staff Proposal in the ongoing building decarbonation proceeding (R.19-01-011 Phase III) that would eliminate IOUs' natural gas-related incentives for developers to defray the cost of extending gas mains and service lines to all new buildings.[122] Although this proposal can encourage all-electric new construction and help alleviate future gas rate escalation, development of a long-term

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[115] CPUC. 2022 "Assigned Commisioner's Amended Scoping Memo and Ruling." *California Public Utilities Commission. Rulemaking 20-01-007.* Available at: *https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M436/K692/436692151.PDF*.

[116] Reyes Lagunero, J. C., and D. P. Roach. 2021."Annual Report of Pacific Gas and Electric Company (U 39 M) on the Results of Its Energy Savings Assistance and California Alternate Rates for Energy Programs." *Pacific Gas & Electric Company*. Available at: *https://liob.cpuc.ca.gov/wp-content/uploads/sites/14/2021/05/PGE-PY2020-Annual-Report.pdf*.

[117] Hansson, R. D. 2021. "Amended Annual Report Activity of San Diego Gas & Electric Company (U 902 M) On Low Income Assistance Programs for 2020." San Diego Gas & Electric Company. Available at: *https://liob.cpuc.ca.gov/wp-content/uploads/sites/14/2021/07/A1411007_SDGE-Amended-ESA_CARE-2020-Annual-Report.pdf*.

[118] Lee, S. L. 2021. "Annual Report Activity of Southern California Gas Company (U 904 G) On Low Income Assistance Programs for 2020." *Southern California Gas Company*. Available at: *https://liob.cpuc.ca.gov/wp-content/uploads/sites/14/2021/05/SoCalGas-PY2020-Annual-Report.pdf*.

[119] This estimate does not include multiple millions of dollars per year for natural-gas appliance product rebates and investments on research and infrastructure projects for renewable natural gas.

[120] Gridworks. 2021. "Gas Resource and Infrastructure for California: A Proposed Approach to Long-Term Gas Planning." Available at: *https://gridworks.org/wp-content/uploads/2021/01/CA_Gas_Resource_Infrastructure_Plan_Report_FINAL.pdf*

[121] Aas, D., A. Mahone, Z. Subin, M. Mac Kinnon, B. Lane, and S. Price. 2020. "The Challenge of Retail Gas in California's Low-Carbon Future: Technology Options, Customer Costs, and Public Health Benefits of Reducing Natural Gas Use." *California Energy Commission*. Publication Number: CEC-500-2019-055-F. Available at: *https://www.energy.ca.gov/sites/default/files/2021-06/CEC-500-2019-055-F.pdf*.

[122] CPUC. 2022 "Assigned Commisioner's Amended Scoping Memo and Ruling." *California Public Utilities Commission. Rulemaking 20-01-007.* Available at: *https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M436/K692/436692151.PDF*.

statewide natural gas plan is needed–and under development–to send appropriate market signals for the transition of the energy industry.

This transition must also include the goal of trimming back the existing gas infrastructure so pockets of gas-fueled residential and commercial buildings do not require ongoing maintenance of the entire limb for gas delivery.

b) Advance Zero-Emission Buildings

i. Strengthen California Building Standards

Given the opportunity to save upfront capital costs to electrify new buildings and to avoid the high cost to retrofit later, a key action is to advance building decarbonization in California's Building Standards Code (Title 24) where feasible. New construction of all-electric buildings also helps to avoid investments in what would become stranded assets of gas pipelines that may no longer be in use the next thirty years.[123] Additionally, new buildings constructed after 2020 will represent between 35 percent to 54 percent of total buildings by mid-century. California has a long history of adopting building standards to regulate new construction of buildings as well as additions and alterations to existing buildings. Energy efficiency, as exemplified by California's Energy Code, has been identified by the state as an essential, least-cost means to reduce GHG emissions and achieve the state's climate action goals.

The 2022 Energy Code supports new construction to forgo natural gas appliances by including mandatory electric-ready provisions for single-family homes and encouraging installation of electric heat pumps in both residential and nonresidential buildings. The electric-ready provisions require dedicated circuits and other infrastructure to enable future replacements with electric appliances and apply when natural gas appliances and equipment are installed. Heat pump measures in the 2022 Energy Code encourage building electrification as part of the CEC's performance standards authority through trade-offs using new metrics that value efficient electrification. Moving forward, the Energy Code can continue to identify efficient building decarbonization measures in future code cycles to advance energy efficiency, reduce consumer bills, and significantly reduce GHG emissions—all at the same time.

[123] Harwood, M., S. Newlin, K. Velez, M. V. Ralston. 2021. "The Flipside Report: A White Paper on Targeted Geographic Electrification in California's Gas Transition." *Building Decarbonization Coalition*. Available at: *https://www.buildingdecarb.org/uploads/3/0/7/3/30734489/the_flipside_report_-_targeted_electrification_for_gas_transition.pdf*.

California also has an opportunity to adopt zero-emission building standards for new construction as part of California's Green Building Standards Code (CALGreen). The CALGreen Code improves public health, safety, and general welfare through standards that promote sustainable design and construction of buildings. Based on the significant emission reduction potential, cost-savings, and public health benefits, California could adopt zero-emission building standards for new construction in CALGreen.

Moving forward, California's Legislature could support this effort by providing explicit direction to State agencies to adopt zero-emission building standards for new construction. Mandatory zero-emission building standards for new construction are an essential part of a broader statewide strategy to reduce building emissions and put California on track to achieve carbon neutrality by mid-century.

Local governments have complementary authority to restrict GHG emissions from buildings. An alternative to standards at the state level is the adoption of local "reach" standards, which are building standards included in local municipal codes. Over 50 local jurisdictions have shown their leadership in this area by passing electrification building codes that go beyond California's building standards code.[124] California can support local leadership by developing and supporting voluntary model building standards, for example in CALGreen, that support decarbonization and can be easily adopted by local governments.

ii. Increase Funding for Incentive Programs and Expand Financing Assistance Programs Focused on Buildings

Current incentive programs are insufficient to support the scale of retrofits needed to meet the State's climate goals and tend to not cover the breadth of retrofits required,[125] including service panel upgrades and building weatherization. California IOU ratepayer-funded programs are funding over $500 million—excluding energy efficiency incentives— focused on developing all-electric new housing and switching to efficient electric technologies in existing

[124] Building Decarbonization Coalition. 2021. *Local Government Decarbonization Ordinances in California*. Available at: *https://www.buildingdecarb.org/active-code-efforts.html*.

[125] Lamm, T., and E. N. Elkind. 2021. "Building Toward Decarbonization: Policy Solutions to Accelerate Building Electrification in High-Priority Communities." *Berkeley Law Center for Law, Energy & the Environment; UCLA Emmett Institute on Climate Change & the Environment; Climate Change and Business Research Initiative*. Available at: *https://www.ourenergypolicy.org/resources/building-toward-decarbonization-policy-solutions-to-accelerate-building-electrification-in-high-priority-communities/*.

buildings within IOU territories.[126] [127] [128]Additional funding sources not included in this total include programs from POUs, local governments, and regional air districts. Several federal incentive programs provide financial assistance for energy efficiency upgrades to buildings.[129] [130] [131] [132] Additional public and private funding would complement current state, utility, and local programs aimed at decarbonizing buildings across California, and help bridge the gap in funding needed to meet the state's climate and air quality goals. Incentive programs could include incentives for strategic pruning of the gas system (i.e., outreach programs to electrify all of the homes or businesses in a particular location that would allow for the gas lines serving that neighborhood to be capped and retired.)

Tailoring funding mechanisms to take building and community characteristics into account can also assist with funding building decarbonization. For example, low-income households often lack capital and credit ratings necessary to take advantage of conventional financing. Many low-income households rent rather than own their homes or apartments and are completely reliant upon the landlord to make improvements. Often affordable housing is owned by groups that operate on very low profit margins making justification of improvements difficult. Financing mechanisms could include revolving loans, green bonds, credit enhancements, interest rate buydown, property assessed clean energy,[133] on-bill financing/repayment/tariffs, direct install, tax equity, energy services agreements, and private investments for energy-

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[126] This includes several incentive programs including the Building Initiative for Low-Emissions Development (BUILD) and Technology and Equipment for Clean Heating (TECH) programs. The TECH program offers incentives for service panel upgrades in some cases.

[127] CEC. Accessed on 19 April 2022. Building Initiative for Low-Emissions Development Program. Available at: *https://www.energy.ca.gov/programs-and-topics/programs/building-initiative-low-emissions-development-program*.

[128] TECH Clean California. Accessed on 10 March 2022. About the TECH Initiative. Available at: *https://energy-solution.com/tech/*.

[129] These programs include a loan program for multifamily upgrades through the Fannie Mae Green Financing Loan Program, a loan program for residential buildings through the Energy Efficient Mortgages Program, and a tax deduction for energy efficient commercial building construction through the Energy-Efficient Commercial Buildings Tax Deduction.

[130] Fannie Mae. Accessed on 18 January 2022. Green Financing. Available at: *https://multifamily.fanniemae.com/financing-options/specialty-financing/green-financing*.

[131] FHA. Accessed on 18 January 2022. Energy Efficient FHA Loans. Available at: *https://www.fha.com/energy_efficient*.

[132] U.S. DOE. Accessed on 18 January 2022. Building Technologies Program Tax Deductions for Commercial Buildings. Available at: *https://www1.eere.energy.gov/buildings/publications/pdfs/corporate/bt_comm_tax_credit.pdf*

[133] Property Assessed Clean Energy (PACE) programs offer a way to finance energy efficiency, renewable energy, and water conservation upgrades with an assessment or special tax added to the property tax bill.

efficiency retrofits, such as through California's Green Bank.[134] New financing models could also be developed to help fund building decarbonization such as leveraging private capital through contracts between local governments and private entities.[135] [136] The CPUC opened proceeding R.20-08-022 on financing mechanisms and through it has directed California's IOUs to develop proposals for new financing programs that can meet these and other goals and has invited non-utility stakeholders to propose new financing programs.

iii. Continue Focus on Public Buildings

Decarbonizing public buildings allows testing new technologies at scale and serves as a workforce development and consumer education opportunity to set the stage to decarbonize other building types.[137] California requires new and renovated state buildings to achieve Leadership in Energy and Environmental Design (LEED) "Silver" certification or higher, and all new state buildings and major renovations starting design in 2025 and later to achieve Zero Net Energy (ZNE) performance.[138] Additionally, California's Department of General Services continues to reduce the state government's carbon footprint and mitigate climate risk from the state's owned and leased facilities.[139] Many California local governments have already set stringent standards for public buildings that they occupy. Approximately 80 percent of jurisdictions that have passed local reach building codes specifically include city-owned properties.[140]

While public agencies within California are already taking aggressive action for their own buildings, more can be done. State agencies could focus solely on future actions to support all-electric construction instead of ZNE. While most local codes in California include mandates

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[134] California State Treasurer. 2022. *California's Green Bank.* Available at: *https://www.treasurer.ca.gov/greenbank/index.asp*.

[135] At the local level, the city of Ithaca, New York is the first to approve a plan to electrify all existing buildings in the city, both public and private, using private capital through a city contract to finance low interest loans for energy efficiency measures, appliance replacements, and EV charging.

[136] Harding, T. 2021. "Ithaca Becomes First City in U.S. to Try and Electrify all Buildings." *Ithaca.com.* Available at: *https://www.ithaca.com/news/ithaca/ithaca-becomes-first-city-in-u-s-to-try-and-electrify-all-buildings/article_03c6e998-41bb-11ec-9a84-47a7c90ee120.html*.

[137] Kirk, C. 2021."Los Angeles Building Decarbonization: Tenant Impact and Recommendations." *Strategic Actions for a Just Economy*. Available at: *https://www.saje.net/resources/reports/building-decarbonization/*.

[138] Office of Governor Edmund G. Brown, Jr. *Executive Order B-18-12.* Available at: *https://www.ca.gov/archive/gov39/2012/04/25/news17508/index.html*.

[139] Executive Department State of California. 2019."Executive Order N-19-19." Available at: *https://www.gov.ca.gov/wp-content/uploads/2019/09/9.20.19-Climate-EO-N-19-19.pdf*.

[140] Building Decarbonization Coalition. 2021. *Local Government Decarbonization Ordinances in California.* Available at: *https://www.buildingdecarb.org/active-code-efforts.html*.

that specifically impact jurisdiction-owned properties, all future zero-emission local building codes could include their public facilities as covered building types. Through leading by example, public agencies can incorporate lessons learned from reducing emissions in their own facilities and apply them to broader strategies for the private sector. Public agencies are in a good position to continue leading the charge moving forward.

iv. Develop Building Performance Standards for Existing Buildings

Building performance standards could help decarbonize the existing building stock by requiring building owners to reduce their energy usage or emissions below specified thresholds. Since existing buildings are the main contributor to building-related emissions, action focused on existing buildings would help achieve climate targets. California is in a prime position to develop statewide building performance standards using numerous examples from local jurisdictions—requiring energy conservation measures or post-benchmarking to demonstrate buildings are high-performing, or complete audits, retro-commissioning, and other improvement measures. Some of these building performance standards require that covered buildings demonstrate a sustained decline in GHG emissions periodically at specified target time intervals.

The California Energy Commission (CEC) currently implements a Building Energy Benchmarking Program that requires owners of large buildings to report energy use data every year. This information allows building owners and operators to compare their building's energy use with similar buildings to identify the need to take action to improve energy efficiency. California could develop building performance standards that build upon this program. However, some building owners may not be able to cover costs needed to either meet a performance standard or perform underlying structural and safety upgrades necessary to support the performance standard. Complimentary incentives would help offset costs for building owners.

c) Increase Production and Use of Zero-Emission Appliances

i. Develop Zero-Emission Standards for Appliances

Zero-emission standards for new appliances sold in California could reduce California's building-related GHG emissions and provide important NOx emission reductions to assist California with meeting state and federal air quality standards[141] and public health benefits. The 2022 State Strategy for the State Implementation Plan (SIP) includes a draft measure for a

[141] CARB. 2022. *Draft 2022 State Strategy for the State Implementation Plan*. Available at: *https://ww2.arb.ca.gov/resources/documents/2022-state-strategy-state-implementation-plan-2022-state-sip-strategy*.

statewide zero-emission GHG standard for new space and water heaters sold in California. Starting in 2030, new space and water heaters sold for new and existing residential and commercial buildings would need to comply with the standard.[142] Approximately 40 percent of annual building-related GHG and NOx emissions could be reduced statewide by 2037 if zero-emission appliance standards were implemented in 2030 for space and water heating. Adopting a statewide zero-emission GHG appliance standard focused on space and water heating could also reduce most building-related emissions by mid-century. In addition to the proposed SIP measure, further emissions could be reduced through electrification of other appliances.

Multiple air districts have adopted control measures to reduce NOx emissions from buildings, the majority of which result from natural gas combustion for space and water heating. To meet future, more stringent air quality standards, additional NOx emission reductions are needed. Air districts could consider more stringent control measures to further reduce NOx emissions from natural gas devices used in buildings. The South Coast Air Quality Management District (AQMD) is proposing to use incentives to encourage purchase of zero-emission technologies, regulations for new zero-emission NOx space and water heating, and regulations to reduce NOx emissions where zero-emission is not technically feasible.[143] The Bay Area AQMD is proposing to require zero-emission NOx space and water heating equipment by 2029 for residential buildings.[144] While these efforts will assist California in meeting air quality standards, a statewide zero-emission GHG standard for new appliances could be a useful action to reduce appliance emissions.

ii. End Rebates for Gas Appliances and Incentivize Efficient, Zero-Emission Appliances

California utilities offer hundreds of millions of dollars in rebates for gas appliances annually. California and ratepayers could transition away from subsidizing the purchase of new natural gas appliances and instead provide incentives to encourage the installation of energy-efficient electric appliances at a lower cost than gas appliances and building envelope and weatherization measures to help align market signals needed for meeting climate targets.

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[142] Ibid.

[143] South Coast AQMD. 2021. "Agenda Item 5 - Proposed Draft NOx Stationary Source Measures." *Air Quality Management Plan - November 10, 2021 Public Workshop*. Available at: *http://www.aqmd.gov/docs/default-source/clean-air-plans/air-quality-management-plans/2022-air-quality-management-plan/am-pres-agenda-item-5-nox-measures-110621.pdf?sfvrsn=6*.

[144] Bay Area AQMD. 2021. "*Draft Amendments to Building Appliance Rules - Regulation 9, Rule 4: Nitrogen Oxides from Fan Type Residential Central Furnaces and Rule 6: Nitrogen Oxides Emissions from Natural Gas-Fired Boilers and Water Heaters.*" Available at: *https://www.baaqmd.gov/rules-and-compliance/rules/reg-9-rule-4-nitrogen-oxides-from-fan-type-residential-central-furnaces?rule_version=2021%20Amendment*.

Furthermore, since additional emission reductions are needed to meet climate and air quality targets, relying on natural turnover of appliances may not be enough. Therefore, incentive programs focused on early replacement of older, but still functioning natural gas appliances to zero-emission technologies—similar to the accelerated turnover programs for older, higher-polluting vehicles—would be helpful. While California currently offers incentives—at the state level[145] [146] and locally through utilities, air districts, and regional energy networks—supporting the installation of heat pump systems in existing single and multi-family buildings in gas utility territories, current incentive programs could be expanded to meet state targets.

In January 2022, the CPUC received a motion from the Sierra Club requesting that non-cost-effective natural gas appliance energy efficiency measures be removed from ratepayer funded energy efficiency programs. The CPUC is considering the motion and how to respond to the request. Furthermore, in March 2022, the CPUC received proposals from IOUs and other program administrators to authorize new energy efficiency programs for 2024-2028. The CPUC may consider building decarbonization priorities when reviewing and approving these portfolios.

iii. Update California's Appliance Standards

Development of water and energy efficiency standards for appliances could help decarbonize buildings by reducing energy consumption and energy costs of switching to electric appliances. Significant energy savings and billions of gallons of water are saved annually through California's appliance efficiency standards, leading to substantial climate, air quality, and health benefits. These appliance efficiency standards, adopted by CEC, regulate numerous residential and commercial appliances sold in California (excluding appliances regulated by federal energy conservation standards). More efficient appliances means fewer natural gas plants generating grid electricity, thus reducing emissions and improving air quality. Future updates to the appliance efficiency standards could include performance standards, test procedures, labeling requirements, and other efficiency standards for various appliances including commercial and industrial fans and blowers, federally exempted linear fluorescent lamps, landscape irrigation controllers, and dipper wells.[147]

There are additional opportunities for appliance standards to reduce potential energy bill impacts associated with building electrification efforts. For example, the CEC has a mandate

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[145] Through CPUC's Technology Equipment for Clean Heating (TECH) program.

[146] TECH Clean California. Accessed on 10 March 2022. About the TECH Initiative. Available at: *https://energy-solution.com/tech/*.

[147] CEC. Accessed on 8 April 2022. Appliance Efficiency Proceedings - Title 20. California Energy Commission. Available at: *https://www.energy.ca.gov/rules-and-regulations/appliance-efficiency-regulations-title-20/appliance-efficiency-proceedings*.

to promote markets for appliances with flexible demand technologies.[148] These standards will provide climate benefits by shifting appliance electricity loads to times of the day when excess renewable resources are available on the grid offering the potential to reduce household energy bills. CEC is drafting a staff report to support consideration of flexible demand standards for the first appliance or group of appliances. Under the proposed phased approach, initial design standards will provide an expandable foundation for future rulemakings to implement performance-based approaches, acting as benchmarks and guides as appliance technologies and test procedures are developed within associated industries.

iv. Expand Use of Alternative Refrigerants

Hydrofluorocarbon (HFC) emissions represent the fastest growing category of GHG emissions in California, with more than 90 percent of HFC emissions from the use of refrigerants used in the commercial, industrial, residential, and transportation sectors.[149] While building decarbonization provides an important opportunity to reduce GHG impacts, the increase of electric technologies using refrigerants (i.e., heat pumps) makes mitigation of HFC emissions even more critical for the building sector to achieve carbon neutrality, and technical hurdles to deploying low and ultra-low[150] GWP refrigerants must be overcome. CARB has several regulations focused on reducing HFCs from the building sector and limiting the use of high-GWP refrigerants; however, if no further action is taken to reduce HFC emissions, the climate benefits of electrification will be partially offset, and the proportion of HFC emissions from buildings will continue to grow. Therefore, additional actions such as through incentives, regulations, and other policy measures focused on accelerating the transition to ultra-low GWP refrigerants, reducing leaks during equipment operation, and recapturing, reclaiming and reusing refrigerants at end-of-life, particularly from existing equipment that utilizes high-GWP refrigerants, could help reduce HFC emissions from buildings.

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[148] Steffensen, S. 2020. "Introduction to Flexible Demand Appliance Standards." *California Energy Commission.* Publication Number: CEC-400-2020-013." Available at: *https://www.energy.ca.gov/event/2020-12/lead-commissioner-workshop-senate-bill-49-flexible-demand-appliance-standards*.

[149] CARB. 2021. "California Greenhouse Gas Emissions for 2000 to 2019 Trends of Emissions and Other Indicators." Available at: *https://ww3.arb.ca.gov/cc/inventory/pubs/reports/2000_2019/ghg_inventory_trends_00-19.pdf*.

[150] Ultra-low GWP refers to refrigerants with a global warming potential of less than ten.

d) Build a Sustainable Market

i. Increase Affordability and Accessibility

Utility Rate Design to Support Building Decarbonization

Because potential bill impacts on customers are a barrier to switching from gas appliances to electric ones, including efficient heat pump technologies, energy rates could be designed to support electrification.[151] [152] [153] [154] The existing electrical rates do not provide incentives for fuel switching. There are many approaches to improve rate design to support building electrification, including rates with higher fixed charges which results in lower volumetric rates, establishing more dynamic pricing and granular time periods, and bundling demand flexibility programs, energy efficiency and new rate designs together.[155] [156]

Electric rates designed for electrification can help provide rate relief for customers who use higher amounts of electricity as a result of retrofitting their appliances with efficient electric alternatives to natural gas. Currently, Southern California Edison is the only investor-owned utility with an electric rate designed for electrification. This rate, schedule TOU-D Prime—designed for customers with electric vehicles, battery storage, and electric heat-pumps for water and space heating—has a higher fixed charge ($12 per month) which allows for lower

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[151] Mahone, A., C. Li, Z. Subin, M. Sontag, G. Mantegna, A. Karolides, A. German, and P. Morris. 2019. "Residential Building Electrification in California: Consumer Economics, Greenhouse Gases, and Grid Impacts." *Energy and Environmental Economics, Inc.* Available at: *https://www.ethree.com/wp-content/uploads/2019/04/E3_Residential_Building_Electrification_in_California_April_2019.pdf*.

[152] Mahone, A., Z. Subin, J. Kahn-Lang, D. Allen, V. Li, G. De Moor, N. Ryan, and S. Price. 2018. "Deep Decarbonization in a High Renewables Future: Updated Results from the California PATHWAYS Model." *California Energy Commission*. Publication Number: CEC-500-2018-012. Available at: *https://www.energy.ca.gov/publications/2018/deep-decarbonization-high-renewables-future-updated-results-california-pathways*.

[153] Deason, J., M. Wei, G. Leventis, S. Smith, and L. Schwartz. 2018. "Electrification of Buildings and Industry in the United States: Drivers, Barriers, Prospects, and Policy Approaches." Lawrence Berkeley National Laboratory, U.S. Department of Energy. Available at: *https://eta-publications.lbl.gov/sites/default/files/electrification_of_buildings_and_industry_final_0.pdf*.

[154] Building Decarbonization Coalition. 2020 "Rapid Building Decarbonization: 10 Policy Recommendations for California's Leadership." Available at: *http://www.buildingdecarb.org/uploads/3/0/7/3/30734489/10_policies_for_rapid_decarbonization_final.pdf*.

[155] Billimoria, S., L. Guccione, M. Henchen, L. Louise-Prescott. 2018. "The Economics of Electrifying Buildings: How Electric Space and Water Heating Supports Decarbonization of Residential Buildings." *RMI.* Available at: *https://rmi.org/insight/the-economics-of-electrifying-buildings/*.

[156] Cunningham, A. M., M. V. Ralston, K. Wu. "Rate Design for Beneficial Electrification." Available at: *http://www.buildingdecarb.org/uploads/3/0/7/3/30734489/bdc_report_2_rate_design.pdf*.

super off-peak and off-peak volumetric rates. A similar rate was recently approved by the CPUC for PG&E (E-ELEC), for which the fixed charge is $15/month.[157] SDG&E also has an application for a pro-electrification rate pending CPUC approval.[158]

The CPUC sought to address this issue more systematically through Phase II of its building decarbonization proceeding (R.19-01-011), which required California's three largest electric IOUs to study bill impacts associated with heat pump water heater adoption and propose rate adjustments, if justified, so as not to cause bill increases for customers switching from gas water heaters. In response to the Decision, SCE, SDG&E, and PG&E submitted studies showing the estimated impact on utility bills for customers switching from gas water heaters to heat pump water heaters, which are currently pending CPUC review. While the CPUC proceeding is focused on IOUs, effective rate design must also be established for other load serving entities, such as community choice aggregators (CCAs) and POUs. California could explore the best ways to keep electricity prices low to encourage customers to switch to electric appliances that will necessitate increased electricity consumption. This process may entail further legislative action, such as changes to the rules governing all-electric baselines and other such ratemaking guidance.[159] A key strategy would be to use general fund taxpayer revenues to remove existing ratepayer expenses, such as wildfire mitigation plans, to lower electricity bills for all ratepayers, thus making electrification a more financially enticing prospect from a bill impact perspective. This would require legislative action.

Increase Research, Development, Demonstration, and Deployment Funding

Research, Development, Demonstration and Deployment (RDD&D) activities can help overcome a range of technology-related challenges to support building decarbonization efforts. To advance the widespread use of high-efficiency, low-carbon technologies, scaled-up RDD&D activities can accelerate improvements in technology performance, reduce cost, mitigate installation challenges, and demonstrate the value proposition to market actors

[157] CPUC. 2021. "Decision Adopting Marginal Costs, Revenue Allocation, and Rate Designs for Pacific Gas and Electric Company." *California Public Utilities Commission. Decision 21-11-016.* Available at: *https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M424/K378/424378035.PDF*.

[158] SDG&E. 2021. "Application of San Diego Gas & Electric Company (U 902 M) to Update Rate Design to Include a Residential Untiered Time-of-Use Rate with a Fixed Charge." *California Public Utilities Commission. Application 21-09-001.* Available at: *https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M404/K291/404291684.PDF*.

[159] Deason, J., M. Wei, G. Leventis, S. Smith, and L. Schwartz. 2018. "Electrification of Buildings and Industry in the United States: Drivers, Barriers, Prospects, and Policy Approaches." Lawrence Berkeley National Laboratory, U.S. Department of Energy. Available at: *https://eta-publications.lbl.gov/sites/default/files/electrification_of_buildings_and_industry_final_0.pdf*.

unfamiliar with new technologies. While California[160] and federal[161] RDD&D programs are delivering high-impact results for the building sector, the pace of technology advancement and the scale-up of building decarbonization solutions can be further accelerated through increased public and private funding. Increased RDD&D funding could support:

- Demonstrating large, high-efficiency, low-GWP heat pumps and other advanced low-carbon HVAC technologies that can reduce reliance on gas boilers for large commercial buildings.
- Advancing highly efficient technologies that help avoid or minimize electric panel upgrades in homes.
- Developing and demonstrating demand flexibility technologies that deliver a range of customer and grid benefits.
- Conducting prize competitions to promote technology awareness and spur new technology designs for improved performance and efficiency.
- Charting a strategic and equitable transition of the gas system by screening for promising sites for natural gas infrastructure decommissioning, such as those with known pipe integrity and corrosion issues.

Equity considerations need to go beyond simply locating new technologies in under-resourced communities. This includes community engagement and outreach in the development and implementation of projects. For example, research programs could focus on supporting relationship-building and partnerships among diverse stakeholders, ensuring meaningful engagement with community-based organizations as key project partners, and investing in diverse businesses. This would help ensure that technologies are applicable to community interests and needs while supporting the sharing of culturally relevant and sensitive project information and educational materials for participating communities.

Expand Incentive Programs to Support the Holistic Retrofit of Existing Buildings, Especially for Priority Populations

Proper and equitable incentives to support the retrofit of existing buildings and ensuring accessibility are essential to the success of building decarbonization. As previously discussed, low-income housing and business owners and renters need more intensive support since they

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[160] California building-related efforts include CEC's Electric Program Investment Charge and the Natural Gas Research and Development Program.
[161] Federal RDD&D building-related efforts include DOE's Energy, Emissions, and Equity Initiative that covers Residential Cold Climate Heat Pump Challenge and the Advanced Water Heating Initiative.

cannot necessarily afford decarbonization costs.[162] [163]Furthermore, stakeholders have suggested holistic building decarbonization retrofit programs focused on existing buildings to protect frontline communities from increased utility bills that would result by focusing solely on fuel-switching. Incentives that support whole building retrofits that include energy efficiency measures, building envelope improvements and weatherization, panel upgrades, on-site renewable energy generation and energy storage, and installation of load management systems, can lower occupants' energy burden due to switching from natural gas to electric appliances.[164] [165] [166] These measures can also improve the climate resiliency for occupants in these buildings. These holistic building incentives could also support electric vehicle recharging infrastructure to align with California's transportation electrification goals and increase access to clean mobility within priority populations.

Additionally, many low-income Californians often live and work in older buildings that may need health and safety upgrades due to hazardous building materials like asbestos or lead paint and/or structural issues like leaky roofs, walls with mold damage, and unsafe electrical wiring. Existing incentive programs require homes to be free of health and safety issues before any energy retrofits can occur. However, programs designed to improve health and safety issues are not always typically connected to energy retrofit programs. There is an opportunity for building decarbonization and health or safety incentive programs to leverage each other and provide funding for holistic retrofits that improve habitability by remediating health and safety issues along with energy-efficiency and all-electric retrofits. At a minimum, a referral loop between energy and health incentive programs would be useful.[167] [168] Holistic retrofit incentive programs should be designed to be as accessible to all low- and moderate-

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[162] Elkind, E. N., and T. Lamm. 2019. "Low Income, High Efficiency: Policies to Expand Low-Income Multifamily Energy Savings Retrofits." *Berkeley Law Center for Law, Energy & the Environment; UCLA Emmett Institute on Climate Change & the Environment*. Available at: *https://www.law.berkeley.edu/research/clee/research/climate/energy-efficiency/limf-energy-savings-retrofits/*.

[163] ARUP. 2021. "Los Angeles Affordable Housing Decarbonization Study Phase 2."Available at: *https://www.nrdc.org/sites/default/files/la-affordable-housing-decarbonization-study-phase2-20211108.pdf*.

[164] Gough, M. 2021. *California's Cities Lead the Way to a Gas-Free Future*. Sierra Club. Available at: *https://www.sierraclub.org/articles/2021/07/californias-cities-lead-way-gas-free-future*.

[165] Greenlining. 2019. "*Equitable Building Electrification: A Framework for Powering Resilient Communities.*" Available at: *https://greenlining.org/publications/reports/2019/equitable-building-electrification-a-framework-for-powering-resilient-communities/*.

[166] Kirk, C. 2021."Los Angeles Building Decarbonization: Tenant Impact and Recommendations." *Strategic Actions for a Just Economy*. Available at: *https://www.saje.net/resources/reports/building-decarbonization/*.

[167] Ibid.

[168] Greenlining. 2019. "*Equitable Building Electrification: A Framework for Powering Resilient Communities.*" Available at: *https://greenlining.org/publications/reports/2019/equitable-building-electrification-a-framework-for-powering-resilient-communities/*.

income homeowners across the state, such as by not requiring low-income homeowners to pay out-of-pocket expenses and including retrofits (or combination thereof) that yield utility bill savings. Special programs should also be designed for rural and tribal areas with limited electric infrastructure.

Specific investment programs coupled with training and technical assistance aimed at affordable housing rental units would help to offset potential upfront costs of retrofits since rental property owners receive no or few benefits of decarbonization. Additionally, there are no laws currently protecting tenants from being evicted or having rent increases post retrofit; regulatory protection could help to shield tenants from rent increases after energy upgrades are performed.[169] [170] [171] California currently has several incentive programs aimed at advancing building decarbonization, including the Building Initiative for Low-Emissions Development (BUILD) program, which provides incentives for all-electric new low-income residential housing,[172] and the Technology and Equipment for Clean Heating (TECH) program, which provides mid-stream incentives for the installation of heat pump technologies in existing residential buildings,[173] and the Self-Generation Incentive Program, which includes an $84 million carve out for heat pump water heaters that are able to act as load-shifting devices. However, more funding for these programs would allow them to scale up across the state. Direct public investments provide a pathway to accelerate decarbonization of affordable and market rate housing to ensure low-income consumers and vulnerable communities are not left behind.[174] Building decarbonization incentive programs should be designed with significant and meaningful involvement from community groups to ensure frontline communities benefit equitably (73).

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[169] Ibid.

[170] Samarripas, S., and A. Jarrah. 2021. "A New Lease on Energy: Guidance for Improving Rental Housing Efficiency at the Local Level" *American Council for an Energy-Efficient Economy*. Available at: *https://www.aceee.org/research-report/u2102*.

[171] Kirk, C. 2021."Los Angeles Building Decarbonization: Tenant Impact and Recommendations." *Strategic Actions for a Just Economy*. Available at: *https://www.saje.net/resources/reports/building-decarbonization/*.

[172] CEC. Accessed on 19 April 2022. Building Initiative for Low-Emissions Development Program. Available at: *https://www.energy.ca.gov/programs-and-topics/programs/building-initiative-low-emissions-development-program*.

[173] TECH Clean California. Accessed on 10 March 2022. About the TECH Initiative. Available at: *https://energy-solution.com/tech/*.

[174] Jones, B. 2021. "Los Angeles Building Decarbonization: Community Concerns, Employment Impacts, and Opportunities." *Inclusive Economics*. Oakland, CA. Available at: *https://www.nrdc.org/resources/angeles-building-decarbonization-community-concerns-employment-impacts-and-opportunities*.

Promote Flexible Demand Programs

Load flexibility—historically done through time-varying rates to reward consumers for shifting their electricity use to non-peak hours—can reduce demand for electricity during peak hours, thus helping to reduce costs from fuel switching and the need for new power plants. Flexible demand management via modern communications and automation technologies enables utility customers to shift the timing of their electricity use without sacrificing comfort or quality of service while taking advantage of cheaper off-peak rates. Additionally, flexible demand management makes use of renewable energy generation that would otherwise be curtailed, in other words, scaled back and/or sent to other markets at a cost.[175] [176] [177] Actions that increase flexible demand resources would support an affordable and reliable grid as the share of carbon-free resources expands.[178]

To increase demand flexibility, the CEC initiated a rulemaking that would require California's five largest electric utilities and all CCAs to maintain an accurate and standardized database of time-varying rates in a publicly available and machine-readable database known as Market Informed Demand Automation Server (MIDAS).[179] This database would enable automation of demand flexibility in real time. Under the rulemaking, CEC would require utilities to educate customers about benefits and how to use devices to automate energy usage during low-price periods. Applying time-varying pricing evenly across all customers would correct the equity issue of smaller and more efficient participants funding larger and less efficient participants.[180]

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[175] In the first half of 2020, California curtailed up to 320 GWh per month—enough to power more than half a million homes.

[176] Herter, K., and G. Situ. 2021. "Analysis of Potential Amendments to the Load Management Standards: Load Management Rulemaking, Docket Number 19-OIR-01." *California Energy Commission*. Publication Number: CEC-400-2021-003-SF. Available at: *https://www.energy.ca.gov/publications/2021/analysis-potential-amendments-load-management-standards*.

[177] Harding, R., and R. Behrens. 2021. "*Use It When We Have It: How to Use More Clean Energy and Decarbonize the Grid with Demand Flexibility*" *NRDC*, R:20-10-A. Available at: *https://www.nrdc.org/sites/default/files/use-it-have-it-demand-flexibility-report.pdf*.

[178] Herter, K., and G. Situ. 2021. "Analysis of Potential Amendments to the Load Management Standards: Load Management Rulemaking, Docket Number 19-OIR-01." *California Energy Commission*. Publication Number: CEC-400-2021-003-SF. Available at: *https://www.energy.ca.gov/publications/2021/analysis-potential-amendments-load-management-standards*.

[179] Ibid.

[180] Historically, customers with higher demand and high energy equipment have been targeted for demand response first, so that more efficient or smaller customers with lower demand—who still contribute to the program with their rates—do not benefit from the program.

[181] In addition, targeted subsidies or equipment incentives for low-income customers can increase equitable access to flexible demand equipment.

In addition, the Self-Generation Incentive Program (SGIP) is offering $84 million in incentives for heat pump water heaters that are able to serve as load shifting devices. In order to receive an SGIP incentive, the water heater must be installed with a thermostatic mixing valve to enable safe water temperature regulation and have the capability of two-way communication with the utility. About half of this budget is dedicated to residential equity customers.[182]

ii. Promote Consumer Education

Expand Education Efforts

Consumer education efforts can increase interest and positive attitudes, willingness to pay, and market penetration of new environmentally friendly technologies.[183] Consumer education efforts should convey the health, climate, air quality, resiliency, comfort, and safety benefits of building decarbonization and impacts of fossil fuel use, explain technology options, life-cycle costs and credible economic information, and provide resources on where to get more information.[184] [185] Since trying out a different technology greatly increases interest and desire, education efforts could include technology demonstrations, as the IOUs currently do with induction cooktops.[186] Public agency-sponsored one-stop shop and educational websites,

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[181] Herter, K., and G. Situ. 2021. "Analysis of Potential Amendments to the Load Management Standards: Load Management Rulemaking, Docket Number 19-OIR-01." *California Energy Commission*. Publication Number: CEC-400-2021-003-SF. Available at: *https://www.energy.ca.gov/publications/2021/analysis-potential-amendments-load-management-standards*.

[182] CPUC. 2021. "Order Instituting Rulemaking Regarding Policies, Procedures and Rules for the Self-Generation Incentive Program and Related Issues." *California Public Utilities Commission. Rulemaking 20-05-012*. Available at: *https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M377/K729/377729072.PDF*.

[183] Jin, L., and P. Slowik. 2017 "Literature Review of Electric Vehicle Consumer Awareness and Outreach Activities." *The International Council on Clean Transportation*. Available at: *https://theicct.org/publication/literature-review-of-electric-vehicle-consumer-awareness-and-outreach/*.

[184] Miller, A., and C. Higgins. 2021. "The Building Electrification Technology Roadmap." *New Buildings Institute*. Available at: *https://newbuildings.org/resource/building-electrification-technology-roadmap/*.

[185] Golden, R. 2019. "Building Electrification Action Plan for Climate Leaders." *Sierra Club*. Available at: *https://www.sierraclub.org/sites/www.sierraclub.org/files/Building%20Electrification%20Action%20Plan%20for%20Climate%20Leaders.pdf*.

[186] Corbelli, S. 2019. "Induction Market Research." *SMUD Market Research*, BECC Conference. Available at: *https://beccconference.org/wp-content/uploads/2019/11/corbelli_presentation.pdf*.

such as "The Switch is On"[187] among others,[188] [189] [190] [191] provide a useful resource and an unbiased and brand-neutral source of information. Tools that help customers calculate lifetime costs and compare different types of appliance models appropriately, such as comparing heat pumps used for space heating and cooling with air conditioners plus furnaces, can help customers understand benefits and maximize cost-savings. These education efforts can be designed to be culturally appropriate, available in multiple languages, and implemented in collaboration with trusted community groups. Both private and public entities could expand education efforts to proactively reach consumers both ahead of a decision and at the time of appliance replacement, including assuring that new products are tested and labeled through ENERGY STAR to raise consumer awareness.

Educational campaigns can be more successful when coupled with incentives for new technologies.[192] Consumer education may be sufficient to facilitate electrification with wealthier early adopters, but incentives are required to help to overcome the additional infrastructure and equipment usually needed to electrify existing mid- and low-income homes.[193] Electric home heating systems are mainly purchased because of contractor recommendation,[194] so education and incentives could be targeted not just to homeowners, landlords, and residents, but also to professionals who influence the decisions of their many customers including builders, architects, real estate agents, electricians, installers, contractors, and appliance sellers.[195] Building inspectors also benefit from training on new electric

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[187] BDC. Accessed on 8 April 2022. The Switch Is On. Available at: *https://www.switchison.org*.

[188] Additional educational websites include Energy Star, Bay Area Regional Energy Network (BAYREN), and CARB's Technology Clearinghouse.

[189] Energy Star, Accessed on 8 April 2022. The simple choice for saving energy. Available at: *https://www.energystar.gov*.

[190] BAYREN. Accessed on 8 April 2022. Let's Save Money, Energy and Water Together! Available at: *https://www.bayren.org/about*.

[191] CARB. Accessed on 8 April 2022. Technology Clearinghouse Tools. Available at: *https://ww2.arb.ca.gov/our-work/programs/technology-clearinghouse/technology-clearinghouse-tools*.

[192] Memory, S., T. Rooney, and J. Yin. 2021. "Electrification of Water and Space Heating in Buildings." *A. O. Smith Corp*. Available at: *https://www.esmagazine.com/ext/resources/images/2021/AOS-White-Paper.Building-Decarbonization.pdf*.

[193] Greenlining. 2019. "*Equitable Building Electrification: A Framework for Powering Resilient Communities.*" Available at: *https://greenlining.org/publications/reports/2019/equitable-building-electrification-a-framework-for-powering-resilient-communities/*.

[194] Whitsett, D. 2019. "Customer Barriers to Residential Building Electrification as a Means to Reduce Greenhouse Gas Emissions". *EMI Consulting*. Available at: *https://beccconference.org/wp-content/uploads/2019/08/BECC_abstract_whitsett.pdf*.

[195] Miller, A., and C. Higgins. 2021. "The Building Electrification Technology Roadmap." *New Buildings Institute*. Available at: *https://newbuildings.org/resource/building-electrification-technology-roadmap/*.

appliances and the infrastructure needed to support them. Restaurants will likely need dedicated outreach and incentives to embrace electric cooking. For example, recruiting successful and celebrity chefs to feature the superior control and speed of induction cooking, as well as safer kitchen environments, targeting incentives to pilot restaurants of varied cuisines can encourage other restaurants to electrify cooking.[196]

Promote Voluntary Recognition for Building Decarbonization

Certifications, rating systems, or labeling schemes of green buildings—which provide independent verification of the green nature of buildings and appliances—can be valuable educational and marketing tools. There are a variety of third-party recognition programs such as ENERGY STAR®,[197] CarbonFree® Product Certification label,[198] various rating systems within the Leadership in Energy and Environmental Design (LEED),[199] GreenPoint Rated,[200] and the Living Building Challenge.[201] These programs certify appliances and buildings for energy efficiency, reduced embodied carbon, use of renewable energy, and incorporating other environmentally preferable features such as reduced water consumption, and avoided solid waste disposal. Promoting those voluntary recognition programs can enhance both consumer awareness and business marketing and stimulate the adoption of decarbonized buildings and appliances. Potential actions California can take include incentivizing new construction projects that adopt the program guidelines and standards, thereby prioritizing public investment to projects using these third-party recognition programs.

5. Areas for Future Consideration

As decarbonized buildings consume less energy to operate, lifecycle emissions become more important than operational emissions alone. Therefore, reducing embodied carbon associated with building materials becomes increasingly important to address.[202] Embodied carbon of

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[196] Some examples of celebrity chefs that cook with induction include Chef Jon Kung and Chef Thomas Keller.

[197] U.S. EPA. 2022. *ENERGY STAR Certification for Buildings*. Available at: https://www.energystar.gov/buildings/building_recognition/building_certification.

[198] Eco Label Index. 2022. *CarbonFree Certified*. Available at: https://www.ecolabelindex.com/ecolabel/carbonfree-certified.

[199] USGBC. Accessed on 2 February 2022. LEED Rating System. Available at: https://www.usgbc.org/leed.

[200] Build It Green. Accessed on 2 February 2022. GreenPoint Rated. Available at: https://www.builditgreen.org/greenpoint-rated/.

[201] International Living Future Institute. Accessed on 2 February 2022. Living Building Challenge 4.0 Basics. Available at: https://living-future.org/lbc/basics4-0/.

[202] Esau, R., M. Jungclaus, V. Olgyay, and A. Rempher. "Reducing Embodied Carbon in Buildings: Low-Cost, High-Value Opportunities." *RMI*. Available at: https://rmi.org/insight/reducing-embodied-carbon-in-buildings/.

buildings—referring to GHG emissions from extracting and manufacturing building materials—contributes at least 11 percent of all energy-related emissions annually world-wide.[203 204] Studies may underestimate embodied carbon; a full life-cycle emissions assessment would include transportation and disposal of building materials. Embodied carbon can be reduced through cost-effective management practices including the optimal use of building materials with high-recycled or low-carbon products.[205] Voluntary certification programs (e.g., LEED, Living Building Challenge, Passive House) and the Carbon Leadership Forum offer concrete pathways such as re-use of existing buildings and material to reduce the embodied carbon of new and existing buildings. Future actions that reduce embodied carbon could include promoting voluntary certification and providing market certainty through long-term programs focused on embodied carbon such as incentives, procurement programs,[206 207]and requirements for new construction that can drive manufacturers' investment in low-carbon technologies and transition their product portfolio[208 209 210]

6. Conclusions

Since buildings are a significant source of statewide emissions, building decarbonization offers great potential to put California on track to achieve climate and air quality targets, while

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[203] International Energy Agency and the United Nations Environment Programme. 2018. "Global Status Report 2018: Towards a Zero-Emission, Efficient and Resilient Buildings and Construction Sector." *Global Alliance for Buildings and Construction.* Available at: *https://www.worldgbc.org/sites/default/files/2018%20GlobalABC%20Global%20Status%20Report.pdf*.

[204] World Green Building Council. 2019. "Bringing Embodied Carbon Upfront: Coordinated Action for the Building and Construction Sector to Tackle Embodied Carbon." Available at: *https://www.worldgbc.org/news-media/bringing-embodied-carbon-upfront*.

[205] Esau, R., M. Jungclaus, V. Olgyay, and A. Rempher. "Reducing Embodied Carbon in Buildings: Low-Cost, High-Value Opportunities." *RMI*. Available at: *https://rmi.org/insight/reducing-embodied-carbon-in-buildings/*.

[206] Buy Clean California is a procurement program in California focused on reducing embodied carbon in building materials.

[207] DGS. Accessed on 18 January 2022. Buy Clean California Act. Available at: *https://www.dgs.ca.gov/PD/Resources/Page-Content/Procurement-Division-Resources-List-Folder/Buy-Clean-California-Act*.

[208] World Green Building Council. 2019. "Bringing Embodied Carbon Upfront: Coordinated Action for the Building and Construction Sector to Tackle Embodied Carbon." Available at: *https://www.worldgbc.org/news-media/bringing-embodied-carbon-upfront*.

[209] National Association of State Energy Officials. Accessed on 1 February 2022. Mandatory vs Voluntary Approaches: Home Labeling Programs and Policies. National Association of State Energy Officials. Available at: *https://empress.naseo.org/mandatory-vs-voluntary-approaches*.

[210] CARB. Accessed on 18 January 2022. Short-Lived Climate Pollutants. Available at: *https://ww2.arb.ca.gov/our-work/programs/slcp/about*.

providing important public health benefits. Additionally, building decarbonization can improve comfort, climate resilience, and safety today as well as in the future as California faces more extreme weather events. Electric alternatives to gas equipment for space and water heating, cooking, and clothes drying are increasing in market share and are technically ready. While it costs less money to build all-electric new buildings, in many cases there are added upfront costs to electrify existing buildings. Under existing energy rate structures, there are mixed results with households expected to see a net increase or decrease in energy bill costs depending on several factors. Long-term planning and investment to harmonize building decarbonization and strategic decommissioning of existing gas infrastructure is also an important strategy to maintain safety and reliability and to minimize rate impacts during the transition.[211]

Decarbonizing California's buildings will be challenging. While the State and utilities are undertaking many efforts to facilitate decarbonization, more work is needed. To ensure that building decarbonization is successful, policymakers must work together across agency jurisdictions and collaborate with and prioritize frontline communities. There are a variety of potential actions that could be pursued to reduce emissions in both new construction and existing buildings. Market-enabling actions lay the foundation to prepare consumers, building developers, appliance manufacturers, and contractors for building decarbonization. While this Appendix provides a menu of potential actions, a comprehensive roadmap would help ensure equitable and cost-effective building decarbonization.

[211] Gridworks. 2021. "Gas Resource and Infrastructure for California: A Proposed Approach to Long-Term Gas Planning." Available at: *https://gridworks.org/wp-content/uploads/2021/01/CA_Gas_Resource_Infrastructure_Plan_Report_FINAL.pdf*.