APPENDIX F
BUILDING DECARBONIZATION

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1. Introduction

Buildings are a large source of greenhouse gases (GHG), and 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 leak reduction, and eliminating fuel combustion by electrifying appliances and equipment, among other actions. Energy efficiency and building electrification are both crucial aspects of building decarbonization. Energy efficiency reduces overall energy demand, allowing for installation of smaller systems to save costs over time.[1] Building electrification—in new and existing buildings—provides one of the most technologically feasible paths to reduce building-related emissions.[2] [3] [4] [5] Therefore, efficient 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.

This appendix examines a range of aspects of this transition. It is important to emphasize that the transition necessarily involves many actors and will require a coordinated and thoughtful strategy across local, state, and federal levels of government with close attention to equity, a process that will extend well beyond this appendix. Successfully decarbonizing buildings will require a range of policies, including workforce development, supportive rate design, grid readiness, incentives, contractor and consumer awareness, and appliance and building standards, including zero-emission[6] standards, among others. The next section of this

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[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] Ibid.

[3] 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/*.

[4] 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*.

[5] 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*.

[6] This appendix follows the Scoping Plan definition of zero-emission buildings as those that have no combustion-based equipment or appliances installed and therefore produce no combustion-based emissions.

appendix focuses on why building decarbonization is one of several key strategies for achieving California's climate change mitigation and air quality goals by summarizing its important benefits. Section three discusses the technical feasibility of electric appliances, costs and cost-savings, and consumer acceptance, adoption, and awareness. Section four outlines a number of potential actions that would support a successful transition for building decarbonization. And section five notes important areas that require increased emphasis moving forward.

2. Building Decarbonization is a Priority for California

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

A. Air Quality and Health Impacts

Combustion of fossil 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.[7] Some of the emissions occur indoors and thus 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 fossil gas appliances in California were replaced with electric ones instantaneously in 2018, one study estimated the emission benefits to result in 354 fewer premature deaths annually.[8] A similar study that considered instantaneous replacements in 2035 in both residential and commercial buildings across California predicted that the emission reductions would avoid 813 premature deaths per year.[9] In

[7] 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*.

[8] Ibid.

[9] 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*.

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 fossil 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 the outside. Homes with a gas stove have higher NOx and CO levels compared to those with an electric stove.[10] [11] A simulation study 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.[12] While cooking food produces similar levels of PM2.5 regardless of whether using electric or gas stoves,[13] UFP are higher in homes with gas stoves due to the additional combustion of gas.[14] [15] [16] Because of their smaller size and larger total surface area, UFPs have been linked with many respiratory, cardiovascular, and central nervous system health effects.[17] 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

[10] 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.

[11] 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.

[12] 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.

[13] 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.

[14] 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.

[15] 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.

[16] 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.

[17] 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.

asthma.[18] The health risk of exposure to emissions from a gas stove is higher for children living in multi-family housing, including the higher likelihood of wheezing, shortness of breath, and chest tightness.[19]

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.[20] However, kitchen ventilation, where it exists, is only used while cooking in 36 percent of homes and 28 percent of low-income apartments.[21] 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 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.[22] [23] [24]

ii. Outdoor Air Quality

Building decarbonization can help California attain federal air quality standards. In California, the ambient air quality in 40 out of 58 counties does not meet federal air quality standards

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[18] 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." *International Journal of Epidemiology* Volume 42, 6, pp. 1724-1737. Available at: *https://pubmed.ncbi.nlm.nih.gov/23962958/*.

[19] 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/*.

[20] 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*.

[21] 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*.

[22] 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/*.

[23] 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*.

[24] 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*.

for safe levels of PM2.5 and ozone.[25] Combustion of fossil gas in residential and commercial buildings in California is projected to contribute to 66 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.[26] In addition, fossil 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.[27]

3. Feasibility and Readiness Factors

This section summarizes critical factors of building decarbonization feasibility—technical feasibility, costs and cost-savings, and consumer acceptance, adoption, and awareness—in order to identify barriers and opportunities to help accelerate the decarbonization of new and existing buildings. There is also a combination of readiness factors that impact feasibility such as adequate funding for incentive programs, building-level electrical panel capacity, and energy rate affordability. Each of these readiness factors is part of building a sustainable market outlined in section 4.A below.

A. Technical Feasibility

Electric alternatives to fossil gas appliances are technically ready to deploy in several applications but there are some technologies that need further development to address barriers to adoption. Manufacturing capacity will need to increase and supply chains will need to be expanded to achieve California's goals in the building sector. Further, some building types offer unique challenges that may make electrification more difficult. For example, existing large commercial buildings utilizing chiller-boiler systems may be challenging to electrify as these systems rely on high hot water temperatures that are not easily achieved via heat pumps.[28] Tables 1-5 summarize the current technical readiness and status of product availability for different technologies by end-use and application.

Technology continues to evolve to address technical and 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

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

[26] 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*.

[27] Ibid.

[28] City of Palo Alto. 2021. "Non-Residential Building Electrification Overview." Available at: *https://www.cityofpaloalto.org/files/assets/public/sustainability/reports/non-residential-building-electrification-overview.pdf*

heat pump—that can run on lower amperage circuits to reduce the need for upgrading electric service panels and electric distribution systems, which are barriers for electrification of multiple end-uses in some existing buildings, especially multi-family.[29] These units may still have installation challenges, however, such as physical space constraints or the need to install a new outlet, along with slower heating times that may limit their applicability in certain cases. Variable speed air source heat pumps can achieve significant energy savings compared to constant single-speed heat pump technology.[30] Heat pumps with two-way grid communication controls can maximize demand flexibility to avoid using electricity during high-carbon and peak hours.[31] Combination space and water heating technologies are emerging that are suitable for many building types and could minimize the need for electric panel upgrades while reducing the need for installing multiple technologies.

Additionally, manufacturers are making technological advancements to improve heat pump efficiency in cold climates since early models had difficulty operating in sub-freezing temperatures.[32] Heat pump manufacturers are also investigating alternatives to the use of high-global warming potential (GWP)[33] refrigerants since replacing fossil fuel appliances with heat pump technologies could increase leak-related emissions of high-GWP refrigerants and therefore offset some of the climate benefits of electrification. For instance, manufacturers have developed commercially available heat pump water heaters that utilize carbon dioxide[34] as the refrigerant, and these systems perform very well in cold ambient conditions without the need for backup supplemental heating. Additional research is occurring to consider other types of low-GWP refrigerants such as natural hydrocarbons and hydrofluoroolefins.

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[29] 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*.

[30] Adhikari, R.S., N. Aste, M. Manfren, and D. Marini. 2012. "Energy Savings through Variable Speed Compressor Heat Pump Systems." Available at: *https://www.sciencedirect.com/science/article/pii/S1876610211045188*

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

[32] 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/*.

[33] Global Warming Potential, or GWP, is a measure of how destructive a climate pollutant is. The GWP of a gas refers to the total contribution to global warming resulting from the emission of one unit of that gas relative to one unit of the reference gas, carbon dioxide (CO_2), which is assigned a value of 1. Refrigerants today are often thousands of times more polluting than CO_2. The value for what is determined to be a "high-GWP" refrigerant is defined differently based on equipment type.

[34] Carbon dioxide is a refrigerant which has a very low GWP of one.

Table 1 Technical readiness of zero-emission space conditioners (heating and cooling)[35] [36] [37] [38] [39]

Technology	***Building Types****	***Status***	***Challenges***
Air Source Heat Pumps	SF, MF, SC, LC, SI	Fully ready and widely available. Three to five times more efficient than gas or electric resistance heating.	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. Limited roof area for packaged rooftop units in large commercial buildings.
Heat Recovery Chiller	LC, SI	Fully ready and widely available.	Requires significant simultaneous heating and cooling loads to be effective. 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. Heating and cooling capacities are limited and often require separate ventilation systems.
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: multi-family home; SC: small commercial; LC: large commercial; SI: schools and institutions

[35] U.S. DOE. Accessed on 1/1/22. "Heat Pump Systems." *Energy Saver*. Available at: *https://www.energy.gov/energysaver/heat-pump-systems*.

[36] 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*.

[37] 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*.

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

[39] 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*.

Table 2 Technical readiness of zero-emission building water heaters[40] [41] [42]

Technology	***Building Types****	***Status***	***Challenges***
Heat Pump Water Heater	SF, MF, SC, LC, SI	Fully ready and widely available. Two to four times more efficient than 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: multi-family home; SC: small commercial; LC: large commercial; SI: schools and institutions

[40] 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*.

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

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

Table 3 Technical readiness of zero-emission swimming pool water heaters[43] [44]

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.	Heat pump pool heaters only work efficiently when the outside temperature remains above 45-50˚F.
Solar Thermal	SF, MF, SI	Uses solar energy to reduce electricity usage.	Only provides heating 5-8 months out of the year.

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

Table 4 Technical readiness of zero-emission cooking equipment[45] [46]

Technology	***Building Types****	***Status***	***Challenges***
Radiant	SF, MF, SC, LC, SI	Decades old and widely available.	Longer heat times, less temperature control, and lower efficiency than induction. Long cool-down time after cooking. 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 performance and safety benefits, along with consumer perception that cooking with gas is better, 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: multi-family home; SC: small commercial; LC: large commercial; SI: schools and institutions

[43] Ibid.
[44] 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*.
[45] 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*.
[46] 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[47]

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 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. Less energy efficient.

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

[47] 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 fossil gas appliances and equipment are becoming increasingly cost-competitive.[48] [49] [50] [51] On average, 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.[52] [53] [54] [55] With respect to water heaters, heat pump water heaters are similarly priced on average as tankless gas water heaters and more expensive than traditional gas storage water heaters, but in some cases can

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[48] 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*.

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

[50] 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/*.

[51] 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*.

[52] 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*.

[53] 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/*.

[54] 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*.

[55] 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*

provide lifetime bill savings.[56] [57] The cost of fossil gas stoves is comparable to electric resistance stoves, but induction stoves are typically more expensive and may require purchasing new cookware.[58] However, induction stoves are a more energy efficient option for cooking and provide a better user experience.[59] [60] Finally, the cost of electric resistance clothes dryers is comparable to fossil gas clothes dryers, but heat pump clothes dryers cost more on average.[61] 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.[62]

ii. Energy Costs

Energy costs are a critical determinant of the long-run cost of decarbonization.[63] However, these costs depend on several factors, including the characteristics of the appliances and buildings, consumer use patterns, climate zone variation, and differing utility rate structures. To minimize the number of households in existing buildings that may experience increased energy bills, actions that support reducing energy demand—such as weatherization and energy efficiency—along with supportive energy rates and load shifting would help reduce

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[56] 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*.
[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*.
[58] Ibid.
[59] Miller, A., and C. Higgins. 2021. "The Building Electrification Technology Roadmap." *New Buildings Institute.* Available at: *https://newbuildings.org/resource/building-electrification-technology-roadmap/*.
[60] 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/.*
[61] 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*.
[62] 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/*.
[63] 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*.

potential cost burdens.[64] [65] [66] Since gas rates currently tend to be lower than electricity rates on a cost per unit energy basis in investor-owned utility (IOU) territories,[67] [68] there is concern that a switch to electric appliances may increase energy bills in those areas. The impacts on individual customers vary depending on user profile. According to an E3 study, 87 percent of single-family homes that already have air conditioners and retrofit these to heat pumps are likely to see bill savings.[69] 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 fossil gas rate. IOU's recently submitted studies regarding bill impacts for customers switching from gas water heaters to heat pump water heaters to the California Public Utilities Commission (CPUC), which are currently pending review. These studies show that bill impacts vary greatly by climate zone, equipment efficiencies, and tank temperature settings. Heat pump water heaters tend to have better performance in hotter climate zones as compared to mountain and coastal climate zones.[70] The studies also show that time-of-use (TOU) rates are generally more favorable for customers switching from gas water heaters to heat pump water heaters, in comparison to non-TOU rates.

Higher energy bills after electrification could especially burden low-income homeowners and renters. However, statewide actions are focused on ensuring energy rates are designed to

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[64] 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/*.

[65] 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*.

[66] 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*.

[67] 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*.

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

[69] 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*.

[70] Advice Letters 4571-G/6497-E (PG&E), 4713-E (SCE), 3952-E/ 3063-G (SDG&E) filed on February 7, 2022 in compliance with Ordering Paragraph 4 of CPUC Decision 21-11-002.

support electrification.[71] [72] [73] [74] For example, as mentioned above, a recently submitted study by Pacific Gas and Electric Company (PG&E)[75] to the CPUC shows bill savings for a vast majority of households and nearly all low-income households[76] when switching from gas water heaters to electric heat pump water heaters under the recently approved pro-electrification TOU rate (E-ELEC).[77] [78] Bill savings for low-income customers could also be due to the California Alternate Rates for Energy (CARE) program, which provides a higher discount of 35 percent for electric service compared to a 20 percent discount for gas service. Southern California Edison (SCE) company's application for a rate adjustment for customers switching from gas water heaters to heat pump systems was approved by the CPUC in August 2022.[79] San Diego Gas and Electric's (SDG&E) application for a pro-electrification rate is pending CPUC review.[80]

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[71] 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*.

[72] 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*.

[73] 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*.

[74] 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*.

[75] 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*.

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

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

[78] 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*.

[79] CPUC Decision (D.22-08-001). Available at: *https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M496/K425/496425527.PDF.*

[80] SDG&E Application (A.)21-09-001 to CPUC: *https://apps.cpuc.gov/apex/f?p=401:56:0::NO:RP,57,RIR:P5_PROCEEDING_SELECT:A2109001.*

Additional special considerations are needed to ensure vulnerable communities are not negatively impacted by building decarbonization policies and programs.[81] For example, some rural and tribal areas within California are not connected to the State's electric grid—nor fossil gas infrastructure—but rely instead on propane and wood burning. These communities need special consideration to ensure they still benefit from building decarbonization efforts. For example, CPUC's San Joaquin Valley Affordable Energy pilot project focuses specifically on ensuring vulnerable communities are not negatively impacted. Finally, as more households move away from using fossil gas, those remaining on the fossil gas system are likely to pay an increasingly larger share of systemwide costs,[82] which could further widen the affordability gap between households that are able to decarbonize early and those that are not. Another vulnerable population includes mobile home parks. CPUC is currently exploring mobile home park electrification.[83] Initial results from this proceeding indicate that there is a potential need to upsize transformers, upgrade electrical service panels, and retrofit wiring for older units in mobile home parks.[84] Low-income customers are less likely to adopt electric appliances first due to higher upfront costs and challenges relating to access to finance. It will be critical for the State to center low-income and disadvantaged communities in the planning process for the long-term gas transition.[85]

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[86] new homes, primarily due to the

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[81] 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*.

[82] Velez, K. 2021. "California's Building Transition Recommendations for Gas Transition Regulatory Proceedings at the California Public Utilities Commission." *Building Decarbonization Coalition*. Available at: *https://www.buildingdecarb.org/uploads/3/0/7/3/30734489/final_draft_rev_3__building_decarbonization_coalition_project__4_.pdf*.

[83] CPUC Decision (D.20-04-004) Available at: *https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M334/K606/334606886.PDF*.

[84] CPUC. 2020. Stakeholder Workshop: Building Decarbonization Phase II Staff Proposal and Mobile Home Park Electrification and Tenant Protection Topics.
Available at: *https://www.cpuc.ca.gov/-/media/cpuc-website/files/uploadedfiles/cpuc_public_website/content/safety/mobile_home_parks/bd-phase-ii-and-mhp-workshop-09152020-final.pdf*.

[85] Ibid.

[86] Mixed-fuel refers to a building that uses both gas/propane and electricity.

avoided costs of fossil gas infrastructure at the building site, with cost-savings in the range of $2,000 to $10,000 per unit.[87] [88] [89] [90] [91] There may be some rare exceptions for extremely cold climates where going all-electric can be more expensive.[92] When factoring in energy costs, all-electric new home construction also reduces costs over the lifetime of appliances when compared to fossil-fueled homes.[93] 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.[94] Statewide actions focused on strengthening California's State standards and local building measures 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

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[87] 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*.

[88] 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/*.

[89] 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*.

[90] 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*.

[91] 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*.

[92] 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/*.

[93] 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/*.

[94] 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*.

or closet locations, and other miscellaneous supplies to make zero-emission equipment fully operational.[95] There may be additional potential costs associated with building retrofits for 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.[96] However, early findings from implementation of the Technology and Equipment for Clean Heating (TECH) Initiative show that when switching to heat pump water heaters, a panel upgrade was needed only in 8 percent of heat pump water heaters incentivized by the program.[97] When existing buildings require electrical distribution system infrastructure upgrades often triggered by electrical panel upgrades,[98] the range of retrofit costs varies depending on building type, end uses, size, age/condition, type and condition of existing wiring, and local workforce availability.

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.[99] [100] [101] [102] [103] There are mixed results with replacing water heaters with heat

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[95] 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*.

[96] 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*.

[97] As of June 2022, about 1200 HPWHs have been incentivized by the program: *https://energy-solution.com/wp-content/uploads/2022/07/TECH-4th-Quarterly-Stakeholder-Meeting.pdf*

[98] PG&E. 2022. “Service Upgrades for Electrification Retrofits Study Final Report.” CALMAC STUDY ID: PG&E0467.01. Available at: *https://pda.energydataweb.com/#!/documents/2635/view*.

[99] 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*.

[100] 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/*.

[101] 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*.

[102] 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*.

[103] 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*.

pump water heaters; there are added life cycle costs with replacing gas storage water heaters and lifecycle savings when replacing gas tankless water heaters with heat pump water heaters. Lifecycle savings can also be achieved when water heater retrofits are combined with heat pump HVAC retrofits.[104] To improve the cost-effectiveness of retrofits, low-amperage heat pump technologies may help avoid the need for electrical panel upgrades.[105] [106] [107] Statewide actions focused on increasing funding for retrofit incentive programs, as well as developing and increasing production of zero-emission appliances that are ready to fit within the existing space 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).[108]

v. Affordable Housing Sector Implications

Building decarbonization efforts are taking place in the context of California's ongoing housing affordability and homelessness crisis. One-third of all California households lack sufficient income to cover basic living expenses.[109] This has been exacerbated by the ongoing impacts of the COVID-19 pandemic.[110] Constructing zero-emission affordable housing and

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[104] 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*.

[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] 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*.

[107] 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*.

[108] 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*.

[109] Ibid.

[110] 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*.

preserving affordability of homes post-retrofit will be critical aspects of any equitable approach to building decarbonization.

To date, comparatively more policy attention has been devoted to regulated (deed-restricted) affordable housing through funding guidelines, and new construction incentive programs. For example, the Affordable Housing and Sustainable Communities (AHSC) Program will require, in Round 7, all-electric appliances to be eligible for funding.[111] The California Energy Commission (CEC)'s Building Initiative for Low-Emissions Development (BUILD) program provides incentives and technical assistance to building owners and developers to support new construction of all-electric deed-restricted affordable housing.[112]

Many affordable housing providers are generally supportive of requiring all-electric new construction in deed-restricted affordable housing developments.[113] They recognize the important benefits and see it as an important next step.[114]

However, unregulated or "naturally occurring" affordable housing (NOAH) makes up the vast majority of the State's affordable housing stock for low-income Californians. In the NOAH context, anti-displacement policies will play a critical role in ensuring that electrification upgrades do not serve as a pretext for displacing vulnerable renters.

There is a split-incentive between owners and renters of existing buildings when deciding if an energy retrofit should be made to a property.[115] Since building owners typically do not pay energy bills, they have little incentive to pay for building retrofits.[116] Incentives to landlords, especially aimed at unregulated affordable housing rental units, could help offset the upfront

[111] Strategic Growth Council. 2022. "Affordable Housing and Sustainable Communities Program Round 7 Funding Guidelines." Available at: *https://sgc.ca.gov/programs/ahsc/resources/guidelines.html*.

[112] 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*.

[113] Kumar, Srinidhi Sampath. "Prioritizing California's Affordable Housing in the Transition Towards Equitable Building Decarbonization" California Housing Parntership, 2021. Available at: *https://chpc.net/resources/ah-building-decarb-report-2021/*.

[114] Ibid.

[115] 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*.

[116] Ibid.

retrofit costs and could include property tax deductions[117] [118] or grants.[119] However, renovations can heighten housing insecurity, especially if a rent-stabilized unit needs to be vacated while retrofits occur and can be rented at market rate once they are complete.[120] In some cases, research shows that property owners have used new repair and maintenance requirements as a pretext for displacing tenants or increasing rents (also referred to as "renoviction").[121] [122] If State or local policy directly or implicitly requires building renovations to comply with new codes or standards, adopting and enforcing associated protective policies will be critical to avoiding renovictions. Just-cause eviction and tenant right-to-counsel policies can help prevent direct displacement, and limiting or banning the pass-through of decarbonization upgrade costs to help ensure that "naturally occurring" affordable housing stays affordable during and after decarbonization.[123]

To date, most consumer-facing incentive programs are more readily accessible to high-income homeowners who have the time and resources to manage a retrofit process, and potentially cover the upfront costs of incentives offered as rebates. Low-income homeowners are less likely to be able to afford the upfront costs of new electric equipment without substantial support.

Because existing 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

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[117] 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.
[118] City of Berkeley. 2021."Existing Buildings Electrification Study." Available at: *https://drive.google.com/file/d/10OY_USkF2MeoBkLXuzQEewpW8rAm-WTk/view*.
[119] 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*.
[120] 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*.
[121] Bouzarovski S., J. Frankowski, S. Tirado Herrero. 2018. "Low-Carbon Gentrification: When Climate Change Encounters Residential Displacement. International Journal of Urban and Regional Research. 42: 845–63. *https://doi.org/10.1111/1468-2427.12634*.
[122] Kirk, C. 2021."Los Angeles Building Decarbonization: Tenant Impact and Recommendations." Strategic Actions for a Just Economy. Available at: *https://www.saje.net/building-decarbonization/*.
[123] Ibid.

than that of higher-income homeowners.[124] [125] The federal Inflation Reduction Act includes $9 billion in consumer home energy rebate programs, focused on low-income consumers, for energy efficiency and electrification.[126] Ten years of consumer tax credits cover home energy investments, including electric service panel upgrade costs, which could offer critical support to facilitate electrification upgrades in households that could otherwise not afford them.[127]

Low-Income Households and Climate Resilience

More frequent extreme weather events from climate change often hit vulnerable and disadvantaged communities hardest and first.[128] More than half (55 percent) 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.[129] 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.[130]

vi. Implications of Costs and Cost-Savings

Large-scale building decarbonization is a vital part of achieving California's climate and federal air quality targets, but it has the potential to be very costly on a total Statewide basis,

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[124] 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*.

[125] 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*.

[126] Inflation Reduction Act of 2022. Available at: *https://www.democrats.senate.gov/07/27/2022/inflation-reduction-act-of-2022*

[127] American Council on an Energy Efficient Economy. 2022. "Congress is Set to Vote on the Largest Efficiency Investments in History." Available at: *https://www.aceee.org/blog-post/2022/08/congress-set-vote-largest-efficiency-investments-history*

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

[129] 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.*

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

and with a wide range of potential household and business-level costs and/or savings. In the new construction sector, the range of potential additional incremental costs is lower, and likelihood of achieving savings is greater, especially because new gas infrastructure costs can be avoided. Decarbonization policies aimed at the new construction sector also place fewer potential cost burdens on existing renters, homeowners, and businesses.

Low-income, disadvantaged, and comparatively under-resourced households and communities may face more significant challenges to decarbonizing at the pace that California's climate goals would require. Careful policy development, planning, and program design can mitigate potential unintended adverse consequences, including higher energy cost burdens, unmanageable retrofit expenses, disproportionate legacy fossil gas system cost burdens, and housing insecurity.

The potential need for funding support likely far surpasses resources that the State can provide. Section 4 will elaborate on potential actions to increase incentives and funding to support healthy, whole building retrofits to minimize costs of decarbonization, and align decarbonization priorities with housing, health, and affordability goals.

C. Consumer Acceptance, Adoption, and Awareness

Increased consumer acceptance, adoption, and awareness of zero-emission appliances would allow manufacturers to take advantage of economies of scale in increasing production capacity, catalyzing a positive feedback loop resulting in zero-emission appliances becoming more widespread and affordable. Over 70 percent of California's households still rely on fossil gas for space heating, water heating, and cooking, and nearly 40 percent rely on gas for clothes drying.[131] [132] Although only five percent of California single-family homes use fossil gas swimming pool heaters, these appliances consume over six times the energy of fossil gas range/ovens on a per unit basis.[133] Consumer preference for appliances they are already familiar with is a major barrier to full-scale electrification.[134] Many utilities offer incentives for high-efficiency heat pump and induction cooking technologies, but adoption has been limited due to the low cost of fossil gas prior to 2021, the extensive network of fossil gas

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[131] 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 fossil gas appliance saturation compared to single-family homes.

[132] 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*.

[133] Ibid.

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

infrastructure in urban areas, and a lack of consumer acceptance and contractor awareness.[135] [136] 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.[137] Thus, actions that increase consumer awareness of 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 fossil gas has been volatile. While PSPS events 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 customers, and the CPUC and Office of Energy Infrastructure Safety are working to reduce the frequency of PSPS events. In fact, California was able to avoid most rolling blackouts during peak summer loads in 2022 through voluntary power cuts. Also, load shifting and distributed generation in combination with energy storage (e.g., battery, thermal, and electric vehicle (EV)) can improve resilience to these events and may help to increase consumer acceptance and 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, EV charging, 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

Chapter 4 of the Scoping Plan summarizes the sector transition needed and the actions that support building decarbonization. Achieving a successful and equitable transition to building decarbonization will require a range of actions by government, utilities, manufacturers, developers, contractors, households, and businesses. The first set of potential actions focuses on laying a foundation for a successful transition by building a sustainable market. Potential

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[135] Ibid.

[136] 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*.

[137] 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*.

actions such as scaling up and aligning building decarbonization incentives, designing affordable energy rates, expanding consumer education efforts and promoting flexible demand programs help build a sustainable market by stimulating consumer adoption, reducing costs and overcoming other barriers, and will be particularly critical to ensure that frontline communities benefit from this transition. Building a sustainable market is a critical first step required to ensure success of all the other potential actions. The next set of potential actions focus on creating certainty for manufacturers and builders through appliance and building standards resulting in increased production of efficient, zero-emission equipment and buildings. Finally, strategically decommissioning existing fossil gas infrastructure is the last set of potential actions featured to reduce costs and send a market signal of the importance of building decarbonization. Success of each step in this transition depends on the magnitude of progress within the previous step. Success of these actions will also rely on balancing equity, sustainability, and affordability as foundational guiding principles moving forward.

California has many initiatives underway to facilitate decarbonization, but more needs to be done. This section helps to highlight the top priority action areas of focus. 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. Build a Sustainable Market

i. Scale up and Align Building Decarbonization Incentive Programs

Incentives aimed at different market actors—such as contractors, households/general consumers, low-income households, rural/tribal households, developers, nonresidential building owners, and manufacturers—play an integral role to advance building decarbonization efforts. Incentives reduce barriers to upfront costs and give contractors and consumers experience with zero-emission technology. Although there are several current building decarbonization incentive programs, as described below, a significant ramp up in funding is needed for these and other new programs to support the scale of building decarbonization necessary to meet the State's climate and air quality goals. Therefore, prioritizing incentive funding for low-income communities within designated nonattainment areas for one or more National Ambient Air Quality Standards is critically important. Additionally, policymakers should also strive for alignment between incentive programs toward building decarbonization and away from fossil gas. Approximately 50% of Californians live in multi-family dwellings. Incentives and programs should be carefully designed to be effective at engaging with multi-family dwelling populations.

a) Contractors

Incentives targeted at contractors and other professionals are intended to help build the market by providing training with installing and maintaining zero-emission technology replacements for gas end uses, which also serve to increase contractor experience and confidence in these systems. These types of incentives not only help prepare the workforce for the decarbonization transition but are also important because of the impact that these professionals play in consumer decision-making.

b) Households/General Consumers

The main goal of consumer incentive programs is to reduce the upfront capital and retrofit costs to decarbonize existing buildings. They can also prepare households for emergency replacement of appliances by providing rebates to upgrade the electric panel (when necessary) to support future electric replacements of gas appliances before it is needed. Many utilities and regional energy networks provide rebates to customers to replace gas appliances with efficient all-electric units. In some cases, they also provide rebates to replace and/or upgrade electrical panels. For example, Marin Clean Energy provides rebates to single-family property owners to replace gas water heaters and furnaces with heat pumps and ranges/cooktops with induction stoves; when necessary, they also provide rebates to upgrade electrical panels.

To ensure alignment with decarbonization goals, consumer incentives for gas appliances should be minimized. For example, California utilities offered millions of dollars in incentives for gas appliances in 2020. California and ratepayers could transition away from subsidizing the purchase of new fossil gas appliances and instead provide incentives to encourage the installation of energy-efficient electric appliances at a lower cost than gas appliances and weatherizing the building envelope to help align market signals needed for meeting climate targets. In January 2022, the CPUC received a motion from the Sierra Club requesting that non-cost-effective fossil gas appliance energy efficiency measures be removed from ratepayer funded energy efficiency programs. In March 2022, the CPUC received proposals from IOUs and other program administrators to authorize new energy efficiency programs for 2024-2028. In August 2022, CPUC released a Staff Proposal to gradually phase out ratepayer funded energy efficiency incentives for the majority of fossil gas equipment over the next ten years with clearly defined steps to give the market predictability and time to adapt to moving away from the use of fossil gas and towards electrification.[138]

c) Low-income Households

Proper and equitable incentives to support the retrofit of existing homes and ensuring accessibility to low-income households are essential to the success of building decarbonization. Programs targeting low-income households must not result in increased

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[138] CPUC. 2022. "EE Natural Gas Incentive Phase Out Staff Proposal." Available at: *https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M496/K397/496397066.PDF*.

utility bills and therefore should include energy efficiency measures, building envelope improvements and weatherization, panel upgrades (when necessary), on-site renewable energy generation and energy storage, and installation of load management systems, as these have been shown to lower occupants' energy burden while reducing GHG emissions.[139] [140] [141] These measures can also improve indoor air quality, increase comfort, and strengthen the climate and extreme heat resiliency of the building. These holistic building incentives could also support EV recharging infrastructure to align with California's transportation electrification goals and increase access to clean mobility within priority populations. The Self-Generation Incentive Program (SGIP), which offers rebates to low-income and disadvantaged households (and non-residential customers) for installing energy storage technology that are able to act as load-shifting devices in buildings, is a program heading in this direction.[142] At a minimum, preparing these homes for emergency replacement by partly or fully offsetting the costs of electrical circuit and panel upgrades needed in homes lacking 240-volt electric connections for stoves, EV charging ports, furnaces, and water heaters places electric and heat pump products on an even playing field with their gas counterparts.

Additionally, many low-income Californians live in older buildings needing health and safety upgrades due to hazardous building materials like asbestos or lead paint and/or structural issues like leaky roofs, mold damage, and unsafe electrical wiring. Existing building decarbonization and energy retrofit programs do not always consider the need or cost of these related health and safety retrofits, which may be needed to facilitate the installation of heat pumps or EV chargers, when designing programs and budgets. CPUC's San Joaquin Valley Affordable Energy pilot project does allow up to $5,000 per home retrofit for health and safety upgrades to bring the building to code. In some cases, this amount has proven insufficient, and the program implementer has to look elsewhere to augment the budget in order to carry out the retrofit. Where feasible, State agencies and developers of building decarbonization and health and safety incentive programs should coordinate to leverage each

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[139] 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*.

[140] 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/*.

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

[142] CPUC. Accessed on 9 September 2022. Participating in Self-Generation Incentive Program (SGIP). Available at: *https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/demand-side-management/self-generation-incentive-program/participating-in-self-generation-incentive-program-sgip*.

other's offerings. At a minimum, it would be useful for energy and health incentive programs to refer customers to each other's programs.[143] [144]

I. Homeowners

As previously discussed, low-income homeowners need more intensive support since they may not necessarily be able to afford decarbonization costs.[145] [146] Incentive programs should be designed to be accessible to all low- and moderate-income homeowners across the State. For example, low-income households often lack capital and credit ratings necessary to take advantage of conventional financing. Direct install public investments provide a pathway to accelerate decarbonization while ensuring low-income consumers are not left behind.[147] The Low-Income Weatherization Program (LIWP), which provides low-income households with solar systems and efficiency retrofits at no cost to residents, is a good example of such a program.[148] Streamlining application approval processes should also be a key consideration for ensuring sufficient uptake of existing and new incentive programs.

II. Renters / Affordable Housing Providers

In addition, as indicated above in the Affordable Housing Sector Implications section, many low-income households rent their houses or apartments and can be caught in a split incentive situation—where the occupant/tenant pays the energy bill and the building owner makes the decisions about building improvements that directly impact the energy bill, occupant comfort, and GHG emissions. Therefore, incentive programs targeting renters / affordable housing providers should be designed with goals of overcoming this split incentive between the

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[143] Ibid.

[144] 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/*.

[145] 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/*.

[146] 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*.

[147] 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*.

[148] CSD. Accessed on 9 September 2022. Low-Income Weatherization Program. Available at: *https://www.csd.ca.gov/Pages/Low-Income-Weatherization-Program.aspx*.

landlord and tenants, building capacity among affordable housing providers through technical assistance, and protecting tenants.

Often affordable housing, either deed-restricted or naturally occurring, is owned by groups that operate on very low profit margins making justification of energy improvements difficult. Financing mechanisms to mitigate these barriers could include revolving loans,[149] green bonds,[150] credit enhancements,[151] interest rate buydowns,[152] property assessed clean energy programs,[153] on-bill financing/repayment/tariffs,[154] direct install incentives,[155] tax equity financing,[156] energy services agreements,[157] and private investments for energy-efficiency retrofits, such as through California's Green Bank.[158] Better alignment between building decarbonization and housing programs, such as Low-Income Housing Tax Credits (LIHTC) would also be beneficial in advancing decarbonization in affordable housing.[159] 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.[160] [161] The

[149] A revolving loan is a type of credit line that allows the borrower to access and pay back the loan as needed with interest based on the amount used.

[150] A green bond is a financial instrument that finances green projects and provides investors with regular or fixed income payments.

[151] Credit enhancements are actions that improve the chances that financing will be repaid.

[152] Interest rate buydown is a way for borrowers to obtain lower interest rates to pay discount points at closing.

[153] 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.

[154] On-bill financing is a mechanism allowing a utility customer to pay for the cost of upgrades, which is then repaid through a fixed monthly installment on their utility bills.

[155] Direct install programs provide for the direct installation of equipment through consultants with zero cost to customers.

[156] Tax equity is a form of project financing that uses a combination of project-generated cash flow and federal tax benefits.

[157] Energy Service Agreement (ESA) is a pay-for-performance, off-balance sheet financing solution that allows customers to implement energy efficiency projects with zero upfront capital expenditure.

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

[159] Kumar, S. S. 2021. "Prioritizing California's Affordable Housing in the Transition Towards Equitable Building Decarbonization." Available at: *https://1p08d91kd0c03rlxhmhtydpr-wpengine.netdna-ssl.com/wp-content/uploads/2021/04/BuildingDecarbonizationSummitAHReport2021.pdf*.

[160] 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.

[161] 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*.

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.

Specific investment programs coupled with training and technical assistance aimed at deed-restricted and unregulated affordable housing rental units would help to compensate for 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.[162] [163] [164] The 2022-23 California State budget created a new $922 million statewide equitable building decarbonization program. The program will offer both a direct install decarbonization program for low- and moderate-income households and an incentive program to advance the installation of high-efficiency electric appliances.

d) Rural/Tribal Communities Not Served by Regulated Fuels

Policymakers must also continue to give special attention to the many rural and tribal communities that rely on unregulated fuels due to the lack of limited electric and fossil gas infrastructure. Numerous rural and tribal communities in California rely on high-cost heating fuels which poses an energy burden for low-income residents in these communities.[165] These households need special programs aimed at the unique needs of these communities, such as the San Joaquin Valley Affordable Energy pilot project, which seeks to increase affordable access to energy for residents in small, rural San Joaquin Valley communities that rely on propane and wood for cooking and heating.[166] Approximately $2 million in grants have already been awarded to California Native American Tribes through the CEC's Tribal Government Challenge Planning Grant Program to support projects that reduce GHG

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[162] Ibid.

[163] 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*.

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

[165] CEC. 2018. Energy Equity Indicators. Available at: *https://www.energy.ca.gov/sites/default/files/2019-12/energy_equity_indicators_ada.pdf*.

[166] CPUC. "San Joaquin Affordable Energy Proceeding" Available at: *https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/infrastructure/identifying-disadvantaged-communitie*.

emissions, improve access to clean energy, and advance climate resiliency on tribal lands;[167] further work with tribal nations will continue to be a priority.

e) Developers and Building Owners

Incentive programs targeted at building developers and building owners are also important to reduce the upfront capital cost in new construction and build technical capacity. For example, the BUILD program, a four-year program with a budget of $80 million, provides technical assistance and incentives to building owners or developers for new, all-electric residential buildings with 40 percent dedicated to construction of low-income residential housing.[168]

Policymakers should also ensure alignment between existing incentive programs toward building decarbonization. For example, utilities encouraged the use of fossil gas in new construction by incentivizing developers through hundreds of millions of ratepayer dollars annually allocated to subsidies for new gas line connections and maintenance of the existing system.[169] [170] [171] [172] [173] Ratepayers spent approximately $130 million on these incentives in 2021. Redirecting resources away from investments that support developers whose buildings increase fossil gas demand, and toward aligned public investments that accelerate building electrification, will help phase out traditional combustion technologies and associated climate

[167] CEC. Accessed on 29 September 2022. State Awards $2 million to 10 California Native American Tribes for Climate and Clean Energy Projects. Available at: *https://www.energy.ca.gov/news/2021-01/state-awards-2-million-10-california-native-american-tribes-climate-and-clean*.

[168] 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*.

[169] 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*.

[170] 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*.

[171] 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*.

[172] 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*.

[173] 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.

impacts and pollution.[174] Furthermore, new installations of fossil 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.[175]

To improve alignment, in September 2022, the CPUC adopted the recommendations of a staff proposal in the ongoing building decarbonation proceeding (R.19-01-011 Phase III) to eliminate gas line extension allowances, the 10-year refundable payment option, and the 50 percent discount payment option provided under the current gas line extension rules for residential and non-residential gas customers.[176] Although this Decision is likely to encourage more all-electric new construction and help alleviate future gas rate escalation, development of a long-term Statewide fossil gas plan is needed—and under development—to send appropriate market signals for the transition of the energy industry.

f) Non-residential: businesses and public buildings

Public buildings and businesses represent a significant segment of California's nonresidential building stock. Public buildings, including state buildings, K-12 schools and colleges, represent nearly 20 percent of total nonresidential square footage and GHG emissions. Incentive programs focused on businesses and public buildings are necessary to reduce the upfront costs due to capital and retrofit expenses, help accelerate the turnover rate, and prepare for emergency replacements. The SGIP is an example of a program that offers rebates for installing energy storage technology in non-residential buildings. There are also a variety of rebates and financial assistance available to businesses and public buildings through programs offered by utilities, community choice aggregators, and regional energy networks. Most of these incentives are focused on improving energy efficiency to help reduce energy bills. Since businesses and public buildings can serve as a model to decarbonize other non-residential buildings, additional incentives are needed to increase the scale of retrofits and demonstrate a path forward to reduce emissions from these buildings.

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[174] 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*

[175] 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*.

[176] CPUC. 2022 D.22-09-026. Available at: *https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M496/K987/496987290.PDF*.

g) Manufacturers

The goal of incentivizing manufacturers is to accelerate technology advancement that supports long-term decarbonization efforts. Therefore, funding for manufacturers to support 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, scaling-up funding for RDD&D activities can accelerate improvements in technology performance, reduce cost, mitigate installation challenges, and demonstrate the value proposition to market actors unfamiliar with new technologies. While California[177] and federal[178] 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:

1) 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.
2) Advancing highly efficient technologies that help avoid or minimize electric panel upgrades in existing homes.
3) Developing and demonstrating demand flexibility technologies that deliver a range of customer and grid benefits.
4) Conducting prize competitions to promote technology awareness and spur new technology designs for improved performance and efficiency.

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.

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[177] California building-related efforts include CEC's Electric Program Investment Charge and the Natural Gas Research and Development Program.
[178] 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.

ii. Design Affordable Energy Rates

Because potential bill impacts on customers are a barrier to switching from gas appliances to electric ones, even for efficient heat pump technologies, energy rates can be designed to support electrification in alignment with cost causation[179] and other rate design principles intended to ensure just and reasonable rates for participants and non-participants[180] alike.[181] [182] [183] [184] There are many approaches to improve rate design to support building electrification, including rates with higher fixed charges, which result in lower volumetric rates, establishing more dynamic pricing and granular time periods as well as real-time rates, and bundling demand flexibility programs, energy efficiency and new rate designs together.[185] [186]

Electric rates designed to advance electrification can help provide rate relief for customers who use higher amounts of electricity as a result of retrofitting to efficient electric appliances

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[179] The cost causation principle means that costs should be borne by those customers who cause the utility to incur the expense. The CPUC has stated that avoiding cross-subsidies and supporting cost-causation principles achieves equity in rates by relating the costs imposed on the utility system to the customer responsible for those costs.

[180] In utility ratemaking, a "participant" is a customer who enrolls in a particular tariff or program. A "non-participant" is a customer of the same utility who does not enroll in the tariff or program in question. Depending on the ratemaking treatment, some utility tariffs and programs result in varying costs and benefits for participants and/or non-participants.

[181] 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*.

[182] 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*.

[183] 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*.

[184] 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*.

[185] 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/*.

[186] 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*.

from fossil gas. It can also mitigate electric rate increases due to large-scale building and transportation electrification. The CPUC sought to address the rates 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. SCE is one of the first IOUs with an electric rate designed for electrification. This rate, schedule TOU-D Prime—designed for customers with EVs, battery storage, and electric heat-pumps for water and space heating—has a higher fixed charge ($12 per month) in order to access the lower super off-peak and off-peak volumetric rates.[187] A similar rate was also approved by the CPUC for PG&E (E-ELEC), for which the fixed charge is $15/month.[188] SDG&E also has an application for a pro-electrification rate pending CPUC approval.[189] Managing grid costs will be essential to achieving building decarbonization goals.

While the CPUC proceeding is focused on IOUs, effective rate design must also be considered for other entities, such as community choice aggregators (CCAs) and POUs. As new tariff rates are developed, it is important to ensure that ratepayers are made aware of these new rates and enrolled in the correct tariff so they can take advantage of these beneficial rates.[190] California State agencies and utilities could continue to explore additional ways to keep electricity prices low to encourage customers to switch to electric appliances that will necessitate increased electricity consumption.

Energy affordability is critical to equitable building decarbonization. The CPUC's 2019 Affordability Report found that 13.3 percent of households in the State whose income falls at the 20th percentile of their local distribution spend over 15 percent of their annual income (after housing costs) on energy, and most of these communities are in the State's inland and

[187] Southern California Edison. 2022. "Time-of-Use Rate: TOU-D-Prime. Available at: *https://www.sce.com/sites/default/files/inline-files/TOU-D-PRIME_Fact_Sheet_0320_WCAG.pdf*.

[188] 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*.

[189] 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*.

[190] CPUC. Accessed on 10 August 2022. Electric Rates. Available at: *https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/electric-rates/*.

rural areas.[191] In the CPUC's Affordability Metrics Implementation and Energy Savings Assistance Program proceedings, the Commission has developed energy affordability metrics, and is exploring the possibility of using those metrics to prioritize program resources for eligible customers.[192] Additionally, AB 209 authorizes the CPUC to require that residential fixed charges be collected on an income-graduated basis, resulting in a more equitable distribution of the costs for shared energy infrastructure and lower energy charges for low-income customers. The CPUC is considering this issue in its ongoing demand flexibility rulemaking (R.22-07-005).

iii. Expand Consumer Education Efforts

Consumer education efforts can increase interest and positive attitudes, willingness to pay, and thus market penetration of new environmentally friendly technologies.[193] [194] 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, lifecycle costs and credible economic information, and provide resources on where to get more information.[195] [196] Since trying out a different technology greatly increases interest and desire, education efforts could include technology demonstrations, as some utilities currently do with induction cooktops.[197] [198] [199] Public agency-sponsored one-stop shop and

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[191] CPUC, 2021. "2019 Annual Affordability Report" Accessible at: *https://www.cpuc.ca.gov/-/media/cpuc-website/industries-and-topics/reports/2019-annual-affordability-report.pdf*.

[192] CPUC. 2021. "Affordability Metrics Implementation Workshop." Energy Division presentation (p. 55). Available at: *https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/affordability-proceeding/affordability-phase-2-workshop-slidedeck_11152021.pdf*.

[193] 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/*.

[194] RMI. 2021. "Building Decarbonization Roadmap." *United States Climate Alliance*. Available at: *https://static1.squarespace.com/static/5a4cfbfe18b27d4da21c9361/t/60c9295c0d6f5b30e2a66948/1623796080027/Alliance+Building+Decarbonization+Roadmap.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/*.

[196] 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*.

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

[198] SMUD. Accessed on 1 September 2022. "Induction Cooking with SMUD: A faster, healthier, safer way to cook." Available at: *https://www.youtube.com/watch?v=J4p8uvwy5vU*.

[199] Southern California Edison 2022. "Food Service Technology Center." Available at *https://www.sce.com/residential/energy-education-centers/Foodservice-Technology-Center*.

educational websites, such as "The Switch is On"[200] among others,[201] [202] [203] [204] 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. 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.[205] Consumer education may be sufficient to facilitate electrification with wealthier early adopters, but incentives are required to help overcome the additional infrastructure and equipment usually needed to electrify existing mid- and low-income homes.[206] Electric home heating systems are mainly purchased because of contractor recommendation,[207] 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.[208] Building inspectors also benefit from training on new electric appliances and the infrastructure needed to support them. Restaurants will likely need dedicated outreach and incentives to embrace electric cooking. For example, recruiting

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

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

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

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

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

[205] 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*.

[206] 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/*.

[207] 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*.

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

successful and celebrity chefs to feature the superior control and speed of induction cooking, as well as safer kitchen environments, and targeting incentives to pilot restaurants of varied cuisines can encourage other restaurants to electrify cooking.[209]

These education efforts can be designed to be culturally appropriate, available in multiple languages, and implemented in collaboration with trusted community groups. Regionally specific consumer awareness, education, and program enrollment strategies can be especially supportive and effective in the State's under-resourced and disadvantaged communities. In the San Joaquin Valley Affordable Energy pilot project, Community Energy Navigators served as local liaisons to provide information to households through community meetings and canvassing to encourage subsidized household electrification.[210]

iv. 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 substitution 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 by 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.[211] [212] [213] Actions that increase flexible demand resources would support an affordable and reliable grid as the share of carbon-free resources expands.[214]

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

[210] CPUC, "San Joaquin Affordable Energy Proceeding" Available at: *https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/infrastructure/identifying-disadvantaged-communitie*.

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

[212] 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*.

[213] 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*.

[214] 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*.

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).[215] 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 automatically run when receiving low price signals. Applying time-varying pricing evenly across all customers would correct the equity issue of traditional demand response programs that excluded smaller and more efficient participants and rewarded larger and less efficient participants.[216] [217] In addition, targeted subsidies or equipment incentives for low-income customers can increase equitable access to flexible demand equipment.

In addition, the 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 low-income customers.[218]

B. 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[219] and achieving public health benefits. The 2022 State Strategy for the State Implementation Plan (SIP), which details the State's strategy and commitments to reduce emissions from State-regulated sources to help

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[215] Ibid.

[216] 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.

[217] 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*.

[218] CPUC. 2021. "Order Instituting Rulemaking Regarding Policies, Procedures and Rules for the Self-Generation Incentive Program (SGIP) 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*.

[219] CARB. 2022. *Proposed 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*.

local air districts attain the federal 70 parts per billion (ppb) 8-hour ozone standard, includes measures CARB has committed to pursue to achieve the necessary emission reductions. One such measure is a Statewide zero-emission GHG standard for new space and water heaters sold in California.[220] Starting in 2030, new space and water heaters sold for new and existing residential and commercial buildings would need to comply with the standard.[221] Approximately 40 percent of annual building-related GHG and NOx emissions could be reduced statewide by 2037 if zero-emission standards were implemented in 2030 for new space and water heating appliances. By focusing on space and water heating, the SIP commitment is intended to align with the 2022 Scoping Plan Update. 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 concerning space and water heaters, 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 fossil 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 fossil 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.[222] The Bay Area AQMD is proposing to require that new space and water heating equipment sold for residential buildings be zero-emission for NOx by 2029.[223] While these efforts will assist California in

[220] CARB adopted the 2022 State SIP Strategy at its Board Hearing on September 22, 2022. See *https://ww2.arb.ca.gov/resources/documents/2022-state-strategy-state-implementation-plan-2022-state-sip-strategy*.

[221] Ibid. Note this is a measure and not a proposed or finalized regulation, nor does its inclusion in the State SIP Strategy necessarily mean CARB will propose or adopt such a regulation. In the State SIP Strategy, CARB is committing to investigate developing a rule that would achieve the NOx emissions reductions anticipated from such a zero-emission space and water heating rule.

[222] 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*.

[223] 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*.

meeting air quality standards, a statewide zero-emission GHG standard for new appliances could be a useful action to further reduce appliance emissions throughout the State.

ii. Update California's Appliance Efficiency and Flexible Demand Standards

Development of water and energy efficiency standards for appliances could help decarbonize existing 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). 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.[224]

There are additional opportunities for appliance standards to reduce potential energy bill impacts associated with building electrification efforts. For example, the CEC has a legislative mandate to promote markets for appliances with flexible demand technologies.[225] These flexible demand appliance 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 proposing a phased approach, where 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. A draft staff report to support flexible demand standards for the first appliance or group of appliances is under development.

iii. 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

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224 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*.

225 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*.

the commercial, industrial, residential, and transportation sectors.[226] 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 and technical hurdles to deploying low and ultra-low[227] 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.

C. 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) within Part 6, Building Energy Efficiency Standards (Energy Code) and Part 11, California Green Building Standards (CALGreen Code) 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 in the next 30 years.[228] 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. Since the 1970s, building energy efficiency standards in combination with appliance energy efficiency standards have saved California consumers more than $100 billion

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[226] 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*.

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

[228] 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*.

in utility bills.[229] 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 fossil gas appliances by including mandatory electric-ready provisions for single-family homes and encouraging installation of the most energy efficient 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 fossil gas appliances and equipment are installed. The 2022 Energy Code also encourages electrification, by setting efficient electric heat pumps as a standard technology for newly constructed single-family homes, multi-family, and select commercial building types. These heat pump standards are the default, but not mandatory, and can be traded off by using approved computed modeling software by increasing energy efficiency in other aspects of the building. Moving forward, the Energy Code will continue to identify cost-effective and technically feasible building decarbonization measures in future code cycles to advance energy efficiency, electrify end-uses, reduce consumer bills, and significantly reduce GHG emissions—all at the same time.

California also has an opportunity to adopt zero-emission building standards for new construction as part of the CALGreen Code. 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 60 local jurisdictions have shown their leadership in this area by passing electrification building codes that go beyond

[229] 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.*

California's building standards code.[230] 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. In addition to standardization of building standards across local jurisdictions, a streamlined permitting process would be helpful to assist with unexpected, emergency situations when appliances burnout and need replacement.

ii. 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. Mandatory performance standards for buildings could achieve an estimated 11 percent reduction in energy use and GHG emissions by 2050 nationwide if two-thirds of existing buildings built before 2020 in the U.S. were required to reduce energy use and emissions by 30 percent on average compared to similar buildings.[231]

The Biden White House launched in January 2022 a Building Performance Standards Coalition of states, cities, labor, and industry aimed at reducing emissions across the building sector. State and local governments have also developed building performance standards specific to their jurisdictions, including Washington and Colorado, and the cities of Berkeley, Brisbane, Chula Vista, Los Angeles, San Francisco, San Jose, New York, and Washington D.C. CEC currently implements the State's Building Energy Benchmarking Program, which 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 and identify the need to take action to improve energy efficiency.

The combination of other jurisdictions' experiences, the Statewide benchmarking program data, interval meter data, and Home Energy Rating System (HERS) compliance reports provides a strong foundation for California to develop building performance standards. Complementary incentives or financial programs would help offset decarbonization and structural costs for low-income building or non-profit owners with small margins.

[230] 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.*

[231] Nadel, S., A. Hinge. 2020. "Mandatory Building Performance Standards: A Key Policy for Achieving Climate Goals." *American Council for an Energy-Efficient Economy.* Available at: *https://www.aceee.org/sites/default/files/pdfs/buildings_standards_6.22.2020_0.pdf.*

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.[232] 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.[233] 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.[234] 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.[235] While public agencies within California are already taking aggressive action for their own buildings, more can be done. State agencies could focus future actions to support all-electric construction in addition to ZNE. Additionally, K-12 public schools could be prioritized for decarbonization and the resulting air quality and health benefits. While most local codes in California include mandates 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. 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

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

[233] 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.

[234] 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.

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

as ENERGY STAR®,[236] CarbonFree® Product Certification label,[237] various rating systems within LEED,[238] GreenPoint Rated,[239] and the Living Building Challenge.[240] 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 State agencies 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.

D. Strategically Decommission Existing Fossil Gas Infrastructure

Limiting the expansion of fossil gas lines can reduce stranded asset risks and strategic decommissioning of fossil gas infrastructure or zonal electrification, especially where gas lines are deteriorating, can reduce system maintenance needs, costs, and emissions.[241] [242] Governments and utilities must ensure this transition is equitable and affordable, and prioritize transitioning low-income and disadvantaged customers off of fossil gas as early as possible since they are most vulnerable to the rate escalation as the gas customer pool shrinks.[243] The CPUC is actively considering these issues, and developing a framework for pruning the gas system in an ongoing rulemaking (R.20-01-007).

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

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

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

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

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

[241] Bilich, A., M. Colvin, T. O'Connor. 2019. "Managing the Transition: Proactive Solutions for Stranded Gas Asset Risk in California." *Environmental Defense Fund.* Available at: *https://www.edf.org/sites/default/files/documents/Managing_the_Transition_new.pdf*.

[242] Velez, K. 2021. "California's Building Transition Recommendations for Gas Transition Regulatory Proceedings at the California Public Utilities Commission." *Building Decarbonization Coalition.* Available at: *https://www.buildingdecarb.org/uploads/3/0/7/3/30734489/final_draft_rev_3__building_decarbonization_coalition_project__4_.pdf*.

[243] 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/*.

5. Areas for Increased Emphasis Moving Forward

A. Lifecycle Performance of Buildings

As decarbonized buildings consume less energy to operate, reducing embodied carbon and other environmental impacts associated with buildings becomes increasingly important.[244] Embodied carbon of buildings—referring to GHG emissions from extracting and manufacturing building materials—contributes at least 11 percent of all energy-related emissions annually world-wide.[245] [246] Studies may underestimate embodied carbon depending on the scope of the lifecycle assessment. A full lifecycle emissions assessment would also include the phases of transportation and disposal of building materials. CARB is required to develop a "framework for measuring and reducing the carbon intensity of materials used in the construction of new buildings," including a comprehensive strategy to achieve a 40 percent net reduction in GHG emission of building materials by the year 2035.[247] In addition to embodied carbon, the public is expressing growing concern over hazardous substances associated with the treatment, disposal, and recycling of appliances and lithium batteries for energy storage as California transitions to electrification. Rearranging the material flow in the product system to create a circulated economy can reduce environmental contamination from disposal as well as the carbon footprint of products.

Embodied carbon can be reduced through cost-effective management practices including the optimal use of building materials with high-recycled or low-carbon products.[248] 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. The California Building Standards

[244] 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/*.

[245] 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*.

[246] 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*.

[247] Health and Safety Code § 38561.3, Embodied carbon emissions: construction materials, Assembly Bill 2446 (AB 2446) (Holden, Chapter 352, Statutes of 2022)

[248] 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/*.

Commission (BSC) also initiated the CALGreen Carbon Reduction Collaborative (CCRC)[249] to discuss the lifecycle performance of buildings as potential voluntary measures during the 2022 Intervening Code Cycle. Some local jurisdictions are already starting to move from voluntary to mandatory embodied carbon standards to help meet their sustainability goals. For example, Marin County developed local ordinances to regulate the embodied carbon of concrete.[250] Multiple State agencies are involved in waste management issues associated with disposal of fossil gas appliances and lithium batteries, including CalRecycle, CARB, CEC, and CPUC, and will continue to work on minimizing impacts to the public.

Future actions that reduce embodied carbon and other lifecycle environmental impacts, such as water consumption, indoor air quality, and waste disposal, could include encouraging voluntary or mandatory programs and providing market certainty through long-term programs focused on embodied carbon such as incentives[251] [252] and requirements for new construction that can drive manufacturers' investment in low-carbon technologies and transition their product portfolio. [253] [254] [255]

B. Equitable Implementation and Governance

This appendix aims to provide a succinct overview of various potential building decarbonization pathways and considerations but cannot fully characterize potential unknown adverse unintended consequences. Ongoing monitoring and iteration upon building decarbonization actions are needed in collaboration with the many stakeholders who will

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[249] Building Standards Commission. 2022. "Pre-Cycle Activities—2022 Intervening Code Cycle: CALGreen Carbon Reduction Collaborative." Available at: *https://www.dgs.ca.gov/BSC/Rulemaking/2022-Intervening-Cycle/2022-PreCycle*.

[250] County of Marin. 2019. "Low-Carbon Concrete Requirements." Available at: *https://www.marincounty.org/depts/cd/divisions/sustainability/low-carbon-concrete*.

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

[252] 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*.

[253] 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*.

[254] 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*.

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

participate in this transition, and especially the State's most vulnerable and disadvantaged residents.

Local strategy planning exercises such as those undertaken by the Cities of Berkeley[256] and Los Angeles[257] are important first steps; geographically specific research and implementation pilots are also a critical opportunity to learn from practice. Balancing the need to focus on vulnerable communities, while also not over-exposing these communities to the risks and uncertainties inherent in early-stage socio-technical transitions, will be an important area of ongoing attention.

Building more capacity for sustained community engagement practices, appropriately matched to the scale and nature of public agency policy and program model deliberations, could help make building decarbonization more successful.

6. Conclusions

Since existing 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, and in doing so provide important public health benefits. Additionally, building decarbonization can improve comfort, provide an important tool for climate resilience and adaptation, and enhance 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. A comprehensive strategy is needed to ensure high-road jobs are the result of workforce training programs to support this transition. Additional information on building a resilient economy and workforce is provided in the 2022 Scoping Plan Update. 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 some households expected to see a net increase in energy bill costs while others are expected to see a net decrease in energy bill costs depending on several factors. Long-term planning and investment to harmonize building decarbonization and strategic

[256] City of Berkeley, 2021. "Existing Buildings Electrification Strategy"

[257] For planning efforts starting, see: *UCLA teams up with LADWP for equitable solutions to reach 100% renewable energy - UCLA Luskin Center for Innovation* available at: *https://innovation.luskin.ucla.edu/2022/07/25/ucla-teams-up-with-ladwp-for-equitable-solutions-to-reach-100-renewable-energy/*.

decommissioning of existing gas infrastructure is also an important strategy to maintain safety and reliability and to minimize rate impacts during the transition.[258]

Decarbonizing California's new and existing buildings will be challenging. While the State, regions, local jurisdictions, 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 to align policies and collaborate with and prioritize frontline communities in those policies. There are a variety of potential actions that could be pursued to reduce emissions in both new construction and existing buildings. Market-enabling actions such as incentives, affordable energy rates, education, and flexible demand programs lay the foundation to prepare consumers, building developers, appliance manufacturers, and contractors for an equitable transition to building decarbonization. Accelerating widespread use of zero-emission appliances will rely on development of new standards, modifications to existing standards, and expanded use of alternative refrigerants. Actions to strengthen building standards for new construction, develop performance standards for existing buildings, decarbonize public buildings, and promote third-party recognition programs can enhance consumer awareness and stimulate the adoption of zero-emission buildings. Decommissioning fossil gas infrastructure is another essential component of achieving the state's decarbonization goals. Actions to reduce the embodied carbon of building materials will be an area of increased emphasis moving forward. Lastly, ongoing community engagement will continue to be a meaningful aspect of increased emphasis to ensure an equitable building decarbonization transition.

[258] 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*.