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California Energy Commission

COMMISSION REPORT

Draft 2021 Integrated Energy Policy Report

Volume I: Energy Efficiency and Building, Industrial, and Agricultural Decarbonization

Gavin Newsom, Governor

December 2021 | CEC-100-2021-001-V1

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ABSTRACT

The *2021 Integrated Energy Policy Report* provides the results of the California Energy Commission's assessments of a variety of energy issues facing California. Many of these issues will require action if the state is to meet its climate, energy, air quality, and other environmental goals while maintaining reliability and controlling costs.

2021 has been an unprecedented year as the state continues to face the impacts and repercussions of multiple challenging events including the continued effects of the COVID-19 pandemic, extreme summer weather, and drought conditions. In addition to these events, the *2021 Integrated Energy Policy Report* covers a broad range of topics, including building decarbonization, energy efficiency, challenges with decarbonizing California's gas system, quantifying the benefits of the Clean Transportation Program, and the *California Energy Demand Forecast*.

Keywords: Integrated Energy Policy Report, building decarbonization, energy efficiency, embodied carbon

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EXECUTIVE SUMMARY

Introduction

The *2021 Integrated Energy Policy Report (IEPR)* provides information and policy recommendations on advancing a clean, reliable, and affordable energy system for all Californians. The *2021 IEPR* is presented in the following volumes:

- **Volume I** addresses actions needed to reduce the greenhouse gases (GHGs) related to the buildings in which Californians live and work, with an emphasis on energy efficiency. It also addresses reducing GHGs from the industrial and agricultural sectors.
- **Volume II** examines actions needed to increase the reliability and resiliency of California's energy system.
- **Volume III** looks at the evolving role of gas in California's energy system, both the importance in near-term reliability and the need for the system to evolve as California works to achieve carbon neutrality — the point at which the removal of carbon pollution from the atmosphere equals or exceeds emissions — by 2045.
- **Volume IV** reports on California's energy demand outlook, including a forecast to 2035 and long-term energy demand scenarios to 2050. The analysis includes the electricity, gas, and transportation sectors.
- **Appendix** assesses the benefits of California's Clean Transportation Program.

Decarbonization and Energy Efficiency

California faces numerous climate change-induced challenges from wildfires to heat waves to droughts. These challenges impact the safety and health of residents, the reliability of energy systems, and the economy of the state. California has studied, planned, and acted over the last 15 years to reduce the emissions of GHGs and impacts of climate change through the energy, transportation, natural lands, agricultural, and industrial sectors. Residential and commercial buildings account for nearly a quarter of GHG emissions and proactive building decarbonization is necessary to meet midcentury climate goals. Building decarbonization is achieved through a combination of:

- Energy efficiency.
- Renewable electricity (utility and distributed generation).
- Electrification of end uses (for example, water heating or air conditioning).
- Implementing distributed energy resources like rooftop solar and batteries.
- Switching to climate-friendly refrigerants and improving refrigerant management.
- Displacing fossil gas.
- Shifting and shaping energy loads with demand flexibility.
- Reducing the embodied emissions of building materials.

Decarbonization requires policies and programs that balance the needs, priorities, and capacities of people, especially those in low-income and disadvantaged communities, and those of manufacturers, distributors, utilities, and builders.

California is taking bold steps to reduce GHG emissions in buildings through statewide regulations such as the Building Energy Efficiency Standards, Appliance Efficiency Standards, Flexible Demand Appliance Standards, Load Management Standards, and minimum requirements for electric vehicle supply equipment in new buildings. The state's research and development efforts are supporting the development of innovative technologies and methods to deepen emissions reductions and reduce costs. Meanwhile, ratepayer- and publicly funded energy programs are adapting to support GHG emission reduction and grid-supporting reliability.

California regulators have a powerful array of tools in the building decarbonization toolbox. These include the Building Energy Efficiency Standards, the California Green Building Standards Code (or CALGreen), and others at the CEC. CARB has authority under AB 32 and other provisions within State law to regulate GHG emissions, and State law makes CARB the lead agency for developing the State Implementation Plan and approving Air Quality Management Plans developed by regional air districts based on relevant air quality authorities. Further, an array of state affordable housing finance programs and local government powers over safety, land use, and utility concession can help advance building decarbonization. Most or all of these tools will be needed to realize the public benefits of shifting to clean electric technologies.

California will need to stimulate significant private market investment into end use decarbonization if it is to achieve a doubling of energy efficiency and stay on track for climate goals. Special regulatory and programmatic attention is also required to ensure that energy services remain affordable and that low-income and disadvantaged communities receive prioritized and direct decarbonization investments.

As described in the *2019 California Energy Efficiency Action Plan*, current programs and policies are not projected to achieve energy savings and GHG reductions that are on a path to 2030 targets. More aggressive efficiency and decarbonization is needed from programs and the private market to get on track for 2030 climate goals. The year 2030 is just around the corner; given the rate of equipment replacement, replacing most existing equipment stocks with low-carbon emission alternatives would take more than 15 years — well beyond 2030. The key space and water heating equipment that drives the bulk of on-site GHG emissions have expected lifetimes of one to two decades. That makes the market transformation of new equipment sales a key priority. Each replacement of major equipment presents a precious opportunity to achieve long-term savings and make additional improvements to the building.

To decarbonize buildings and industrial and agricultural processes, California must extend the suite of policy and programmatic action on topics ranging from state interagency coordination; continued use of regulatory authority for standard setting; alignment of funding and incentives with decarbonization objectives; expanding, training, and supporting the clean energy workforce; improving public outreach; supporting local and federal leadership; and continued research and development of low-carbon technologies and practices. Specific recommendations are available in the body of the volume.

CHAPTER 1: Achieving Decarbonization

Reducing greenhouse gas (GHG) emissions and increasing the resiliency of buildings and energy systems are critical for California to manage the costs of climate change costs. The International Panel on Climate Change found that to limit global warming to 1.5 degrees Celsius (1.5°C), the power sector must be almost completely decarbonized by midcentury.[1] The report also notes building end-use energy efficiency and electrification are key strategies to limit global warming.[2]

California agencies and local jurisdictions are focused and coordinating on reducing GHG emissions economywide. This effort is supported by many pieces of legislation and Executive Order B-55-18, which set a goal to achieve economywide carbon neutrality[3] no later than 2045. Since 2000, California has reduced roughly 40 million metric tons[4] of carbon dioxide (CO_2) emissions per year from the electricity sector by aggressively supporting renewable energy generation, supporting energy efficiency, reducing imports of coal-fired generation, and shifting to a decreased reliance on fossil natural gas.[5] By comparison, buildings, industrial processes, and agricultural processing sectors, which contribute about 36 percent of direct GHG emissions, have not been as successful as the electricity sector in reducing emissions (Figure 1).[6] When distributing the GHG emissions of electricity generation and refrigerant use

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1 IPCC. 2018. *Special Report: Global Warming of 1.5 Degrees Celsius*. Chapter 2, p. 130. https://www.ipcc.ch/sr15/chapter/chapter-2/.

IPCC's Special Report on Global Warming includes an FAQ that states, "the overwhelming majority of countries around the world adopted the Paris Agreement in December 2015, the central aim of which includes pursuing efforts to limit global temperature rise to 1.5°C." It also states that "in some regions and vulnerable ecosystems, high risks are projected even for warming above 1.5°C'." (https://www.ipcc.ch/sr15/faq/faq-chapter-1/.)

2 Ibid. Chapter 2, p. 134. https://www.ipcc.ch/sr15/chapter/chapter-2/.

3 Carbon neutrality occurs when the sum of carbon dioxide emission and sequestration results in no increase of atmospheric carbon dioxide levels.

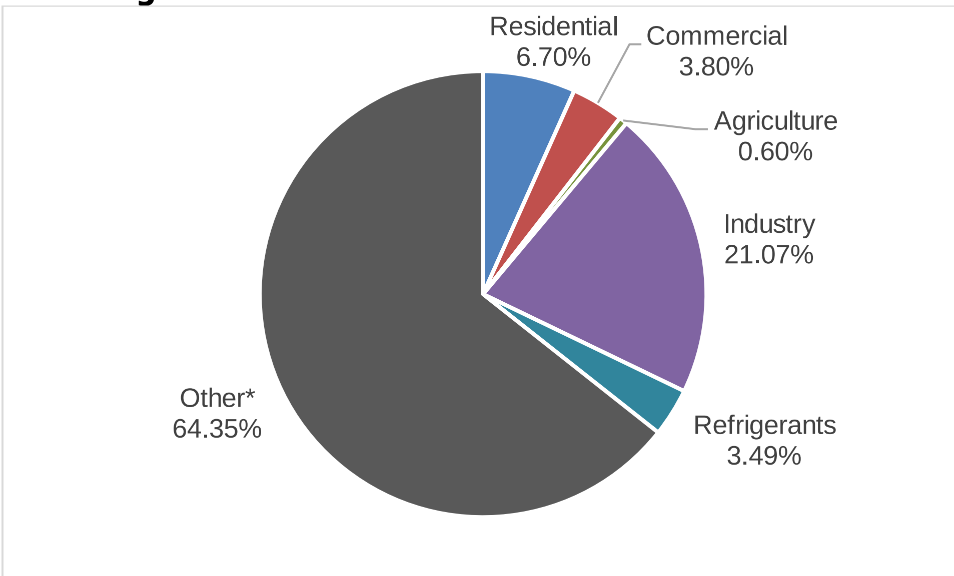
4 Metric ton is a unit of weight equal to 1,000 kilograms or approximately 2,205 pounds.

5 California Energy Commission (CEC). *Final 2019 Integrated Energy Policy Report including Errata - PDF.* Publication Number: CEC-100-2019-001-CMD. https://www.energy.ca.gov/data-reports/reports/integrated-energy-policy-report/2019-integrated-energy-policy-report.

6 California Air Resourced Board (CARB) GHG Emissions Inventory webpage, https://ww2.arb.ca.gov/ghg-inventory-data.

to the appropriate sector, buildings and industrial and agricultural processes then contribute about 50 percent of statewide emissions (Figure 2).

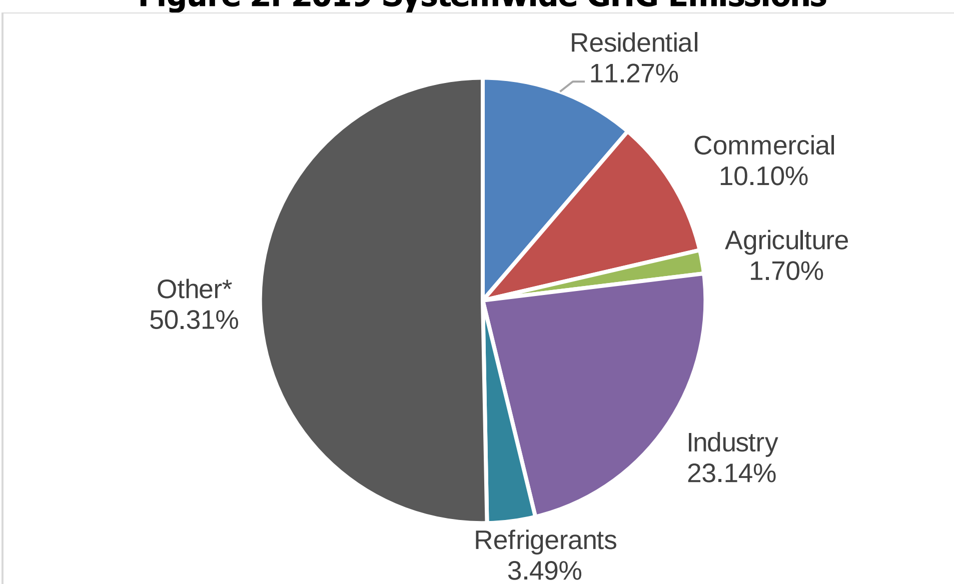
Figure 1: 2019 California Direct GHG Emissions



*Other includes emissions from transportation, electricity generation, recycling and waste, transportation refrigerants, and non-fuel-use-related emissions from agriculture including livestock and crops.

Source: CARB

Figure 2: 2019 Systemwide GHG Emissions



*Other includes emissions from transportation, recycling and waste, transportation refrigerants, and non-fuel-use-related emissions from agriculture including livestock and crops.

Source: CARB

The challenge of building decarbonization is much greater for existing buildings than newly constructed ones. This is partly due to the scale of the two markets — California has an estimated 13.7 million existing homes[7] and 7,392 million square feet of existing commercial space (Figure 3).[8] In 2020, California multifamily construction starts totaled 47,000 units, while single-family home construction starts in 2020 totaled 59,000.[9] On average, 1,614 commercial buildings are added statewide each year.[10] Despite the more limited scale, decarbonizing new buildings during the design and construction phases is most cost-effective and significantly easier than retrofitting existing buildings due to the ability to install electrical infrastructure and omit gas infrastructure during construction when walls and ceiling are open, equipment space is not established, and people are not using the space. This action also prevents locking in gas infrastructure and appliances that may become uneconomical during their useful life. While retrofits to existing buildings offer the greatest potential for emission reductions, they also face more barriers, such as scheduling around occupant presence, equipment installation requirements, upfront costs, space constraints, structural issues, and building upgrade requirements for a construction permit. The building owner might be unaware of these issues, or might have chosen to defer maintenance because of cost or the split incentive where the building owner is not the occupant who pays the energy bills. Technological innovation, best practices, and contractor experience can help limit these costs. Careful attention should be paid to the technical assistance, financial products, and incentives that would make these retrofits attractive and feasible to building owners. Similarly, large public and private investments and technological shifts are necessary to decarbonize industrial and agricultural processes by converting them from using fossil fuels use to renewable forms of energy. To meet the state's climate goals, private markets, with greater capital, must be activated to direct funds into retrofits.

7 CEC staff analysis of Department of Finance data

8 CEC staff analysis of data provided by Dodge Data and Analytics.

9 firsttuesday Journal. August 19, 2021. "The Slowing Trend in California Construction Starts." https://journal.firsttuesday.us/the-rising-trend-in-california-construction-starts/17939/.

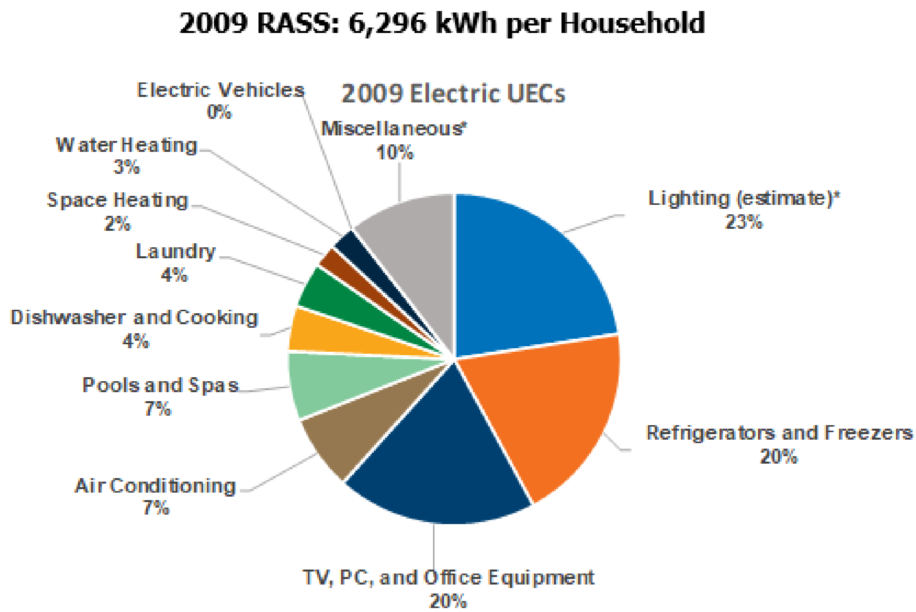
10 Landvision is a database service contracted by CEC to identify commercial and multifamily buildings, data is not available to the public.

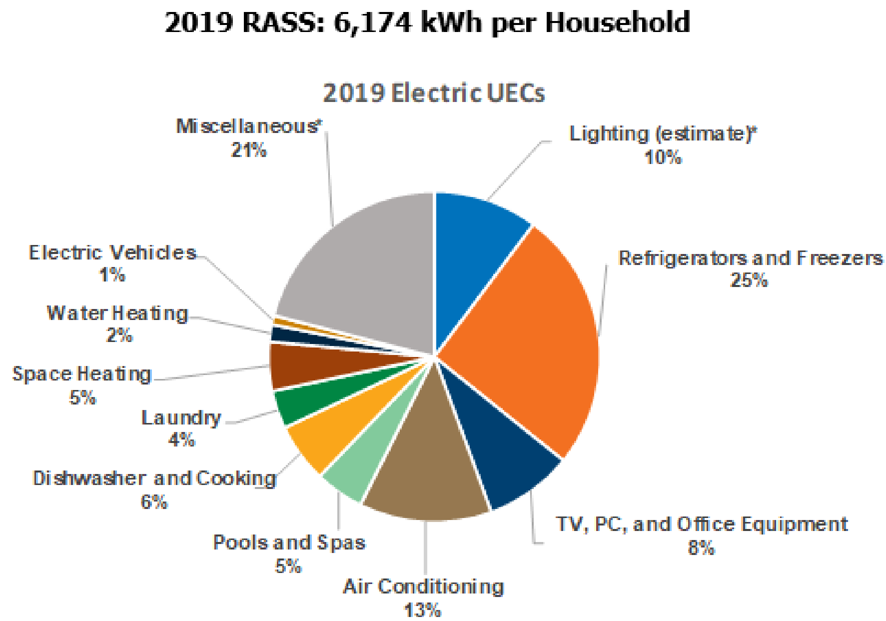
Figure 3: California Residential and Commercial Buildings

Source: CEC 2019 Energy Demand Forecast

Building and appliance efficiency standards and programs have been successful at reducing electricity and gas usage, also referred to as *load*, and avoiding GHG emissions even as population and the number of appliances has grown. Limiting load growth as consumers shift to electric equipment in buildings or increase energy demand as result of efforts to withstand extreme heat and poor outdoor air quality continues to be critical. Further, the capability of people and business to shift and reduce their energy usage to reduce GHG emissions is key to constraining the consumer and infrastructure costs of a clean energy future.

Figure 4: Statewide Residential Appliance Electricity Consumption, 2009 and 2019

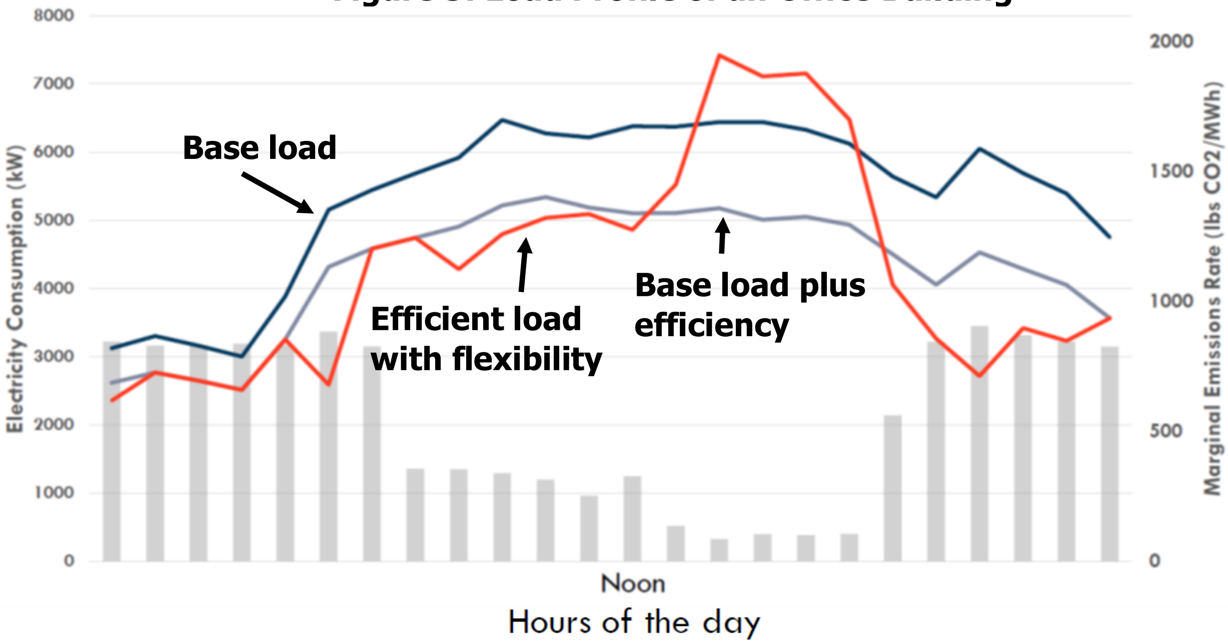




Source: 2019 California Residential Appliance Saturation Survey

Energy costs and GHG emissions can be reduced through efficiency and demand flexibility. Better designed building envelopes and other technologies can reduce energy consumption and improve the resilience of the building and grid infrastructure to extreme temperatures. Further, flexible loads offer the potential to decrease demand when the grid is otherwise strained, which coincides with high real-time prices, and to take advantage of opportunities when the grid has excess renewable resources. An example of how the energy use of a building can be shaped by demand flexibility and energy efficiency to minimize grid strain and maximize renewable energy consumption was shared by RMI during the IEPR workshop on grid-interactive efficient buildings (Figure 5). The line labeled "base load" shows a standard office buildings energy consumption in a given day, the line labeled "base load plus efficiency" is that daily consumption adjusted by energy efficient technologies, and the "efficient load with flexibility" shows the efficient building moving load to times of the day when the marginal emissions (the gray bars) are lowest.

Figure 5: Load Profile of an Office Building



Source: RMI

The need for extreme weather resiliency and affordability is therefore both well aligned with investments in building retrofits, well insulated buildings, distributed energy resources, and demand-flexible technologies. Coordinating these investments with targeted energy efficiency programs and greater penetration of electric appliances results in fewer GHG emissions and a more resilient built environment.

As California pushes for greater decarbonization, energy services must remain affordable and reliable. Affordable and reliable energy services are particularly important for low-income households and disadvantaged communities. In its first annual affordability report released in April 2021, the California Public Utilities Commission (CPUC) found that 13.3 percent of California's lower income households spend more than 15 percent of their income on electricity service. The CPUC also found that 6 percent of lower income households spend more than 10 percent of their income on gas service. The specific areas where affordability is a significant concern are similar for both electricity and gas service.[11] These households and communities require direct investment to remedy the systemic inequalities, environmental hazards, and energy burdens affecting them. The COVID-19 pandemic and related recession have only exacerbated these issues and made investments all the more urgent.[12] There is a real risk that these Californians become some of the last to receive the benefits of a clean energy future due to lack of capital, credit, and access to infrastructure. It is imperative that California prioritize its most vulnerable people in its efforts to decarbonize.

California must communicate, and to the extent possible ensure building occupants benefit financially from, the co-benefits of decarbonization. These co-benefits include indoor air quality improvements leading to fewer doctor visits or hospitalizations, improved indoor temperature regulation leading to fewer illnesses or deaths, and more.

Decarbonization Strategies

The CEC identified seven pathways in the *2021 Building Decarbonization Assessment*, which fulfilled the statutory requirements of Assembly Bill 3232 (Friedman, Chapter 373, Statutes of 2018) for reducing GHG emissions from buildings:[13]

1. **Efficient Electrification of End Uses**: Since the electricity generation sector is rapidly becoming less carbon intensive, it provides a perfect pathway to decarbonize buildings. Electric end uses will benefit from an increasingly clean energy supply, and some technologies — notably heat pumps — are substantially more energy-efficient than the combustion alternative. Electrification also reduces local emissions of the criteria pollutants associated with combustion. Therefore, substituting energy-efficient electric equipment for gas equipment can not only reduce GHG emissions, but also save energy and improve public health.
2. **Clean Electricity**: Buildings consume significant amounts of electricity, which drives GHG emissions in the electricity system. The mix of generation resources needed to meet electricity demand has fluctuating GHG content, or GHG emission intensity, across hours

11 CPUC. 2021. *2019 Annual Affordability Report*. https://www.cpuc.ca.gov/-/media/cpuc-website/industries-and-topics/reports/2019-annual-affordability-report.pdf.

12 Memmott, T., S. Carley, M. Graff, et al. "Sociodemographic Disparities in Energy Insecurity Among Low-Income Households Before and During the COVID-19 Pandemic." *Nat Energy* 6, 186–193 (2021). https://doi.org/10.1038/s41560-020-00763-9.

13 Kenney, Michael, Nicholas Janusch, Ingrid Neumann, and Mike Jaske. 2021. *California Building Decarbonization Assessment*. California Energy Commission. Publication Number: CEC-400-2021-006-CMF. https://www.energy.ca.gov/publications/2021/california-building-decarbonization-assessment.

and seasons. Renewable energy resources generate no carbon emissions, while energy generated from fossil fuel sources is more carbon-intensive. The electric system has become increasingly powered by renewable energy, which is expected to continue to lower GHG emission intensity.

3. **Energy Efficiency**: The least-cost strategy for reducing GHG emissions is energy efficiency. The less fuel that is used to perform the same task, whether electricity or gas, provides a reduced utility bill and fewer GHG emissions. Improving the envelope of buildings can save energy regardless of fuel type and can enable heating and cooling demand flexibility. California has pursued energy efficiency savings for more than 40 years through codes and standards, incentive programs, financing, and outreach.
4. **Refrigerant Conversion and Leakage Reduction**: Existing cooling and other heat-pump-driven systems rely on high global-warming-potential (GWP) hydrofluorocarbons (HFCs) as refrigerants. While all new heating, ventilation, air conditioning, and refrigeration equipment sold in California will soon be required to comply with CARB’s lower-GWP refrigerant standards, encouraging building owners to transition their existing high-GWP systems with lower-GWP systems and encouraging the proper disposal of refrigerants when the system is replaced will help decrease GHG emissions.
5. **Distributed Energy Resources**: Numerous distributed energy resources support building decarbonization, including rooftop solar photovoltaic (PV) systems, solar thermal systems, thermal batteries like tank water heaters, electric vehicles, and stand-alone batteries. These resources provide clean electricity, load shifting, and grid services, among other benefits.
6. **Gas System Decarbonization:** While the electricity generation system is rapidly decarbonizing with renewable resources, the state’s gas system delivers gas that is 99 percent fossil-based.[14] The pathways to decarbonize the gas system are less developed and the focus of ongoing research and development. Moreover, the markets providing renewable gas today are structured for use in the transportation sector, electric generation, or onsite consumption, not for delivery to homes or businesses via the gas distribution system.
7. **Demand Flexibility**: Some equipment can respond automatically to a price or grid signal. This automatic response enables alignment of electricity demand with renewable energy generation, the shifting and shedding of loads, the lowering of customer utility bills, and the increasing reliability of buildings and the electric system.

14 CEC staff analysis based on CARB LCFS data and CEC data.

While the above strategies were developed for homes and businesses, they are also applicable to the industrial and agricultural sectors, where the focus is on decarbonizing processes and energy sources. This IEPR volume also presents the decarbonization pathways and challenges in these sectors and applies the same strategies with some caveats.

Building Decarbonization Policies

Over the last 20 years, California has passed several pieces of legislation aimed at combatting climate change. Much of this legislation has focused on reducing economywide GHG emissions, which to date has been driven through electricity generation decarbonization and transportation electrification.[15] More recently, the conversation has turned to reducing GHG emissions from buildings — recognizing that decades of energy efficiency activity can be honed into building decarbonization through proper equipment replacements, understanding time and locational values of energy usage, and displacing the use of fossil gas.

Recent State Legislation and Executive Orders

- Senate Bill 350 (De León, Chapter 547, Statutes of 2015) codified California's goals to reach 50 percent procured renewable energy sources, double energy efficiency savings in electricity and gas end uses by 2030, and study barriers to energy efficiency and clean energy for low-income customers and disadvantaged communities.
- Senate Bill 32 (Pavley, Chapter 249, Statutes of 2016) amended the Global Warming Solutions Act of 2006. It called for a statewide reduction of GHG emissions of 40 percent below 1990 levels by 2030. The bill codified the goal initially set in former Governor Edmund G. Brown Jr.'s Executive Order B-30-15.
- Senate Bill 1383 (Lara, Chapter 395, Statutes of 2016) sets targets for statewide reductions in short-lived climate pollutants that are more potent than CO_2 such as black carbon (soot), methane, and HFCs. The goals are to reduce methane and HFCs to 40 percent below 2013 levels by 2030 and anthropogenic black carbon by 50 percent below 2013 levels by 2030, as well as provide specific direction for reductions from dairy and livestock operations and from landfills by diverting organic materials.
- Executive Order B-55-18[16] established a statewide goal to achieve carbon neutrality no later than 2045 and maintain net negative emissions thereafter.

15 Transportation electrification is the process by which vehicles are switched to rely on electricity for power instead of fossil fuels.

16 Executive Order B-55-18, https://www.ca.gov/archive/gov39/wp-content/uploads/2018/09/9.10.18-Executive-Order.pdf.

- Senate Bill 100 (De León, Chapter 312, Statutes of 2018) increased the Renewables Portfolio Standard (RPS)[17] to 50 percent by 2025 and 60 percent by 2030. Moreover, the bill sets a policy that eligible renewable resources and zero-carbon resources supply 100 percent of retail sales of electricity to end-use customers and 100 percent of electricity procured to serve all state agencies by December 31, 2045. The California Energy Commission (CEC), California Air Resources Board (CARB), CPUC, and California Independent System Operator (California ISO) are collaborating on this process. An initial report was published in March 2021.[18]
- Assembly Bill 3232 (Friedman, Chapter 373, Statutes of 2018) required the CEC to assess the potential to reduce GHG emissions from homes and businesses by at least 40 percent of 1990 levels by 2030. An assessment of the potential reduction pathways and associated barriers was published in August 2021.[19]
- Senate Bill 1477 (Stern, Chapter 378, Statutes of 2018) requires the CPUC, in coordination with the CEC, to establish the Building Initiative for Low-Emissions Development (BUILD) and Technology and Equipment for Clean Housing (TECH) programs funded by the auction of Cap-and-Trade Program allowances that are allocated to natural gas utilities. The BUILD program is intended to provide incentives to build new buildings with low GHG emissions, with a focus on low-income new construction. The TECH program is meant to drive market transformation in key building and appliances technologies that will drive down GHG emissions in the state.
- Assembly Bill 33 (Ting, Chapter 226, Statutes of 2021) calls on the CEC to provide grants and loans to local governments, public institutions, and Native American tribes to advance energy efficiency, energy storage, and electric vehicle charging in existing and planned buildings.
- Senate Bill 68 (Becker, Chapter 720, Statutes of 2021) requires the CEC to provide information to building owners, the construction industry, and local governments to help overcome the barriers to building electrification and electric vehicle charging. The CEC will work in coordination with relevant state agencies and stakeholders to gather

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17 The Renewable Portfolio Standard is a regulatory mandate requiring increased renewable energy production over time.

18 CARB staff, CEC staff, CPUC staff. 2021*. [2021 SB 100 Joint Agency Report](https://www.energy.ca.gov/publications/2021/2021-sb-100-joint-agency-report-achieving-100-percent-clean-electricity).* CEC-200-2021-001. https://www.energy.ca.gov/publications/2021/2021-sb-100-joint-agency-report-achieving-100-percent-clean-electricity.

19 Kenney, Michael, Nicholas Janusch, Ingrid Neumann, and Mike Jaske. 2021. *California Building Decarbonization Assessment*. California Energy Commission. Publication Number: CEC-400-2021-006-CMF. https://www.energy.ca.gov/publications/2021/california-building-decarbonization-assessment.

and publish a variety of tools such as best practices, guides, and information on equipment, incentives, permitting, and financing.

In the 2021 legislative session, the Budget Act of 2021 (Senate Bill 170, Skinner, Chapter 240) approved $75 million in one-time funding to implement and administer a complementary program to BUILD providing incentives for all-electric new construction in multifamily and single-family buildings. The budget also approved millions of dollars for solar energy permitting, SB 100 planning and grants, offshore wind outreach and research, and energy emergency planning.[20]

Changing Energy Efficiency Landscape

While electrification of buildings is a key strategy to decarbonizing buildings, energy efficiency remains a foundational strategy to limit load growth, keep consumer costs down, and reduce GHG emissions. As said best by Jessica Granderson, panelist at the IEPR workshop discussing the role of energy efficiency in building decarbonization, "This is our tried-and-true strategy that's brought us extraordinary consumer, system, and greenhouse gas benefits for decades. And it's going to remain critical to our success in decarbonization."[21] It is essential for energy efficiency programs to evolve to take advantage of whole-building approaches, flexible-demand appliances, and dynamic rates that together enable decarbonization. Energy efficiency can also reduce the marginal cost and total portfolio cost of renewable energy generation by limiting the new capacity needed.[22]

Evolving Metrics

Efficiency savings have been historically evaluated on an annual basis and assumed the same value to the customer and utility in all hours. This evaluation framework worked well while the grid was delivering energy with a nearly constant GHG intensity and rates were not dynamic. However, the growth of renewable energy resources changed the GHG intensity and demands of the electricity system, and new "smart" electric meters allowed for more dynamic rates. Efficiency programs and standards now have more granular metrics with which to evaluate and track potential and realized energy and GHG savings. In addition, the more granular data

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20 Budget Act of 2021 https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=202120220SB170.

21 Comments by Jessica Granderson at the August 24, 2021, IEPR Workshop on the Role of Energy Efficiency in Building Decarbonization — The Importance of Energy Efficiency. Session 1 transcript, p. 28. https://efiling.energy.ca.gov/getdocument.aspx?tn=240005.

22 Presentation by Eric Cutter at the August 24, 2021, IEPR Workshop on the Role of Energy Efficiency in Building Decarbonization — The Importance of Energy Efficiency. "GHG Value of EE for a Zero-Carbon Electric Grid." Slide 7. https://efiling.energy.ca.gov/getdocument.aspx?tn=239442.

can be compared with the GHG intensity of the grid and the varying costs of producing energy at different hours of the year.

California Energy Code — Time-Dependent Valuation and Hourly Source Energy Metrics

The CEC has used the time-dependent valuation (TDV) metric to determine the life-cycle cost-effectiveness and impacts of the Building Energy Efficiency Standards (Energy Code) since 2005. TDV is based on the concept that the energy impacts of a building energy feature should be valued when energy is consumed. This concept reflects the actual cost of energy to consumers and to the grid. TDV offers incentives for building designs that perform well during high-energy-cost hours. The TDV multipliers are developed for every hour of the year using long-term forecasts (15- and 30-year forecasts) of hourly electricity, gas, and propane costs to consumers and accounts for the primary marginal cost of producing and delivering the energy. TDV is calculated for each of California's 16 climate zones.

While the TDV metric provides a strong signal for energy efficiency, demand flexibility, and grid harmonization, as well as keeping the monthly energy bills low, the metric provides only a modest signal for building decarbonization. As the state's climate change goals demand accounting for GHG reductions, the CEC used the long-run marginal source energy as an additional performance metric in the 2022 Title 24, Part 6 Update. This metric is a variation of hourly source energy (HSE) and evaluates the environmental impact of energy use in buildings. HSE is defined as the long-run marginal source energy following the long-term effects of any associated changes in resource procurement to align the Energy Code with the state's environmental goals and policies. This new metric focuses specifically on the amount of fossil fuels associated with demand-side energy consumption, assessed over a 15-year and 30-year lifetime. HSE is calculated differently for electricity, gas, and propane consumption, based on planned changes for each fuel. Specific to electricity for example, HSE accounts for long-term changes to the grid in response to RPS and SB 100 mandates. The resulting HSE values are proportional to the GHG emissions for each hour of the year, and therefore are a good proxy to evaluate GHG emissions. HSE is not intended to replace TDV, but to provide a complementary metric.

To comply with the Energy Code, the TDV and HSE target budgets must be met independently by the building design. Pairing both TDV and HSE metrics in the Energy Code ensures strong signals for energy efficiency, demand flexibility, grid harmonization,[23] and building decarbonization, all while ensuring energy standards are cost-effective for building owners.

23 Grid harmonization refers to strategies and measures that harmonize customer owned distributed energy resources with the grid to maximize self-utilization of PV array output, and limit grid exports to periods beneficial to the grid and the ratepayer.

CPUC Energy Efficiency Portfolio

The CPUC also has a new approach to evaluate energy efficiency programs.[24] The new total system benefit metric makes use of the cost-effectiveness tool and the avoided cost calculator to evaluate avoided costs from transmission, distribution, grid services, GHG emissions, refrigerant emissions, and generation.[25] The granularity provided by this metric allows program operators to understand where and when certain efficiency measures have the greatest savings.

Diminishing Value of Gas Efficiency Investments

The combustion and leakage of fossil gas and propane emit GHGs and contribute to climate change. Continued investments in gas appliances and infrastructure in buildings will require ratepayers to pay back the investment. While some of these investments are understandable in the present, as time goes on, it becomes increasingly important to consider how gas-related investments are made in and for buildings.

When upgrading or replacing natural gas equipment, increased energy efficiency provides valuable GHG reductions. However, while achieving even modest GHG reductions is progress towards the state's goals, the limited timeframes to accomplish deep reductions creates a need to be strategic with gas efficiency investments. Water heaters are expected to operate for 10-15 years and HVAC equipment for even longer.[26] Significant GHG reduction targets exist in those timeframes, and the state is targeting to be carbon negative during the first or second replacement of all current equipment. This means gas equipment efficiency investments have a growing likelihood over time of becoming stranded assets, a liability for carbon offsets, or cause the state to miss its goals. Some gas efficiency programs include improvements to

24 CPUC. May 26, 2021. Assessment of Energy Efficiency Potential and Goals and Modification of Portfolio Approval and Oversight Process. Decision 21-05-031. R. 13-11-005. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M385/K864/385864616.PDF.

25 Ibid.

26 To estimate the scale of building retrofits needed to reach building decarbonization goals, staff used equipment turnover rates as a proxy for building retrofit rates. CEC assumed a 7 percent annual turnover for water heaters, based on effective useful life. This major appliance was chosen as the proxy because of the wide adoption of the appliance and significance for building decarbonization. The Department of Finance estimates that there are 9.2 million single-family homes. Applying the estimated turnover rates results in about 644,000 water heater changeouts per year. A similar exercise for multifamily units shows about 69 percent, or 3.1 million of the 4.5 million multifamily units have water heaters. Assuming the same 7 percent turnover rate, about 217,000 water heaters are replaced each year. In total, Californians are replacing about 861,000 water heaters across single- and multifamily buildings each year. At that rate of replacement, it would take up to 14 years to convert each water heater to an efficient electric alternative or, if used as a proxy, 14 years to retrofit the existing building stock with electric water heating.

building insulation, duct work, and sealing. These investments do not have the same dynamic as equipment investments and are valuable whether the equipment is gas or electric.

Demand Flexibility

Technologies that shift the timing of electricity use can optimize building operations, enable customer savings, and allow clean energy supplies to be used rather than curtailed. Policies and regulations that increase the availability of flexible demand resources will support an affordable and reliable grid as the share of carbon-free resources expands.

Indoor Air Quality

Energy efficiency programs also result in indoor air pollution reductions. Indoor air pollution caused by gas stove combustion in kitchens is a public health issue as indoor air is largely unregulated in the United States and is often more polluted than outdoor air.[27] In 2019, roughly two-thirds of California households used fossil fuels such as gas and propane for cooking.[28] Fossil gas combustion for household cooking is a large source of health-damaging pollutants including nitrogen dioxide (NO_2) and fine particulate matter (PM2.5) in the indoor environment where individuals spend most of their time. Gas stove combustion in California homes routinely exposes occupants to pollutant concentrations that are considered harmful outdoors.[29]

Previous research has shown that children are at a higher risk of developing childhood respiratory illnesses such as asthma due to air pollution exposure.[30] Even at relatively low concentrations, well below the EPA's annual average ambient air quality standard of 53 parts

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27 U.S. Environmental Protection Agency. 2020. The Inside Story: A Guide to Indoor Air Quality. Accessed December 8, 2020. https://www.epa.gov/indoor-air-quality-iaq/inside-story-guide-indoor-air-quality.

28 U.S. Census Bureau. 2020. American Housing Survey (AHS). Accessed December 8, 2020. https://www.census.gov/programs-surveys/ahs/data/interactive/ahstablecreator.html?s_areas=00006&s_year=2019&s_tablename=TABLE3&s_bygroup1=1&s_bygroup2=1&s_filtergroup1=1&s_filtergroup2=1.

29 Mullen, Nasim, Jina Li, and Brett Singer. 2012. *Impact of Natural Gas Appliances on Pollutant Levels in California Homes*. Berkeley: Lawrence Berkeley National Laboratory. https://indoor.lbl.gov/sites/all/files/impact_of_natural_gas_appliances.pdf.

30 Vrijheid, Martine. 2014. "Commentary: Gas Cooking and Child Respiratory Health—Time to Identify the Culprits?" *International Journal of Epidemiology* 42: 1737-1739.

U.S. Environmental Protection Agency. 2016. "Integrated Science Assessment (ISA) for Oxides of Nitrogen – Health Criteria (Final Report, Jan 2016)." Washington, DC.

CARB. 2021. Asthma & Air Pollution. https://ww2.arb.ca.gov/resources/asthma-and-air-pollution.

NO_2 per billion, exposures to NO_2 can increase asthma morbidity among children.[31] A 2013 meta-analysis found that children in homes with gas stoves have a 42 percent increased risk of having current asthma, a 24 percent increased risk of lifetime asthma, and an overall 32 percent increased risk of having current and lifetime asthma.[32] Also, asthmatic children living in lower-income communities and communities of color are likely the most disproportionately burdened by indoor air pollution from gas stoves because of factors such as inadequate mechanical exhaust ventilation above cookstoves and smaller unit size in lower-income, multifamily buildings.[33] However, contrary to the above research, a global study of asthma among children reported no association between gas cooking and symptoms of asthma.[34] These differing and conflicting results suggest a need for research — such as that to be supported through an Electric Program Investment Charge Grant Funding Opportunity (GFO-21-301) released fall 2021 — to help resolve inconsistencies and provide California-specific observations.[35]

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31 Belanger, Kathleen, Theodore R. Holford, Janneane F. Gent, Melissa E. Hill, Julie M. Kezik, and Brian P. Leaderer. 2013. "Household Levels of Nitrogen Dioxide and Pediatric Asthma Severity." *Epidemiology* 24: 320-330.

32 Lin, Weiwei, Bert Brunekreef, and Ulrike Gehring. 2013. "Meta-Analysis of the Effects of Indoor Nitrogen Dioxide and Gas Cooking on Asthma and Wheeze in Children." *International Journal of Epidemiology* 42: 1724-12737.

33 Seals, Brady, and Andee Krasner. 2020. *Health Effects from Gas Stove Pollution*. RMI, Physicians for Social Responsibility, Mothers Out Front, and Sierra Club. https://rmi.org/insight/gas-stoves-pollution-health.

Wolstein, Joelle, Ying-Ying Meng, and Susan H Babey. 2010. *Income Disparities in Asthma Burden and Care in California*. UCLA Center for Health Policy, Los Angeles, CA. Accessed July 8, 2021. https://healthpolicy.ucla.edu/publications/search/pages/detail.aspx?PubID=45.

California Department of Public Health. 2017. *Asthma Prevalence in California: A Surveillance Report*. Environmental Health Investigations Branch, Richmond. Accessed July 8, 2021. https://www.cdph.ca.gov/Programs/CCDPHP/DEODC/EHIB/CPE/Pages/CaliforniaBreathingData.aspx#.

34 Wong, Gary WK, Bert Brunekreef, Philippa Ellwood, H Ross Anderson, M Innes Asher, Julian Crane, and Christopher KW Lai. 2013. "Cooking Fuels and Prevalence of Asthma: A Global Analysis of Phase Three of the International Study of Asthma and Allergies in Childhood (ISAAC)." *The Lancet* 1: 386-394.

35 California Energy Commission. 2021. GFO-21-301-Randomized Trial Study to Investigate the Impact of Gas Stove Interventions on Children with Asthma. Accessed September 16, 2021. https://www.energy.ca.gov/solicitations/2021-09/gfo-21-301-randomized-trial-study-investigate-impact-gas-stove-interventions.

Electrification has been identified as a clean, relatively low-cost strategy for improving indoor air quality.[36] In an intervention study, researchers found that replacing a gas stove with an electric stove decreased median NO_2 concentrations by 51 percent in the kitchen.[37] While field and simulation modeling studies have looked at the impacts of household interventions, such as improved ventilation, outreach/education, air cleaners, and high-efficiency filtration on children with asthma,[38] there are no known studies that directly investigate the impact of kitchen electrification on asthma outcomes.

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36 Aas, Dan, Amber Mahone, Zack Subin, Michael Mac Kinnon, Blake Lane, and Snuller 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.

Billimoria, Sherri, Mike Henchen, Leia Guccione, and Leah Louis-Prescott. 2018. *The Economics of Electrifying Buildings: How Electric Space and Water Heating Supports Decarbonization of Residential Buildings*. RMI. http://www.rmi.org/insights/reports/economics-electrifying-buildings/.

37 Paulin, L.M., G.B. Diette, M. Scott, M.C. McCormack, E.C. Matsui, J. Curin-Brosnan, D.L. Williams, et al. 2014. "Home Interventions are Effective at Decreasing Indoor Nitrogen Dioxide Concentrations." *Indoor Air* 24: 416-424.

38 Lajoie, P., D. Aubin, V. Gingras, P. Daigneault, F. Ducharme, D. Gauvin, D. Fugler, et al. 2014. "The IVAIRE Project – A Randomized Controlled Study of the Impact of Ventilation on Indoor Air Quality and the Respiratory Symptoms of Asthmatic Children in Single Family Homes." *Indoor Air* 25: 582-597.

Butz, Arlene M., Elizabeth C. Matsui, Patrick Breysse, Jean Curtin-Brosnan, Peyton Eggleston, Gregory Diette, D'Ann Williams, Jie Yuan, John T. Bernert, and Cynthia Rand. 2011. "A Randomized Trial of Air Cleaners and a Health Coach to Improve Indoor Air Quality for Inner-City Children with Asthma and Secondhand Smoke Exposure." *Arch Pediatr Adolesc Med*. 165: 741-748

Moreno-Rangel, Alejandro, Juha Baek, Taehyun Roh, Xiaohui Xu, and Genny Carrillo. 2020. "Assessing Impact of Household Intervention on Indoor Air Quality and Health of Children with Asthma in the US-Mexico Border: A Pilot Study." *Journal of Environmental and Public Health* 9

Bennett, Deborah, Nicholas Kenyon, Daniel Tancredi, Marc Schenker, Rebecca Moran, Katya Roudneva, Xiangmei Wu, and Paula Krakowiak. 2018. *Final Report: Benefits of High-Efficiency Filtration to Children with Asthma.* Sacramento: CARB.

Wu, Felicia, and Tim K. Takaro. 2007. "Childhood Asthma and Environmental Interventions." *Environmental Health Perspectives* 115.

Krieger, James K., Tim K. Takaro, Carol Allen, Lin Song, Marcia Weaver, Sanders Chai, and Phillip Dickey. 2002. "The Seattle-King County Healthy Homes Project: Implementation of a Comprehensive Approach to Improving Indoor Environmental Quality for Low-Income Children with Asthma." *Environmental Health Perspectives* 110.

Chan, Mei, Melinda Gray, Christine Burns, Louisa Owens, Susan Woolfenden, Raghu Lingam, Adam Jaffe, and Nusrat Homaira. 2021. "Community-Based Interventions for Childhood Asthma Using Comprehensive Approaches: A Systematic Review and Meta-Analysis." *Allergy, Asthma & Clinical Immunology* 17.

California has made substantial progress toward reducing indoor air pollution through efforts such as continuous indoor-outdoor air exchange ventilation as required by the Energy Code and decarbonization efforts that support building electrification. State regulatory agencies (such as the California Department of Public Health [CDPH] and CARB) have strategic goals and programs to address the public health issue of indoor air quality. To effectively and appropriately support policies that maximize health co-benefits of California's energy policies, systematic measurement of health impacts of gas stove replacements is needed, particularly health impacts to children in under-resourced communities (such as low-income or disadvantaged communities or both as defined by Assembly Bill 523 [Reyes, Chapter 551, Statutes of 2017]). Understanding the health benefits of electrification in vulnerable populations, such as children and the elderly, is critical to developing strategies for equitable energy transitions in California.

Decarbonization programs are looking at ways to monetize or put a dollar value on the benefit of improved occupant health as a result of removing or limiting indoor gas combustion. Future proposed research under the Electric Program Investment Charge (EPIC) could support integration of health co-benefits of electrification in policy implementation (for example, Energy Code and building decarbonization pilots discussed in Chapter 3), as well as strategic design of residential building decarbonization projects that maximize health co-benefits and affordability in low-income and disadvantaged communities.

Mechanical ventilation is also important for protecting indoor air quality, particularly in homes with gas-powered cooking appliances. The 2022 Building Energy Efficiency Standards adopted in August 2021 incorporated results from CEC-funded research that recommended tightening kitchen exhaust ventilation standards through a performance standard designed to keep pollutant concentrations below health-based thresholds.[39] The updated kitchen exhaust ventilation requirements are tailored to protect air quality in smaller homes more common among low-income renters. However, the efficacy of ventilation-based strategies depends on consistent use of mechanical ventilation, and these new standards apply only to new homes. Existing homes will need other strategies — such as electrification or retrofit ventilation systems — to address indoor air quality issues.

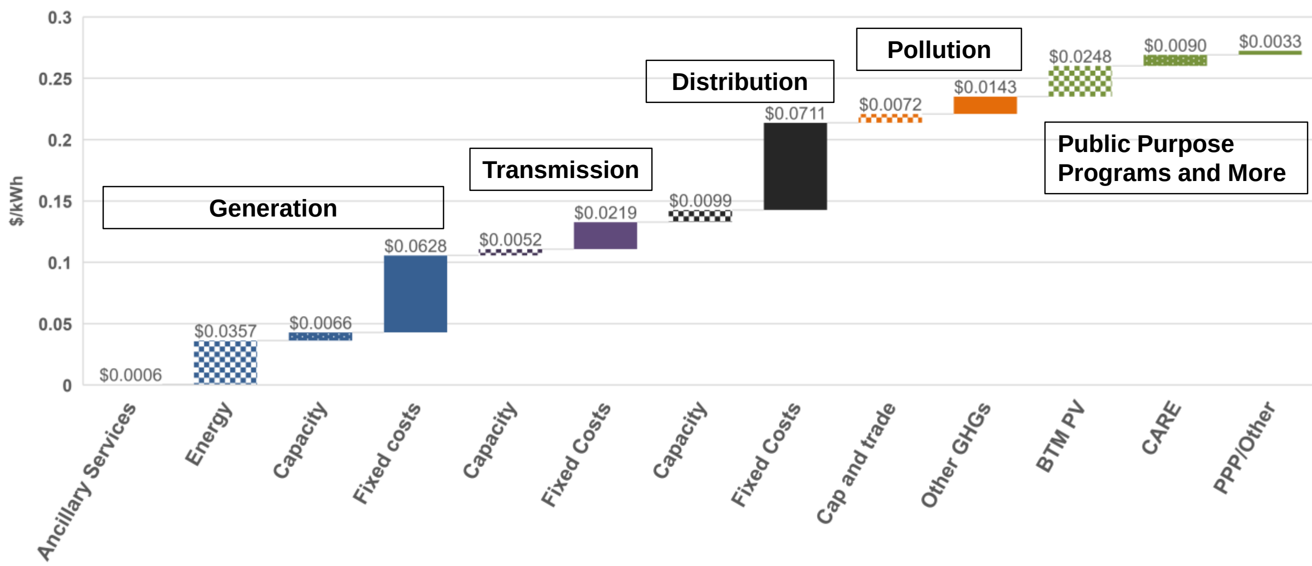
Tieskens, Koen F., Chad W. Milando, Lindsay J. Underhill, Kimberly Vermeer, Jonathan I. Levy, and M. Patricia Fabian. 2021. "The Impact of Energy Retrofits on Pediatric Asthma Exacerbation in a Boston Multifamily Housing Complex: A Systems Science Approach." *Environmental Health* 20.

39 Singer, Brett C., Wanyu Rengie Chan, William W. Delp, Iain S. Walker, and Haoran Zhao. 2021. *Effective Kitchen Ventilation for Healthy Zero Net Energy Homes with Natural Gas*. California Energy Commission. Publication Number: CEC-500-2021-005.

Decarbonization and Rates

The CPUC forecasts the annual electricity and gas costs for the residential sector to grow at an annual rate of 3.5 to 3.7 percent between 2021 and 2030.[40] This growth is due in part to the numerous fixed costs and programs funded by the volumetric rate (see example rate breakdown of 2019 Pacific Gas and Electric Company [PG&E] in Figure 6). Recent work by Severin Borenstein, Meredith Fowlie, and James Sallee at the Energy Institute at Haas, University of California, Berkeley (UC Berkeley), have pointed out the need to align rates with the associated true cost of generating electricity, transmission and distribution capacity, and GHG emissions. Making this move would lower electricity rates. The numerous fixed costs currently recovered from volumetric electricity rates have pushed the rates away from the actual cost of providing electricity, creating an economic disincentive to use electricity.[41]

Figure 6: Example Electricity Rate Breakdown – PG&E



Source: Modified after "Designing Electricity Rates for An Equitable Energy Transition." Energy Institute at Haas. https://www.next10.org/publications/electricity-rates.

40 Jain, Ankit, Bridget Sieren-Smith, Jefferson Hancock, Jeremy Ho, and Wylen Lai. April 2021. 2019 Annual Affordability Report. https://www.cpuc.ca.gov/-/media/cpuc-website/industries-and-topics/reports/2019-annual-affordability-report.pdf.

41 Borenstein, Severin, Meredith Fowlie, and James Sallee. Designing Electricity Rates for An Equitable Energy Transition. February 2021. University of California, Berkeley, Energy Institute at Haas. https://haas.berkeley.edu/wp-content/uploads/WP314.pdf.

The electricity and gas rates consumers pay will greatly affect the success of end-use decarbonization. Many stakeholders have raised the need for a managed decarbonization transition to limit the possibility of runaway gas rates for customers that remain tied to the system, alongside the imperative to keep electric bills affordable as reliance on electricity grows.[42] Rate design is therefore a key part of decarbonization strategy, with rates that enable savings accelerating decarbonization while the rates that increase costs are a significant barrier. Rates are particularly critical for low-income customers who are particularly sensitive to costs, and therefore will be key to an equitable decarbonization.

A CPUC rulemaking proceeding on building decarbonization (R.19-01-011) is evaluating whether electric utility rates are a cost barrier that disincentivizes residential customers from switching from fossil gas to electricity for water heating. On November 4, 2021, the CPUC adopted D.21-11-002, which directs PG&E, Southern California Edison Company, and San Diego Gas & Electric Company to each study the electric and gas bill impacts for residential customers switching from a fossil gas water heater to an electric heat pump water heater (HPWH). If a study shows a net increase in a customer's bill, the IOUs are required to propose a rate adjustment that covers the bill increase.[43] For more information on gas transition and rates, see the *2021 IEPR, Volume III: Decarbonizing the State's Gas System*.

Building GHG Emissions Reduction Analysis to 2030 and 2045

As required by SB 350, the CEC regularly assesses the state's progress toward doubling energy efficiency savings by 2030.[44] In 2015, California set an ambitious goal to achieve a statewide cumulative doubling of energy efficiency savings and demand reductions in electricity and gas end uses by January 1, 2030, to the extent doing so is feasible and cost-effective. In addition to traditional efficiency programs, efficient electrification offers energy and GHG savings.

The *California Building Decarbonization Assessment* highlighted the significant energy and emissions savings opportunities from electrifying newly constructed and existing buildings with

42 Example - Karas et al., Environmental Defense Fund. January 2021. *Aligning Gas Regulation and Climate Goals*. p. 26.

43 CPUC. Decision on Incentive Layering, The Wildfire and Natural Disaster Resiliency Rebuild Program, Data Sharing, Rate Adjustments for Electric Heat Pump Water Heaters, and Propane Usage. (D.21-11-002), November 9, 2021. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M421/K107/421107786.PDF.

44 See Senate Bill 350: Doubling Energy Efficiency Savings by 2030 (2017) Report and 2019 California Energy Efficiency Action Plan for prior updates.

efficient equipment.[45] Achieving a doubling of energy efficiency by 2030 while reducing GHG emissions from buildings requires continued success of traditional efficiency programs, as well as new efforts to electrify end uses. To this end, CEC staff has modeled scenarios that achieve the 2030 goal to double energy efficiency while striving to achieve GHG reduction benchmarks introduced by AB 3232. Analysis, including figures, will be available in late 2021.

45 Kenney, Michael, Nicholas Janusch, Ingrid Neumann, and Mike Jaske. 2021. California Building Decarbonization Assessment. California Energy Commission. Publication Number: CEC-400-2021-006-CMF. https://www.energy.ca.gov/publications/2021/california-building-decarbonization-assessment.

CHAPTER 2: Implementing Decarbonization

Across federal, state, and local initiatives, California is pursuing many decarbonization strategies. These include energy efficiency codes and standards, incentive and financing programs, benchmarking requirements, and research and development. This combined effort has led to energy and greenhouse gas (GHG) reductions across residential, commercial, industrial, and agricultural sectors, as noted in Chapter 1. Still, more investment is necessary to further reduce energy consumption and GHG emissions from end uses to meet 2030 and midcentury climate goals. Although a plethora of programs are available, they do not provide enough capital for successful statewide decarbonization. The state needs bold policies to encourage and advance additional investment in decarbonization.

Federal Efforts

The federal government has taken many steps in the last year to support decarbonization including passing legislation, issuing executive orders, and establishing internal policies, including:

- Executive Order 13990 of January 20, 2021, directs federal agencies to review existing regulations, orders, policies, and guidance issued in 2017 through 2020 that may be inconsistent with or conflict with improving public health, protecting the environment, accessing clean air and water, reducing GHG emissions, and bolstering resiliency to climate change. The executive order also establishes an interagency working group on the monetary impact of GHG emissions resulting from regulations and actions.
- Executive Order 14008 of January 27, 2021, sets goals for a carbon pollution-free electricity sector by 2035 and economywide net-zero emissions by 2050. It also created the White House Environmental Justice Interagency Council, which is responsible for developing a strategy to address current and historical environmental injustice, and the Justice40 initiative. The Justice40 initiative is focused on ensuring energy equity and directs that 40 percent of benefits from federal investments in climate and clean energy flow to disadvantaged communities.[46]

46 July 20, 2021, Memorandum from the Executive Office of the President, Office of Management and Budget, on Interim Implementation Guidance for the Justice40 Initiative, https://www.whitehouse.gov/wp-content/uploads/2021/07/M-21-28.pdf.

- Energy Act of 2020[47] is the first comprehensive update to federal energy policy since 2008 and was signed into law December 27, 2020. It contains provisions and funding for energy and water efficiency, renewable energy and storage, carbon management and removal, industry and manufacturing technologies, grid modernization and resiliency, phasedown of HFCs, and research, development and deployment. The act extends tax credits and incentives for decarbonization activities.

Federal Agency Policy

The General Services Administration (GSA) is set to procure 100 percent renewable electricity for federal buildings by 2025, electrify all new federal buildings, and achieve net-zero carbon emissions by 2030. Further, the Council on Environmental Quality launched a federal interagency initiative with GSA, United States Department of Energy (U.S. DOE), and the U.S. Environmental Protection Agency (U.S. EPA) to develop the first federal building performance standards. These performance standards will define metrics, goals, and tracking tools and methods to achieve federal carbon emissions goals.

One building model that captures many of the decarbonization strategies is a grid-interactive efficient building (GEB) as detailed by the U.S. DOE.[48] The goal is to construct and retrofit buildings to accommodate carbon-free, but intermittent, energy resources. These buildings combine energy efficiency and demand-flexible appliances and provide health, comfort, safety, energy affordability, and grid-services. Over the next two decades, the U.S. DOE estimates that the national adoption of GEBs could be worth between $100 billion and $200 billion in national electric power system cost savings.[49] By reducing and shifting the timing of electricity consumption, GEBs could decrease CO_2 emissions by 80 million tons per year by 2030, or 6 percent of total power sector CO_2 emissions.[50] That is more than the annual emissions of 50 medium-sized coal plants or 17 million fossil fuel-powered cars.[51]

47 H.R. 133 — 116th Congress (2019–2020): Consolidated Appropriations Act, 2021. December 27, 2020. https://www.congress.gov/bill/116th-congress/house-bill/133/.

48 U.S. Department of Energy's webpage on Grid-Interactive Efficient Buildings, accessed September 22, 2021. https://www.energy.gov/eere/buildings/grid-interactive-efficient-buildings.

49 Prepared by U.S. DOE Buildings Technology Office. *A National Roadmap for Grid-Interactive Efficiency Buildings*. May 2021. page 8. https://gebroadmap.lbl.gov/.

50 Ibid.

51 Ibid.

State Agency Efforts

State agencies are studying and advancing decarbonization across an array of programs. While the California Energy Commission (CEC), California Public Utilities Commission (CPUC), and the California Air Resources Board (CARB) are the agencies with the greatest focus on building decarbonization, a number of other agencies are also coordinating and implementing policies such as the California Department of Food and Agriculture,[52] Strategic Growth Council,[53] California Department of Community Services and Development, California Alternative Energy and Advanced Transportation Financing Authority, and California Department of Resources Recycling and Recovery (CalRecycle).[54]

The CPUC has several ongoing proceedings that support building decarbonization strategies.

- Building decarbonization: The CPUC launched a rulemaking in 2019 to address building decarbonization in phases.[55] This rulemaking includes the implementation of the BUILD and TECH programs, the development of pilot programs including wildfire rebuild programs, direction on incentive layering, and reconsideration of residential natural gas allowances; coordination with CEC on Title 24 and Title 20-related[56] building decarbonization, and future policy framework guiding building decarbonization.[57]
- Long-term planning: The long-term gas system planning rulemaking launched in 2020 will examine the regulations, processes, and standards governing or being used by gas utilities.[58] The three tracks of this rulemaking include examining the reliability standards for the gas transmission system to determine if design changes are necessary to

52 California Department of Food and Agriculture, State Water Efficiency and Enhancement Program, https://www.cdfa.ca.gov/oefi/sweep/.

53 Strategic Growth Council programs webpage. (Decarbonization program examples: Transformative Climate Communities, Affordable Housing and Sustainable Communities.) https://sgc.ca.gov/programs/.

54 CalRecycle webpage, https://www.calrecycle.ca.gov/organics/slcp.

55 CPUC rulemaking R.19-01-011, https://apps.cpuc.ca.gov/apex/f?p=401:56:0::NO:RP,57,RIR:P5_PROCEEDING_SELECT:R1901011.

56 Within this document, *Title 24* refers to California Code of Regulations, Title 24, Part 6 (California Energy Code) and Part 11 (California Green Building Standards Code). *Title 20* refers to California Code of Regulations, Title 20, Division 2, Chapter 4, Article 4 (Appliance Efficiency Regulations) and Article 5 (Load Management Standards).

57 CPUC. Assigned Commissioner's Scoping Memo and Ruling. May 17, 2019. R.19-01-011. https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M290/K324/290324466.PDF.

58 CPUC. R.20-01-007. Order Instituting Rulemaking to Establish Policies, Processes, and Rules to Ensure Safe and Reliable Gas Systems in California and Perform Long-Term Gas System Planning. https://apps.cpuc.ca.gov/apex/f?p=401:56:0::NO:RP,57,RIR:P5_PROCEEDING_SELECT:R2001007.

account for climate change; reviewing proposals for mitigating the negative impacts from gas system operational issues, prices, and system reliability; and finally, determining the regulatory solutions and planning strategy that should be implemented.

- Energy efficiency program portfolio:[59] The CPUC addressed the barriers to electrification in the energy efficiency program portfolio in mid-2019.[60] In June 2021, the CPUC updated the structure of the energy efficiency portfolio to address cost-effectiveness requirements for equity and market transformation programs and introduced a new metric to measure the success of energy efficiency programs.[61] This metric tracks the life-cycle energy, capacity, and GHG benefits of a program in dollar values.
- Distributed Energy Resources (DERs):[62] This rulemaking will deal with questions related to distribution planning and modernization of the grid to support increasing numbers of DERs. The CPUC will address issues along three tracks, including high-level policy issues regarding distribution system operator roles and responsibilities as well as investor-owned utility (IOU) and aggregator business models, carryover work from previous DER proceedings focusing on optimizing grid investments to allow DER growth while supporting resiliency and electrification goals and community engagement, and grid infrastructure investments in the near and medium term that allow smart inverters to be grid services and further align the general rate case filings with planned investments identified in IOU distribution planning. The rulemaking includes issues left over from the prior Distributed Resources Planning and Integrated Distributed Energy Resources proceeding.
- The CPUC is also expected to issue two rulemakings pertaining to DERs following closure of the Distributed Resources Planning and Integrated Distributed Energy Resources rulemakings in 2021. One will be a successor to the Integrated Distributed Energy Resources proceeding focused on how DERs should be sourced; a second will focus on customer demand.

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59 CPUC Rulemaking R.13-11-005

60 CPUC. August 2019. "Decision 1908009, Decision Modifying the Energy Efficiency Three-Prong Test Related to Fuel Substitution, R.13-11-005."

61 CPUC. R13-11-005. "Decision 2105031, Assessment of Energy Efficiency Potential and Goals and Modification of Portfolio Approval and Oversight Process."
https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M385/K864/385864616.PDF

62 CPUC R.21-06-017. Order Instituting Rulemaking to Modernize the Electric Grid for a High Distributed Energy Resources Future. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M390/K664/390664433.PDF.

CARB is updating the Climate Change Scoping Plan for 2022.[63] This update will assess progress toward the 2030 GHG reduction targets and highlight a path to achieving carbon neutrality by 2045. Building decarbonization is a focus of the 2022 plan, especially the GHG reduction potential from electrification. CARB is also working on air pollution and refrigerant issues that impact decarbonization across all sectors.

Many other state agencies operate programs that reduce GHG emissions from buildings, industry, and agriculture and support one or more of the strategies described above. Most of these efforts are funded by the state's GHG Cap-and-Trade Program.[64] Economywide GHG reduction policies are the primary drivers of these efforts, including those introduced by SB 32 and SB 100.

California Energy Code, Title 24 Part 6

The Energy Code, Title 24, Part 6, applies to newly constructed buildings and retrofits to reduce wasteful and unnecessary energy consumption and save consumers money. California's residential and commercial buildings use nearly 70 percent of California's electricity and are responsible for a quarter of California's GHG emissions. The Energy Code increases energy efficiency and promotes all-electric buildings in a cost-effective manner for building owners, contributing to the state's decarbonization goals. It also reduces impacts on the electricity grid by encouraging demand flexibility and on-site solar photovoltaic (PV) generation. In addition, the Energy Code focuses on improving comfort and health for building occupants.

The CEC updates the Energy Code triennially through a technically rigorous process that depends heavily on public engagement and stakeholder feedback. The most recent version is the 2022 update,[65] which becomes effective January 1, 2023. The most notable updates related to the state's building decarbonization strategy are listed below.

- Heat pump technology: The 2022 Energy Code includes prescriptive requirements for the use of heat pump technology in single-family homes, multifamily buildings, and select commercial buildings.
- Solar PV and battery storage: The 2019 Energy Code was the first Energy Code update to include prescriptive requirements for solar PV, which applied to single-family homes

63 CARB AB 32 Climate Change Scoping Plan webpage, https://ww2.arb.ca.gov/our-work/programs/ab-32-climate-change-scoping-plan.

64 CARB webpage for California's Cap-and-Trade Program, https://ww2.arb.ca.gov/our-work/programs/cap-and-trade-program.

65 California Energy Commission. July 14, 2021. 2022 California Energy Code, Title 24 Parts 1 and 6. https://efiling.energy.ca.gov/GetDocument.aspx?tn=238848.

and low-rise residential buildings (multifamily with three stories or less). The 2022 Energy Code expands on these requirements by prescriptively requiring solar PV and battery storage[66] for high-rise multifamily buildings (multifamily with four stories or more) and selected commercial occupancy types (such as office and tenant spaces, schools, warehouses, retail, grocery, restaurants, medical clinics, theaters/auditoriums, convention centers, and hotel/motels). These prescriptive requirements specify system sizes to ensure that most PV generation is used on-site.

- Mandatory "electric-ready" and "energy storage-ready" requirements: Electric-ready means being able to accommodate the installation of electric appliances by having the designated space, circuitry, and breaker panel available. The 2022 Energy Code includes electric-ready requirements for the installation of heat pump space heaters, heat pump water heaters, electric cooktops, and electric clothes dryers for single family homes and multifamily buildings. It also includes requirements for interconnection ability of energy storage or a panel rating of 225 amps. These requirements are included to support all-electric homes.

As with every code update, the 2022 Energy Code includes changes that introduce new energy efficiency requirements or increase the stringency of existing requirements. Lighting, building envelope, mechanical systems, and covered process requirements for all building types were added or revised that result in significant energy and cost savings. Mechanical ventilation requirements were also strengthened to improve indoor air quality for homes and building occupants.

While the Energy Code has resulted in significant GHG reductions of buildings in California and has potential to continue to do so in future code cycles, important limits in its authority in federal and state law prevent the code alone from being able to decarbonize new buildings.

California Green Building Standards, Title 24, Part 11

The California Green Building Standards (CALGreen), Title 24, Part 11,[67] improves public health and safety through mandatory requirements for building design and construction. These requirements reduce negative environmental impacts and encourage sustainable practices, as well as provide voluntary provisions (often termed "reach codes"). CALGreen applies to the

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66 Battery storage refers to rechargeable energy storage systems consisting of electrochemical storage batteries, battery chargers, controls, and associated electrical equipment designed to provide electrical power to a building. Such systems are typically used to provide standby or emergency power, uninterruptable power supply, load shedding, load sharing, or similar capabilities. (California Code of Regulations, Title 24, Part 6, Section 100.1)

67 2019 California Green Building Standards Code, Title 24, Part 11. California Building Standards Commission. https://codes.iccsafe.org/content/CAGBSC2019/cover.

planning, operation, construction, use and occupancy of newly constructed buildings, and could also apply to additions and alterations to the building

The CEC is responsible for developing and maintaining the voluntary measures for energy efficiency in CALGreen (Appendices A4 and A5).[68] The intent of these voluntary provisions is to provide the basis for local jurisdictions to adopt local energy efficiency standards that go beyond the statewide requirements of the Energy Code. The CEC updates the voluntary measures for energy efficiency in CALGreen triennially, coinciding with updates to the Energy Code.

The updates to 2022 CALGreen include revised residential design rating performance margins and four new residential prerequisite options: heat pump space and water heating, heat pump water heater demand management, battery storage system controls, and high-performance vertical fenestration.

Appliance Efficiency Standards, Title 20

The CEC sets water and energy efficiency standards for non-federally regulated appliances. These regulations cover most major residential and commercial appliances sold or offered for sale in California. Following the adopted energy standards for computers, computer monitors, and state-regulated light-emitting diode (LEDs) lamps in 2017, the CEC adopted efficiency standards for several appliances.[69] In 2018, the CEC adopted efficiency standards for portable air conditioners and updated the efficiency standards for portable electric spas, estimated to save 369 gigawatt-hours per year (GWh/year)[70] and 242 GWh/year[71] after stock turnover statewide, respectively. In 2019, water performance standards for spray sprinkler bodies were adopted, saving California billions of gallons of water — roughly 152,286 billion gallons per year and 543 GWh/year of embedded energy after stock turnover.[72] Between 2019 and 2020,

68 The model language in Appendices A4 and A5 outlines the energy design rating performance margins above the Energy Code that buildings must achieve to comply and specifies a menu of prerequisite energy efficiency measure options for local jurisdictions to additionally.

69 Docket for computer and computer monitors 16-AAER-02 https://efiling.energy.ca.gov/Lists/DocketLog.aspx?docketnumber=16-AAER-02.

Docket for LEDs 17-AAER-15 https://efiling.energy.ca.gov/Lists/DocketLog.aspx?docketnumber=17-AAER-15

70 Staff Presentation on Portable Air Conditioners Public Hearing. November 27, 2018. TN# 225965, https://efiling.energy.ca.gov/GetDocument.aspx?tn=225965&DocumentContentId=56657.

71 Presentation on Portable Electric Spas and Battery Charger Systems and the Negative Declaration. April 12, 2018. TN#223187, https://efiling.energy.ca.gov/GetDocument.aspx?tn=223187&DocumentContentId=31347.

72 Final Staff Analysis of Water Efficiency Standards for Spray Sprinkler Bodies. April 25, 2019. CEC-400-2018-005-SF, https://efiling.energy.ca.gov/GetDocument.aspx?tn=227860&DocumentContentId=59234.

the CEC adopted energy efficiency standards for commercial and industrial air compressors, general service lamps, and replacement pool pump motors estimated to save 217 GWh/year,[73] 4,060 GWh/year,[74] and 451 GWh/year,[75] respectively, in electricity consumption after stock turnover statewide.

The CEC is considering standards, test procedures, labeling requirements, and other efficiency measures for several appliances, including commercial and industrial fans and blowers, federally exempted linear fluorescent lamps, gas hearth products, and irrigation controllers.[76] Further, since energy use by plug loads and miscellaneous electrical loads are growing rapidly in the residential and commercial sectors, the CEC is developing a roadmap for reducing device electricity consumption in standby and other low-power modes.[77]

Benchmarking and Performance Standards

California's Building Energy Benchmarking Program has been in effect since 2018, requiring building owners of more than 50,000 square feet of gross floor area, and with no residential utility accounts or 17 or more utility accounts, to track and annually submit the energy use intensity (EUI) of their building, as determined by dividing the building energy use by the square footage. The EUI provides a baseline and allows owners and operators to compare the efficiency of buildings.

Building upon their respective benchmarking programs, states such as Washington and Colorado, and cities such as New York City and Washington, D.C. have enacted building performance standards, requiring owners of buildings to take action to reduce their EUI below a specified threshold (Figure 7 shows building performance standards across the United States).[78] According to the U.S. EPA, "BPS [building performance standards] can improve the comfort and productivity of building occupants. As building owners seek to manage indoor air

73 CEC Air Compressor Public Hearing Presentation. January 1, 2019. TN# 226210, https://efiling.energy.ca.gov/GetDocument.aspx?tn=226210&DocumentContentId=56962.

74 Supplemental Staff Analysis for General Service Lamps Expanded Scope. August 16, 2019. TN#229471, https://efiling.energy.ca.gov/GetDocument.aspx?tn=229471&DocumentContentId=60864.

75 Final Analysis of Efficiency Standards for Replacement Dedicated-Purpose Pool Pump Motors. February 20, 2020. CEC-400-2020-001. https://efiling.energy.ca.gov/GetDocument.aspx?tn=232151&DocumentContentId=64054.

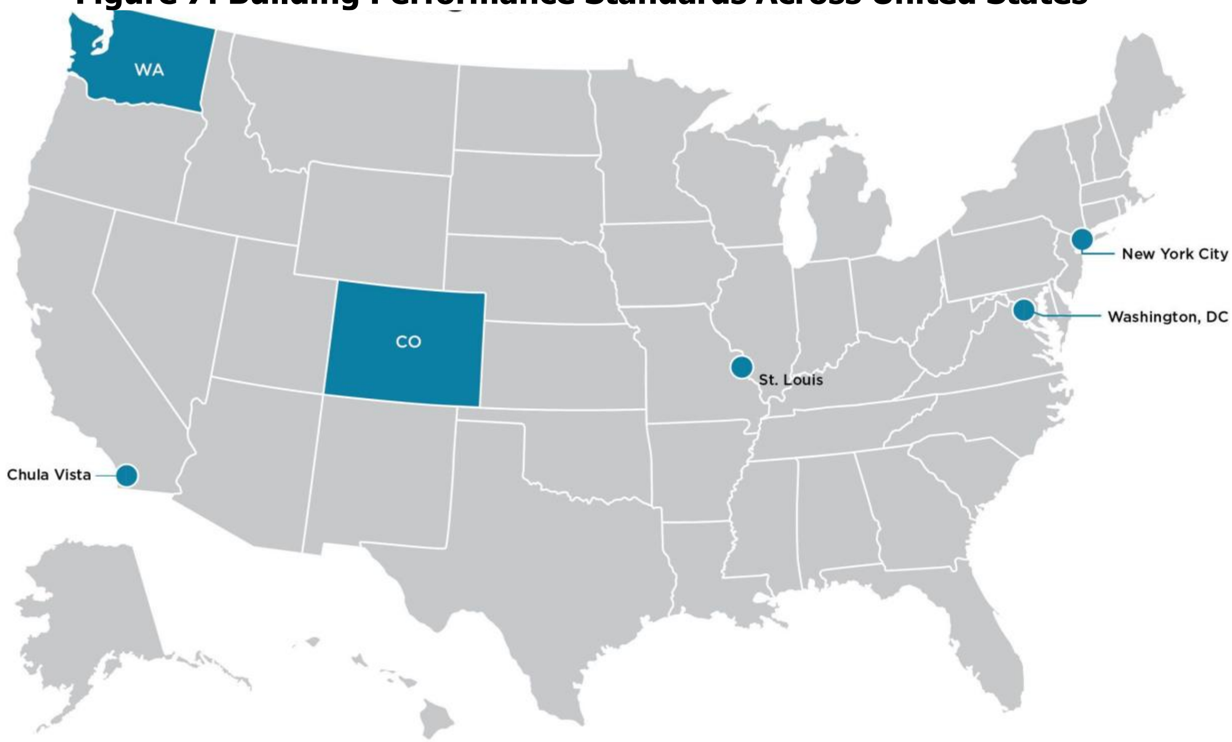
76 CEC webpage for Appliance Efficiency Proceedings- Title 20, https://www.energy.ca.gov/rules-and-regulations/appliance-efficiency-regulations-title-20/appliance-efficiency-proceedings.

77 Ibid.

78 May 25, 2021, IEPR workshop on Building Decarbonization — National, Regional, and California Activities, Session 1 transcript, p. 72, https://efiling.energy.ca.gov/getdocument.aspx?tn=239358.

quality, high-efficiency HVAC systems with improved controls have become increasingly important. Clean energy upgrades can also lead to EPA recognition, such as ENERGY STAR® Tenant Space recognition for efficient tenants or ENERGY STAR certification for building owners at the property level".[79] An ACEEE white paper estimates that if a mandatory performance standard requiring 30 percent energy and emission reduction is applied to two-thirds of the pre-2020 U.S. building stock, there is a potential for 11 percent reduction in energy use and CO_2 emissions in 2050 compared to a base case.[80]

Figure 7: Building Performance Standards Across United States



Source: Institute for Market Transformation

In California, the cities of Berkeley, Los Angeles, and San Francisco have implemented building performance standards and other energy-conservation measures that building owners must

79, United States Environmental Protection Agency. 2021. "Section 2. Building Performance Standards: Overview for State and Local Decision Makers." EPA-430-F-21-002. https://www.epa.gov/sites/default/files/2021-02/documents/benchmarking_building_performance_standards_section2.pdf.

80 Nadel, Steven and Hinge, Adam (American Council for an Energy-Efficiency Economy). 2020. *Mandatory Building Performance Standards: A Key Policy for Achieving Climate Goals*. https://www.aceee.org/sites/default/files/pdfs/buildings_standards_6.22.2020_0.pdf.

satisfy on a five-year cycle. Chula Vista, Brisbane, and San Jose will implement similar requirements in 2022 and 2023. Post-benchmarking requirements amongst California's local benchmarking programs generally allow building owners to demonstrate their building is high-performing, or complete audits, retrocommissioning,[81] and other improvement measures. California is in a prime position to implement and enforce a building performance standard using the numerous local, state, and national examples.

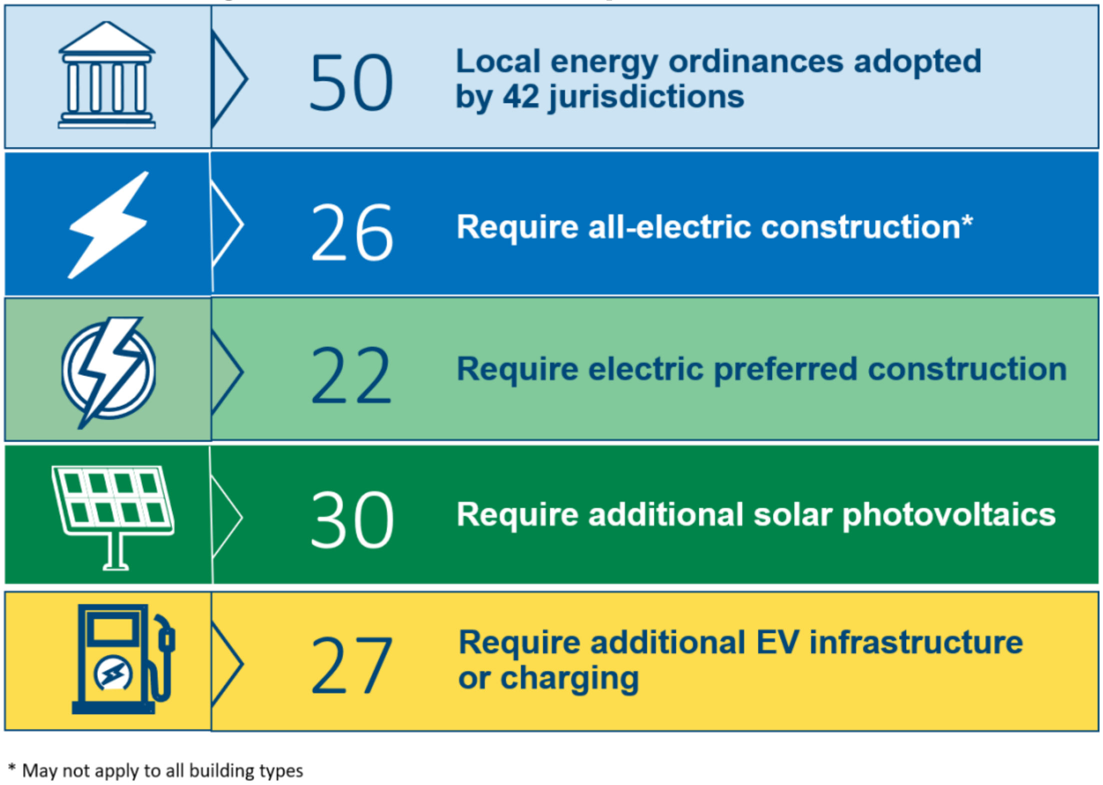
Reach Codes

The 2019 Energy Code cycle has seen increasing movement on the part of local jurisdictions to adopt electric-preferred, all-electric, and gas infrastructure limiting local ordinances. As shown in Figure 8, roughly 42 local jurisdictions in California have adopted energy ordinances stricter than state standards, with 26 requiring all electric construction and an additional 10 banning or limiting the installation of new gas lines as of October 2021. However, this situation is dynamic as more jurisdictions throughout the state are adopting or considering local ordinances that address climate change on an ongoing basis.

In addition, some jurisdictions that have adopted and enforced energy-efficient or electric-preferred ordinances are reconsidering that decision and adopting all-electric ordinances or gas bans.

81 *Retrocommissioning* refers to tuning the energy consuming systems in an existing building to operate more efficiently.

Figure 8: Reach Code Adoption in California



Source: CEC

All-Electric and Electric-Ready

Gas bans and all-electric requirements for all new construction have been in effect for a few jurisdictions since the beginning of 2020, with more adopting ordinances as the year progressed and throughout 2021. Gas bans apply to all new construction, all-electric requirements vary by jurisdiction and don't necessarily apply to all building types.

To tabulate the number of residences subject to these new requirements, staff at the CEC has been tracking and compiling new construction permits for single-family homes in jurisdictions that adopted gas bans or all-electric construction, for single-family homes, beginning after the ordinance requirements went into effect. These homes will have heat pump water heaters, heat pump space conditioning equipment for heating and cooling, and induction stovetops. In 2020, 1,293 new single-family housing construction permits were issued in those jurisdictions. As of August 2021, 2,056 permits have been issued. It's important to recognize the impact of the pandemic and the depressing effect it had on new construction permits in 2020.

Gas-Infrastructure Limitations

In July 2019, the City of Berkeley became the first jurisdiction in the nation to prohibit gas infrastructure in new buildings. Its ordinance applies to all new buildings that request permits after January 1, 2020.[82] In the time since, over 50 additional jurisdictions have taken action to reduce future gas infrastructure.[83] Jurisdictions that use their police powers to adopt bans on the use of gas do not have to seek CEC approval to enforce their local ordinances.

Decarbonization Codes Outside California

Across the country, states and cities are setting notable decarbonization policies and taking actions to address their respective building sectors. The following profiles highlight examples of decarbonization policies from states and cities throughout the country.

The City and County of Denver, Colorado, adopted *Denver's 2020 Net-Zero Energy (NZE) New Buildings and Homes Implementation Plan*.[84] The Denver NZE plan sets goals for new and existing buildings stock to achieve net-zero energy by 2030. Additional guidelines include objectives on energy efficiency, all-electric, renewable electricity, and demand flexibility. By 2024, new homes will be all-electric under the city's Building Code.[85] Denver is also working on a "Beneficial Electrification Implementation Plan" for existing buildings. This plan is expected to be completed late 2021.

In late 2020, the Washington State Department of Commerce released the Washington 2021 State Energy Strategy.[86] The strategy calls for a building decarbonization policy framework and a planned transition off the gas system. The strategy assesses actions to help the state achieve its 2050 emissions reduction targets.

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82 Ordinance NO. 7,672-N.S, City of Berkeley, City Council July 23, 2019 Meeting, https://www.cityofberkeley.info/Clerk/City_Council/2019/07_Jul/City_Council__07-23-2019_-_Regular_Meeting_Agenda.aspx.

83 Gough, Matt. *California's Cities Lead the Way to a Gas-Free Future*. November 2021. Sierra Club. https://www.sierraclub.org/articles/2021/07/californias-cities-lead-way-gas-free-future

84 January 2021. Denver's Net Zero Energy (NZE) New Buildings & Homes Implementation Plan, by City of Denver's Office of Climate Action, Sustainability, and Resiliency (CASR). https://www.denvergov.org/files/assets/public/climate-action/documents/denver-nze-implementation-plan_final_v1.pdf.

85 City of Denver's, Net Zero Energy (NZE) goals for 2024 Building Code. https://denvergov.org/Government/Agencies-Departments-Offices/Climate-Action-Sustainability-Resiliency/Initiatives/High-Performance-Buildings-and-Homes/Net-Zero-New-Buildings-Homes.

86 The 2021 State Energy Strategy was produced by the Washington State of Department of Commerce as a roadmap to meet the state's greenhouse gas limits. View Chapter D, Buildings, of the Energy Strategy to understand the proposed buildings decarbonization framework. https://www.commerce.wa.gov/growing-the-economy/energy/2021-state-energy-strategy/.

In December 2020, the Massachusetts Executive Office of Energy and Environmental Affairs, released the *Massachusetts 2050 Decarbonization Roadmap*.[87] With more than 2 million buildings in Massachusetts, decarbonizing commercial and residential buildings will require an intervention in every home and commercial structure over the next 30 years.[88] The Massachusetts roadmap lays out pathways to meet its overall goal of achieving net-zero emissions while reducing emissions equitably and cost-effectively across the economy, including the buildings sector. Massachusetts seeks to reduce GHG emissions 85 percent by 2050.

New York is also working on a building decarbonization policy. The state is developing the *Carbon Neutral Buildings Roadmap*[89] to address emissions from their buildings sector. The New York roadmap is intended as a long-term planning tool to reduce emissions from the state's buildings sector and will include action steps. Ultimately, the roadmap is intended to identify pathways to decarbonize New York's building stock by 2050, and the final draft is expected to be publicly available by late 2021.

Quality Installation of Heating and Air Conditioning Equipment

Since the 1990s, the CEC has recognized the need to improve the installation of space-heating and air-conditioning equipment. Research has indicated that poor quality installation can lead to the loss of 30–40 percent of the energy savings benefits of energy efficiency improvements[90] and can compromise indoor air quality, comfort and potentially health and safety. The CEC has developed minimum quality installation standards to address important installation problems in residential buildings and has included requirements for meeting those standards in the Energy Code, beginning in 2001 for newly constructed homes and in 2005 for equipment replacements in existing homes.

87 December 2020, Massachusetts 2050 Decarbonization Roadmap, released by the Massachusetts Executive Office of Energy and Environmental Affairs, https://www.mass.gov/info-details/ma-decarbonization-roadmap#final-reports-.

88 The buildings figure is from Executive Summary of the December 2020 *Buildings Sector Report: A Technical Report of the Massachusetts 2050 Decarbonization Roadmap Study* https://www.mass.gov/info-details/ma-decarbonization-roadmap#final-reports-.

89 The Carbon Neutral Buildings Roadmap is scheduled for release late 2021. Visit the Carbon Neutral Buildings webpage for policy material and other related information. https://www.nyserda.ny.gov/All-Programs/Programs/Carbon-Neutral-Buildings.

90 John Proctor, Chris Neme, and Steve Nadel. National Energy Savings Potential from Addressing Residential HVAC Installation Problems. February 1999. p. 16. https://www.proctoreng.com/dnld/NationalEnergySavingsPotentialfromAddressingResidentialHVACInstallationProblems.pdf.

Assembly Bill 2021 (Levine, Statutes of 2006, Chapter 734) directed the CEC to develop a plan to improve the energy efficiency and decrease the peak electricity demand of air conditioners. In collaboration with the CPUC, the CEC formed a 45-member working group of heating, ventilation, and air conditioning (HVAC) professionals to prepare the plan. The working group concluded:

> "Failure to ensure quality installations or maintenance of cooling systems result in a 20 to 30 percent increase in the peak electricity needed by such systems to provide customers with the cooling and comfort they demand on hot summer afternoons."
>
> "The lack of quality control is exacerbated by the failure of many contractors to pull building permits and verify minimum quality installation when replacing air-conditioning systems."[91]

The working group concluded that only 10 percent of an estimated 350,000 residential replacement installations per year are done with building permits, and only 15 percent of those installations would meet CEC minimum quality installation standards. This level of peak savings is comparable to the peak savings of 166 MW reported for Southern California Edison's entire energy efficiency program portfolio in 2006.

Several efforts were conducted to address these quality installation problems:

- Following Governor Arnold Schwarzenegger's Executive Order S-20-04, the CEC entered into a Memorandum of Understanding with the Contractors State Licensing Board (CSLB) to collaborate to improve the performance of licensed contractors in their responsibility to comply with the Energy Code.
- The CPUC established a large industry collaborative, the Western Heating, Ventilation, and Air Conditioning (HVAC) Performance Alliance to work on solutions.[92]
- The investor-owned utility (IOU) Codes and Standards Program formed the Construction Improvement Advisory Group that developed a series of white papers on approaches to improve installation quality.[93]

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91 California Energy Commission. Strategic Plan to Reduce the Energy Impact of Air Conditioners. 2008. p. 5 and v. http://web.archive.org/web/20190228183210/https://www.energy.ca.gov/2008publications/CEC-400-2008-010/CEC-400-2008-010.PDF.

92 California Public Utilities Commission. California Energy Efficiency Strategic Plan: Codes and Standards Action Plan, 2012-2015. https://www.cpuc.ca.gov/-/media/cpuc-website/files/uploadedfiles/cpuc_public_website/content/utilities_and_industries/energy/energy_programs/demand_side_management/ee_and_energy_savings_assist/cs-actionplan-20140219.pdf.

93 Ibid.

- The California Attorney General's Office requested that IOUs mandate incentive applications of high-efficiency HVAC equipment in existing homes require affirmation that the installation had been done in accordance with all applicable permitting requirements and, where applicable, by a licensed contractor.[94]
- The CEC emphasized quality installation in programs aimed at home HVAC replacements using funding from the American Recovery and Reinvestment Act (ARRA), requiring incented projects with incentives be completed by licensed contractors, to pull permits and comply with the CEC's quality installation standards.

In 2017, DNV-GL, under contract to the CPUC, revisited the top-down estimates made by the AB 2021 working group regarding the rate to which contractors pull permits when installing HVAC units in existing homes. The comparable estimates made by that study were that 7.9 percent of about 1 million such installations in 2014 pulled permits for the project.[95] This estimated number of annual installations was triple the number from the AB 2021 working group.

In recent years, the Legislature enacted two bills directly related to quality installation of heating and air-conditioning equipment:

- Senate Bill 350 (De León, Statutes of 2015, Chapter 547) directs the CEC to "adopt, implement, and enforce a responsible contractor policy … to ensure that retrofits meet high-quality performance standards and reduce energy savings lost or foregone due to poor-quality workmanship." "adopt, implement, and enforce a responsible contractor policy … to ensure that retrofits meet high-quality performance standards and reduce energy savings lost or foregone due to poor-quality workmanship."
- Senate Bill 1414 (Wolk, Statutes of 2016, Chapter 678) directs the CEC to "promote compliance with Part 6 of Title 24 of the California Code of Regulations in the installation of central air-conditioning and heat pumps" and "adopt regulations to increase compliance with permitting and inspection requirements for central air conditioning and heat pumps, and associated sales and installations."

Another major consequence of poor-quality installation of heating and air-conditioning equipment is the failure of contractors to properly recapture the HFC-gas, or for older

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94 CEC. March 14, 2014. Testimony to the Little Hoover Commission. Underground Economy: Contractors Failure to Pull Permits for Residential HVAC Replacements. p. 7.

95 Palmgren, Claire, Miriam Goldberg, Ph.D., Bob Ramirez, Craig Williamson, and DNV GL Energy Insights USA, Inc. 2019. *2019 California Residential Appliance Saturation Study*. California Energy Commission. Publication Number: CEC-200-2021-005. https://www.energy.ca.gov/publications/2021/2019-california-residential-appliance-saturation-study-rass.

appliances predating HFCs — ozone depleting hydrochlorofluorocarbon-gas (HCFC) — refrigerant when the equipment is replaced. Commonly used refrigerants, HFCs and HCFCs, are potent GHGs, with a warming effect that is hundreds to thousands of times more powerful than CO_2. Senate Bill 1383 (Lara, Chapter 395, Statutes of 2016) directs CARB to "achieve a reduction in the statewide emissions of … hydrofluorocarbon gases by 40 percent … below 2013 levels by 2030." CARB estimates that 80 percent of the refrigerant in heat pumps and air conditioners is lost to the atmosphere at the end of life of the equipment (at replacement).[96]

In the past, quality installation problems have resulted in substantial lost energy savings and peak-demand reductions for California. As the state advances building decarbonization, the number of heat pumps will greatly increase. Consistent quality and code-compliant installation is essential to accomplishing the full value of the expected energy savings, to properly recapturing and recycling the refrigerant from replacement heat pumps and air conditioners, and thus to accomplish the state's commitment to achieve carbon-neutrality.

On September 10, 2021, the CEC conducted a public workshop on actions needed to address quality installation problems for residential replacement of heating and air-conditioning equipment. The IEPR workshop supplements the record previously established in docket 17-EBP-01 for preparation of the SB 1414 Plan. The SB 1414 Plan is expected to be finalized in 2021 with the following initial recommendations:

- Expand the authority, responsibility, and resources of the CSLB to identify and take disciplinary action with higher consequences for (1) licensed contractors who fail to pull permits and fail to meet CEC quality installation standards for heating and air-conditioning projects and (2) other persons who complete such projects without a license to do so.
- Require distributors to only sell heating and air-conditioning equipment only to licensed contractors and report to the CEC the number of equipment units sold to each purchaser.
- Work with manufacturers and distributors to ensure warranty registrations include the permit number for the equipment installation and that warranty claims require permits to have been pulled for the installation.
- Require all permits record the license number of the installing contractor.

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96 CARB. 2016. California's High Global Warming Potential Gases Emissions Inventory: Emission Inventory and Technical Support Document. Table 2, p.10. https://www.arb.ca.gov/cc/inventory/doc/methods_00-14/ghg_inventory_00-14_technical_support_document.pdf.

- In coordination with CARB and the U.S. EPA, take action to ensure refrigerants are properly recaptured and recycled upon equipment replacement.
- Consider alternatives to demonstrate compliance with the CEC's quality installation standards, including participation in utility programs that verify quality installation, verified use of remote quality control monitoring systems, and installation of fault detection and notification equipment.
- Encourage simplification of building department permitting and inspection for heating and air-conditioning system replacement installations, including online permitting and remote inspections.
- Encourage training for contractors and technicians to properly meet quality installation standards and refrigerant recapture and recycling procedures.
- Encourage consumer protection information regarding the benefits of quality and code-compliant installation be provided to persons for whom space heating and air-conditioning is installed.

State and Federal Regulation of Refrigerants

HFC refrigerants are a major source of building GHG emissions. The *California Building Decarbonization Assessment* found that HFC refrigerants contributed about 15 percent of direct building emissions.[97] As the state installs more heat pumps, the use of refrigerants will increase and could lead to greater emissions if work is not done to use lower GWP refrigerants and more effectively capture and recycle refrigerants at the end of their useful life.

State Regulation

As noted above, SB 1383 requires CARB to reduce HFC emissions 40 percent below 2013 levels by 2030.[98] HFCs are potent GHGs with a warming effect that is hundreds to thousands of times more powerful than carbon dioxide. Nearly 90 percent of HFC emissions in California come from HFC use as refrigerants.[99] With the increasing use of refrigerant-based equipment

97 Kenney, Michael, Nicholas Janusch, Ingrid Neumann, and Mike Jaske. 2021. Page 34. California Building Decarbonization Assessment. CEC. Publication Number: CEC-400-2021-006-CMF. https://www.energy.ca.gov/publications/2021/california-building-decarbonization-assessment.

98 Senate Bill 1383 (Lara, Chapter 395, Statutes of 2016), https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB1383.

99 CARB. October 2020. Public Hearing to Consider the Proposed Amendments to the Prohibitions on Use of Certain Hydrofluorocarbons in Stationary Refrigeration, Chillers, Aerosols-Propellants, and Foam End-Uses Regulation. https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2020/hfc2020/isor.pdf?_ga=2.219140569.1510372616.1634743827-787897627.1600907038.

to heat and cool buildings, and heat water, actions are needed to reduce HFC emissions. In 2017, CARB published the *Short-Lived Climate Pollutant Reduction Strategy*,[100] which contains recommendations to phasedown HFC supply, prohibit sales of very high GWP refrigerants, provide incentives for climate-friendly refrigerant technologies, and prohibit sales of new equipment that uses high-GWP refrigerants.

In 2017, CARB initiated a regulation to prohibit the use of certain HFCs in stationary refrigeration and air conditioning, the HFC Regulation.[101] The Final Revised Regulation Text and Final Statement of Reasons were submitted October 14, 2021.[102] The proposed regulatory language would limit refrigerants with a GWP less than 150 for stationary refrigeration systems containing more than 50 pounds of refrigerant in new facilities effective January 1, 2022. Additionally, there are GWP limits for refrigeration systems in existing food retail facilities. The proposed regulatory language would limit refrigerants to a GWP less than 750 in new residential and nonresidential air conditioning equipment (the HFC Regulation uses 100-year GWP values based on the IPCC Fourth Assessment Report). The air conditioning measures would be effective in:

- 2023 for new room air-conditioning equipment and dehumidifiers.
- 2025 for new residential and commercial stationary air-conditioning equipment.
- 2026 for air-conditioning equipment that is variable refrigerant flow or are variable refrigerant volume systems.[103]

The HFC Regulation also implements the Refrigerant Recovery, Recycle, and Reuse (R4) Program. This new program requires air-conditioning manufacturers to use 10 percent reclaimed refrigerant annually for 2023 and 2024. The regulation gives early action credit for low-GWP refrigerant use implemented before the regulation deadlines. For variable refrigerant flow systems, 15 percent of refrigerant use must be reclaimed in 2023 and 2024, increasing to 25 percent in 2025. The R4 Program also specifies the reclaim refrigerant quality, limiting the amount of virgin refrigerant that can be added to 15 percent. CARB will work with

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100 CARB. March 2017. Short-Lived Climate Pollutant Reduction Strategy. https://ww2.arb.ca.gov/sites/default/files/2020-07/final_SLCP_strategy.pdf.

101 CARB. Prohibitions on Use of Certain Hydrofluorocarbons in Stationary Refrigeration, Chillers, Aerosols-Propellants, and Foam End Uses Regulation. December 10, 2020. https://ww2.arb.ca.gov/rulemaking/2020/hfc2020.

102 CARB. Prohibitions on Use of Certain Hydrofluorocarbons in Stationary Refrigeration, Chillers, Aerosols-Propellants, and Foam End Uses Regulation. https://ww2.arb.ca.gov/rulemaking/2020/hfc2020.

103 Heat pump system that can modulate the amount of refrigerant needed to cool or heat an area.

stakeholders to develop the R4 Program further, with the aim of expanding and catalyzing national action.

Federal Regulation

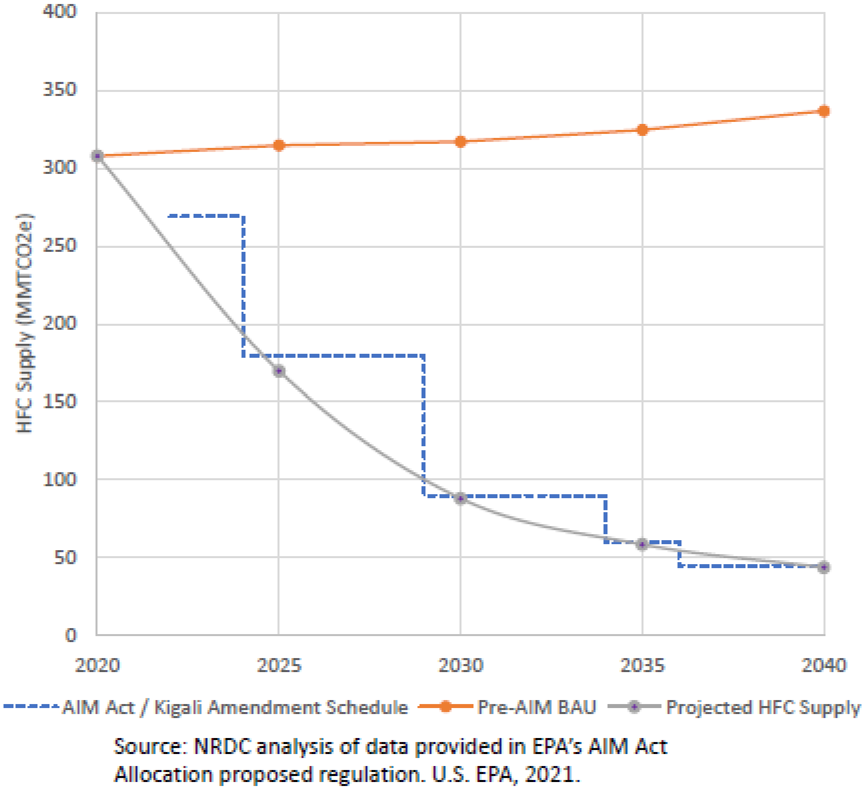
The American Innovation and Manufacturing (AIM) Act of 2020,[104] enacted by Congress, directs the U.S. EPA to address HFCs by providing new authorities in three main areas:

1) Phasing down production and consumption
2) Maximizing reclamation and minimizing releases from equipment
3) Facilitating the transition to next-generation technologies through sector-based restrictions

The HFC production and consumption phase down follows a step-down schedule, starting at 90 percent of baseline in 2022 and reducing down to 15 percent in 2036. Figure 9 shows the projected decrease of HFC supply with the phase down compared to a business-as-usual HFC supply without the AIM Act.

104 https://www.epa.gov/climate-hfcs-reduction/aim-act.

Figure 9: U.S. HFC Supply Under the AIM Act – 20-Year Outlook



Source: NRDC analysis of data provided in the U.S. EPA's AIM Act Allocation proposed regulation. U.S. EPA, 2021.

The phase down will be implemented through an allowance allocation and trading program. The U.S. EPA has established the HFC production and consumption allowance caps from 2022 to 2036. The phase down is expected to prevent 171 $MMTCO_2$ emissions in 2036.[105] Companies that use HFCs to manufacture refrigeration and air-conditioning equipment may be affected by the AIM Act. The impact of phasedown on recovery and reclaim amounts can be seen from the previous phase out of ozone depleting substances. Recovery and reclamation increase as the cost of refrigerant increases, which is expected as less refrigerant is produced. This is being observed in the case of previous ozone depleting substance refrigerants, such as

105 U.S. EPA. Final Rule – Phasedown of Hydrofluorocarbons: Establishing the Allowance Allocation and Trading Program Under the American Innovation and Manufacturing (AIM) Act Fact Sheet. September 2021. https://www.epa.gov/system/files/documents/2021-09/hfc-allocation-rule-nprm-fact-sheet-finalrule.pdf.

R-22.[106] There was an upward trend of reclaimed R-22 from 2000 to 2008, leading up to a ban on production in 2010. From 2010 to 2020, there is a somewhat steady amount of reclaimed R-22 even after no more was produced. A similar impact is expected to occur on HFCs gradually over the next 15 years.

Research and Development

The CEC's research and development programs fund innovation, enabling a safer, more reliable, equitable, decarbonized, and affordable energy system. Building decarbonization is one of the focus areas of the CEC's EPIC and Natural Gas Research and Development programs. Other areas include the entrepreneurial ecosystem, resiliency, health and safety, grid decarbonization and decentralization, industrial and agricultural innovation, low emission transportation including electrification, and gas system decarbonization.

EPIC

EPIC was established by the CPUC in 2011 to fund research leading to technological advancement and scientific breakthroughs supporting California's clean energy goals, with a focus on providing ratepayer benefits, including reliability, lower costs, and safety. The program annually provides about $133 million in Research and Development funding.

To date, EPIC has provided substantial benefits to the state, including:

- Directing 65 percent of technology demonstration and deployment project funding to research in, and benefiting, low-income or disadvantaged communities.
- Commercializing more than 34 technologies and related service companies.
- Contributing to the ability of companies funded by EPIC research to collectively receive more than $2.2 billion in private investment and subsequent funding.
- Improving the effectiveness of energy-related codes and standards. Five such research projects could lead to more than $1 billion in annual energy cost savings if adopted into regulatory codes.

As of December 2020, roughly $194 million has been invested in building decarbonization projects.[107] This includes investments in new sustainable energy efficiency and demand response technologies that improve the affordability, health and comfort of homes and

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106 U.S. EPA. Summary of Refrigerant Reclamation Trends. https://www.epa.gov/section608/summary-refrigerant-reclamation-trends.

107 2020 EPIC Highlights. https://www.energy.ca.gov/sites/default/files/2021-05/CEC-500-2021-029-SUM_1.pdf.

businesses. These investments helped to validate technology solutions that reduce electricity use while increasing production of goods and products on which much of the world relies.

Natural Gas Research and Development

The 2004 CPUC Decision 04-08-010 designated the CEC as the administrator for the Natural Gas Research and Development Program. The CPUC allocates $24 million annually and defines public interest gas research activities as those "directed towards developing science or technology, and (1) the benefits of which accrue to California citizens, and (2) are not adequately addressed by competitive or regulated entities." The annual research funding focuses on advancing technology innovation and scientific breakthroughs that enable the gas sector to support California's energy and environmental goals. One of the major objectives is to drive large-scale customer adoption of efficient and low-carbon technology solutions for gas end uses, especially for those that are difficult to electrify.

As of October 2020, about $55 million has been invested on building decarbonization novel technologies to improve the energy efficiency, affordability, health, and comfort of California's homes and businesses.[108]

Demand Flexibility

Demand flexibility is a growing and critical component of building decarbonization. It allows for maximization of renewable energy resources, alignment of energy demand with real-time energy prices, and other beneficial grid services without disrupting customer needs. With communications and automated control technologies, customers can shift electric services to take advantage of cleaner and cheaper supplies without sacrificing comfort or quality of service. Buildings and water can be precooled or preheated. Batteries and electric vehicles can be charged on schedules that meet the needs of both consumer and grid. Consumers can set dishwashing, laundry, and many other services to be automatically scheduled based on the electricity cost or GHG content. Advanced meters, communications, and automation technologies make this possible today. Across federal and state levels, work is ongoing to put this strategy into action through standards, programs, and research and development in the residential, commercial, industrial, and agricultural sectors.

Load Management Standards

The Warren-Alquist Act defines load management as "any utility program or activity that is intended to reshape deliberately a utility's load duration curve" (Public Resources Code

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108 CEC. *2020 Natural Gas Research and Development Program, Annual Report, July 1, 2019 – June 30, 2020*. https://www.energy.ca.gov/sites/default/files/2021-05/CEC-500-2020-073.pdf.

Section 25132). Load management strategies, including those established by the CEC's first load management standards, have been used to help balance the supply and demand of energy in California since the 1970s. Today, existing load management resources are largely met by utility incentive programs that reward customers for reducing demand when it is at a peak. However, these programs are incapable of shifting loads to periods of high renewable generation and, thus, are inadequate for supporting the carbon-free grid of the future.

Throughout 2020, CEC staff worked with the CPUC, California ISO, utilities, community choice aggregators[109] (CCAs), automation service providers, equipment manufacturers, and other stakeholders to identify the steps needed to increase demand flexibility statewide. In March 2021, the CEC released the *Draft Staff Report: Analysis of Potential Amendments to the Load Management Standards*.[110] This report recommended CEC amend the Load Management Standards[111] to require the state's five largest electric utility service territories in California — Pacific Gas and Electric (PG&E), Southern California Edison (SCE), Los Angeles Department of Water and Power (LADWP), Sacramento Municipal Utility District (SMUD), and San Diego Gas & Electric (SDG&E) — and the community choice aggregators (CCAs) operating within these service territories to:

1) Maintain the accuracy of existing and future time-varying rates in the publicly available and machine-readable Market Informed Demand Automation Server (MIDAS) rate database.[112]
2) Implement a single statewide standard method for providing automation service providers with access to their customers' rate information.
3) Develop retail electricity rates that change at least hourly to reflect locational marginal costs and submit those rates to the utility's governing body for approval.
4) Integrate information about new time-varying rates and automation technologies into existing customer education and outreach programs.

109 A CCA is a local, not-for-profit, public entity that determines energy sources for local electricity needs.

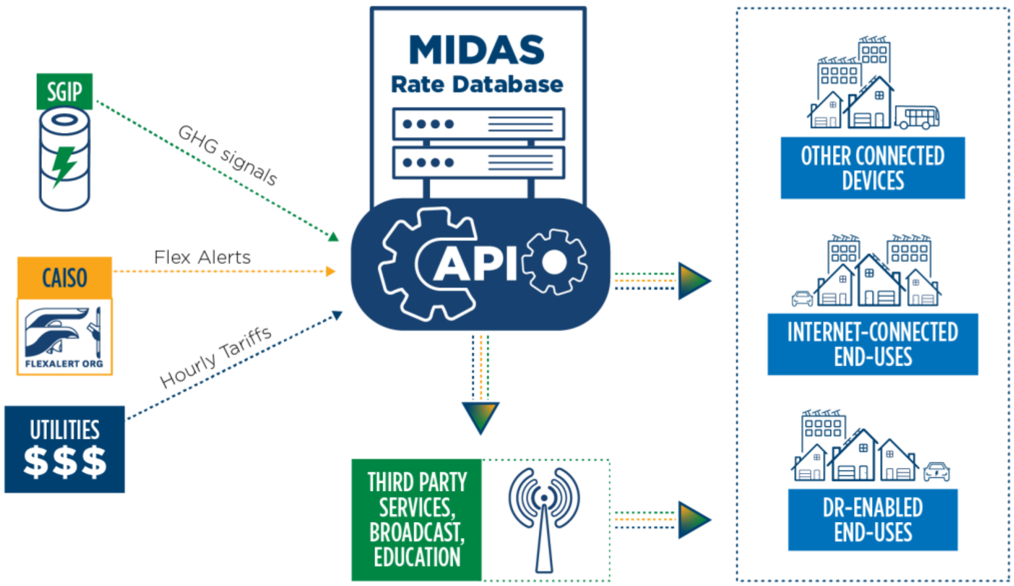
110 Herter, Karen and Gavin Situ. 2020. Analysis of Potential Amendments to the Load Management Standards: Load Management Rulemaking. Docket Number 19-OIR-01. CEC. Publication Number: CEC-400-2021-003-SD. https://www.energy.ca.gov/proceedings/energy-commission-proceedings/2020-load-management-rulemaking.

111 Load Management Standards are cost-effective programs which result in improved utility system efficiency, reduced or delayed need for new electrical capacity, reduced [fossil] fuel consumption, and lower long-term economic and environmental costs to meet the State's electricity needs. (California Code of Regulations, Title 20, Section 1621(a))

112 MIDAS database, https://midasapi.energy.ca.gov/.

The proposed amendments intend to form the foundation for a statewide system of granular time- and location-dependent signals that can be used by automation-enabled loads to provide building owners and operators more control of their energy usage and real-time load flexibility on the electric grid. In August 2021, the CEC published a limited version of the MIDAS, a statewide real-time signaling system that can collect and share time-varying electricity rates, California ISO Flex Alerts, and marginal GHG emissions data and then share that information via a signal to utilities, aggregators, and homeowners.[113]

Figure 10: Proposed Load Management Signal Framework



Source: CEC

This work will be further piloted and tested in the FlexHub studies of EPIC and will help form the foundation for successful implementation of future flexible demand appliance standards. Staff is collecting public feedback on MIDAS and aims to begin the rulemaking for load management standards in 2021.

Flexible Demand Appliance Standards

Governor Gavin Newsom signed Senate Bill 49 (Skinner, Chapter 697, Statutes of 2019) in October 2019, giving the CEC new authority to set flexible demand standards and labeling

113 Ibid.

requirements for appliances.[114] Flexible demand means the capability to schedule, shift, or curtail the electrical demand of a load-serving entity's (LSE's) customer through direct action by the end user, a third party, the LSE, or a grid-balancing authority, each with the consumer's consent. Since then, the CEC held a public workshop on approaches to develop successful and acceptable flexible demand appliance standards,[115] submitted a request for information,[116] and published a staff report.[117] The staff report proposes introducing flexible demand standards for select groups of appliances in three phases beginning in late 2022 and ending in 2024 (Table 1). For the first phase, load shift potential (kilowatt-hours or kWh), ability to shed capacity (megawatts or MW), and GHG avoidance metrics are included in the staff report for four appliances.

Table 1: Proposed Initial Flexible Demand Appliance Standards — Implementation Phases

Schedule	Appliance
Phase 1	Thermostats
Phase 1	Pool Pump Controls
Phase 1	Consumer Dishwashers
Phase 1	Electric Clothes Dryers
Phase 2	Electric Water Heaters
Phase 2	Behind-the-Meter Batteries
Phase 3	Electric Vehicle Supply Equipment

Source: CEC staff

Using a phased approach, designs standards will be required initially but are expandable. The aim is to provide a foundation for future rulemakings to implement a performance approach as technologies and test procedures are developed within industry. For example, preliminary design standards can specify:

- Minimum timer functions as a direct action by the consumer.

114 Senate Bill 49. Skinner, Chapter 697, Statutes of 2019. https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201920200SB49.

115 December 14, 2020, CEC staff workshop on Flexible Demand Appliance Standards. https://www.energy.ca.gov/proceedings/energy-commission-proceedings/flexible-demand-appliances.

116 CEC. Request for Information: Flexible Demand Appliances. 2021. https://efiling.energy.ca.gov/GetDocument.aspx?tn=239571&DocumentContentId=73004.

117 Steffensen, Sean. 2020. *Introduction to Flexible Demand Appliance Standards*. California Energy Commission. Publication Number: CEC-400-2020-013. https://efiling.energy.ca.gov/GetDocument.aspx?tn=235899.

- Automated price response capability as a direct action by a third party, LSE, or grid-balancing authority.
- Scheduling features that provide consumers the ability to better control when appliances use electricity.
- Basic cybersecurity and communication features that protect the consumer and the electric grid.
- Certification, labeling, and enforcement requirements to support the sales and leasing prohibition for noncompliant appliances.

Appliances will be considered based on several criteria, including feasibility, risk of pre-emption or inaccurate savings, innovation and market growth, equity, and synergy with state and CEC policy.

California FlexHub

In 2021, the CEC launched the California FlexHub.[118] The FlexHub was designed to conduct research projects that would increase the use and market adoption of advanced, interoperable, and flexible demand technologies and strategies. These flexible demand technologies and strategies would provide enhanced grid-stabilizing energy resources by modifying demand load based on grid and user needs while helping integrate intermittent renewable energy generation such as wind. The FlexHub projects will not only develop, demonstrate, and deploy advanced signal (GHG or price or both) responsive, interoperable, and scalable technology solutions, but document the performance, economic and environmental value, and customer acceptance to create technology pathways to market adoption.

Residential Demand Flexibility

Electrifying buildings shifts end uses such as water heating and space heating away from gas combustion equipment to electric alternatives. These additional demands for electricity may add stress to the electric grid unless they are modulated to match the available energy supply. Load management or demand flexibility can reduce consumer energy costs, reduce GHG emissions, reduce the need to curtail renewable energy, and support grid resiliency when optimized. Demand-flexibility enabling technologies are needed to balance these end uses as grid energy resources while cost-effectively operating to meet the customer needs. Programs such as OhmConnect's OhmHour incentive program have successfully demonstrated that

118 California Load Flexibility Research and Development Hub (CalFlexHub) webpage, https://calflexhub.org/.

homeowners are willing to shed or shift their load to times of day with less grid stress and modify their demand if they are compensated for their efforts.[119]

Commercial Demand Flexibility

Commercial electricity loads are made up of mostly air conditioning, lighting, refrigeration, and ventilation. Space heating, water heating, and cooking are usually fueled by gas and are large contributors to the energy demand. These end uses are prime targets to be electrified. With the shift to commercial building electrification and operation occurring during the morning and afternoon hours, commercial demand flexibility is critical to maintaining grid stability, especially during the winter months when demand for space heating increases and availability of renewable energy generation is lowest.

The Ideal Building: Efficient, Low Carbon, and Flexible

First and foremost, buildings must be comfortable, safe, and affordable environments in which people live and work. Each of the decarbonization measures described here have its own merits — when combined, many of the measures support and amplify each other. Together they form a vision of an "ideal building" that both satisfies occupant energy needs and cost-effectively minimizes environmental impact.

For example, efficient building envelopes and high-performance windows not only improve comfort and reduce heating and cooling costs, but also increase the potential for valuable automated load shift. Improving envelopes is a necessary first step to retrofitting the existing building stock toward this ideal building vision since it reduces energy costs regardless of fuel. An improved building envelope effectively creates additional thermal storage at no cost. Installing technology that communicates and automates demand shift while prioritizing customer needs can ensure that customers receive a share of the value they generate and that the changes persist over the long-term. Figures 11 and 12 show examples of ideal single-family and multifamily decarbonized residential buildings.

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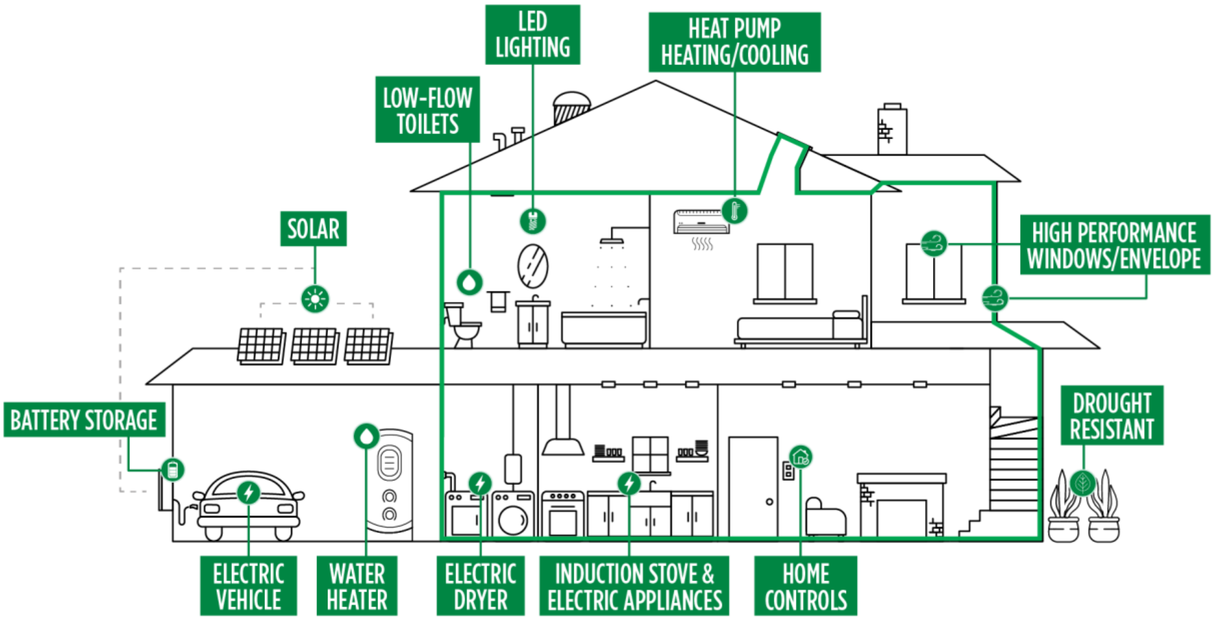
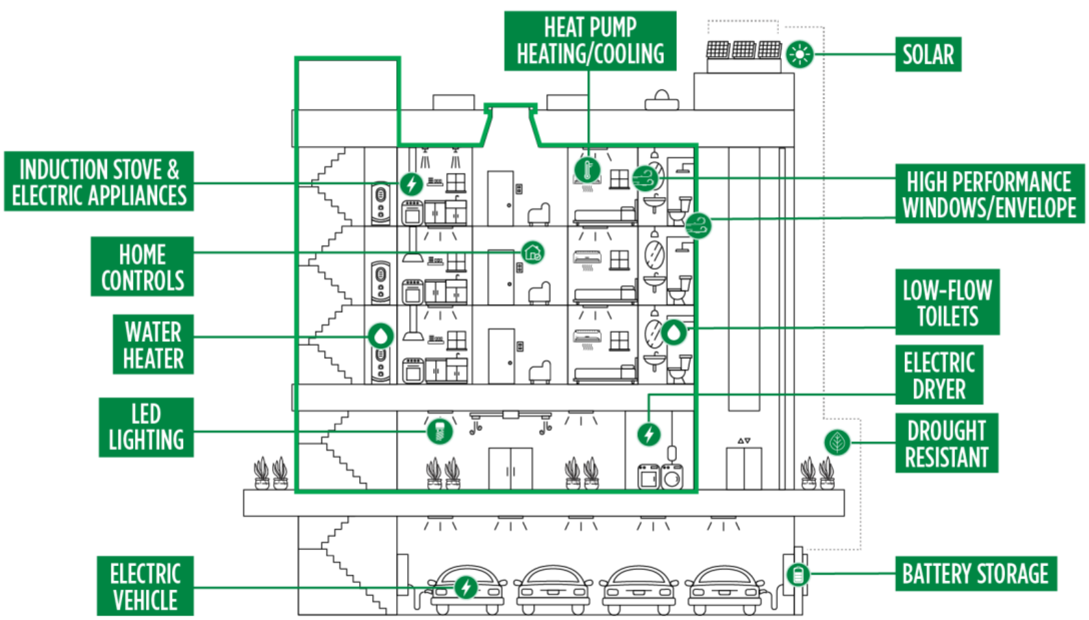
119 Duesterberg, Matt, and Lillian Mirviss. 2021. *Reinventing Residential Electric Demand Response*. California Energy Commission. Publication Number: CEC-500-2021-019. https://www.energy.ca.gov/publications/2021/reinventing-residential-demand-response-breaking-through-barriers-gamification.

Figure 11: Efficient, Low Carbon, Flexible Single-Family Homes



Source: CEC

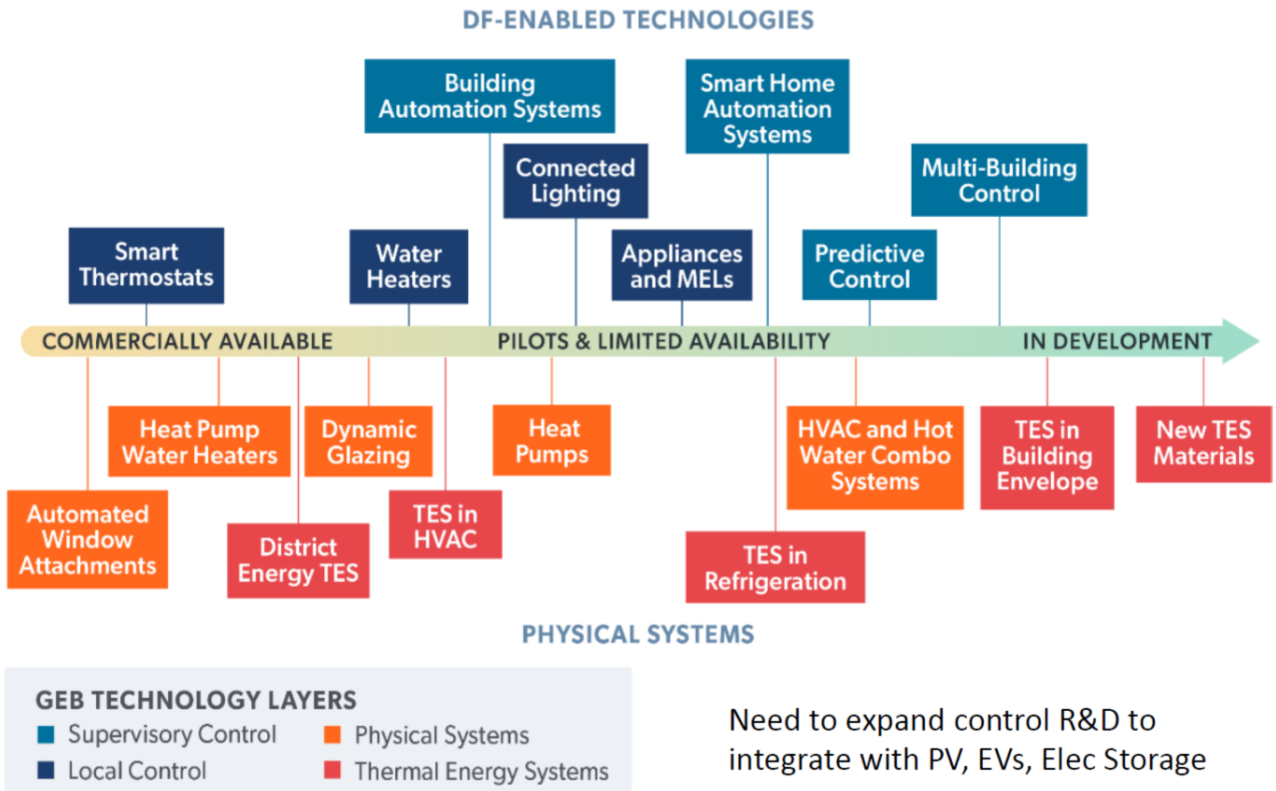
Figure 12: Efficient, Low Carbon, Flexible Multifamily Homes



Source: CEC

Many of the key technologies necessary to achieve this vision are already available and others are in development (Figure 13). Most notably, smart thermostats allow automated load shifting for space conditioning and heat pump water heaters decarbonize fossil gas heating loads and allow for intelligent scheduling without reducing customer hot water supply. Space heating and water heating are key building decarbonization concerns since fossil fuels continue to be the dominant energy source for both.[120]

Figure 13: Demand Flexibility (DF) Enabled Technology Availability



Credit: Lawrence Berkeley National Lab, 2021. https://efiling.energy.ca.gov/getdocument.aspx?tn=239952.

Improving utility ability to accept the benefits of such buildings will be key both through forward looking grid planning tools and real time system analytics and management.[121] This will require updates to utility resource planning, rate structures, and billing systems. These changes in turn will require updates to utility regulatory frameworks. The CEC and CPUC have already begun to address some of these issues under the CEC's Load Management Standards

120 The Regulatory Assistance Project. 2021. https://efiling.energy.ca.gov/getdocument.aspx?tn=239958.

121 Southern California Edison. 2021. *Grid-Interactive Efficient Buildings*. https://efiling.energy.ca.gov/getdocument.aspx?tn=239953.

authority[122] and multiple CPUC proceedings,[123] but research is ongoing to support the utility transition.[124] Applying open-source and normalized energy savings measurement methodologies will also be necessary to compare technology and program performance between utilities and climate zones.[125]

This vision of an ideal building in California shares many common goals with the U.S. DOE's work on *A National Roadmap for Grid-Interactive Efficient Buildings*.[126] Both California and the Federal government see significant potential value and environmental benefits through combined implementation of building energy efficiency, grid interactivity, occupant centric automation, and cost-effective load flexibility. These measures combined with a 100 percent clean energy grid, electrification of fossil fuel combustion, and attention to the embodied carbon of buildings form the basis for the building decarbonization approach outlined in this report.[127] While California has historically been a leader in sustainable building and appliance policy, the increasing support from the Federal government and other jurisdictions (both nationally and globally) will accelerate adoption of this vision.

Decarbonization and Energy Efficiency Workforce

As California heads toward a clean energy future, the workforce making it happen is central to success. Decision makers need information on what skillsets the current workforce provides, what a future workforce will need, and how to achieve what is needed in the workforce to support decarbonization.

122 CEC Load Management Rulemaking (19-OIR-01). https://www.energy.ca.gov/proceedings/energy-commission-proceedings/2020-load-management-rulemaking.

123 CPUC, 2021. IEPR Commissioner Workshop on Grid Interactive Efficient Buildings - Load Flexibility: Demand Response Policies, Programs, and Initiatives. https://efiling.energy.ca.gov/getdocument.aspx?tn=239966.

124 State and Local Energy Efficiency Action Network. 2020. *Determining Utility System Value of Demand Flexibility from Grid-Interactive Efficient Buildings*. Prepared by Tom Eckman, Tom, Lisa Schwartz, and Greg Leventis, Lawrence Berkeley National Laboratory. https://emp.lbl.gov/publications/determining-utility-system-value.

125 Presentation by Carmen Best, "CEC-IEPR Building Decarbonization Workshop." October 5, 2021, IEPR workshop on Grid-Integrated Efficient Buildings. https://efiling.energy.ca.gov/getdocument.aspx?tn=239957.

126 U.S. DOE and LBNL. 2021. *A National Roadmap for Grid-Interactive Efficient Buildings*. https://gebroadmap.lbl.gov/.

127 RMI. 2021. *The Value of Grid Interactive Efficient Buildings*. https://efiling.energy.ca.gov/getdocument.aspx?tn=239959.

The Current Workforce and Training Environment

Decarbonizing California's buildings will require a trained and locally available workforce. 7.5 million workers at the end of 2020 across the electric power generation, fuels, transmission, distribution, and storage, energy efficiency, and motor vehicles sectors, a 10 percent decline year over year.[128] Employment in these sectors grew twice the rate of the general economy prior to the pandemic and investments in infrastructure may help restore growth according to the report. The California Energy and Employment report has found that the energy workforce is roughly 800,000 people and receives around 34 percent higher wages compared to other industries in the United States.[129]

Table 2: California Energy Jobs by Sector – 2019 and 2020

Sector	2019 Employment	2020 Employment
Energy Efficiency	323,529	283,839
Motor Vehicles	221,077	191,315
Electric Power Generation	182,559	169,987
Transmission, Distribution, and Storage	152,204	144,820
Fuels	77,049	66,147

Source: National Association of State Energy Officials and BW Research

128 U.S. DOE. "United States Energy Workforce in 2020: A Snapshot of Key Findings From the 2021 United States Energy and Employment Report." https://www.energy.gov/sites/default/files/2021-07/USEER%202021%20Key%20Findings.pdf.

129 BW Research. 2020. California Energy and Employment Report. Prepared for the CEC and CPUC. https://www.energy.ca.gov/filebrowser/download/2272.

The 2019 University of California, Los Angeles (UCLA), report on *California Building Decarbonization Workforce Needs and Recommendations*[130] highlighted the differences in the workforce for residential retrofits/construction, as opposed to the large commercial, multifamily, and institutional markets. The report showed residential jobs tend to be easier to access but are also price-driven with high turnover rates, while the latter is unionized, well-trained, and relatively stable. In public workshops, Randy Young from Sheet Metal Workers stated that job opportunities are lacking in disadvantaged and underserved communities,[131] while the University of California, Davis (UC Davis), California Lighting Technology Center noted the current workforce is getting older and choosing retirement over retraining.[132]

The 2019 UCLA study further found that decarbonizing and electrifying 100 percent of California's existing and new buildings by 2045 would result in a net increase of 64,200 to 104,100 jobs.[133] The greatest increase in jobs is in the building retrofit and renewable energy construction industries (59,200–100,200 jobs), whereas there is a small decrease of jobs in the gas distribution (6,800–14,400) and labor-saving all-electric new construction (3,100–3,600) industries.[134]The study also found that three out of five jobs would be in "high-road" sectors — positions in which worker pay tends to increase with training and experience. These high-road sectors are large commercial and municipal, university, school and hospital construction, utility employment, and electricity construction and generation. The residential construction sector is forecasted to compose 40 to 47 percent of all construction jobs created;

130 Jones, Betony, Jason Karpman, Molly Chlebnikow, and Alexis Goggans. 2019*. California Building Decarbonization Workforce Needs and Recommendations.* UCLA Luskin Center for Innovation. https://innovation.luskin.ucla.edu/wp-content/uploads/2019/11/California_Building_Decarbonization.pdf.

131 Presentation by Randy Young, "Current and Future Workforce and Training Ecosystems." July 13, 2021, IEPR Commissioner Workshop on Building Decarbonization – Decarbonization and the Workforce, Session 3: Decarbonization and Workforce transcript. https://efiling.energy.ca.gov/getdocument.aspx?tn=239943-3.

132 Presentation by Cori Jackson, "Workforce Development Opportunities and Challenges Related to Building Decarbonization." July 13, 2021, IEPR Commissioner Workshop on Building Decarbonization, Session 3: Decarbonization and Workforce.
https://efiling.energy.ca.gov/GetDocument.aspx?tn=238818&DocumentContentId=72223.

133 Jones, Betony, Jason Karpman, Molly Chlebnikow, and Alexis Goggans. 2019*. California Building Decarbonization Workforce Needs and Recommendations.* UCLA Lushkin Center for Innovation. https://innovation.luskin.ucla.edu/wp-content/uploads/2019/11/California_Building_Decarbonization.pdf.

134 Ibid.

thus, policymakers must ensure that jobs created by residential building electrification follow high-road approaches.[135]

Like many industries, the energy sector was significantly impacted by the COVID-19 pandemic. In 2020, energy sector jobs decreased by roughly 840,000 jobs or 10 percent from 2019 to 2020 across the United States, with energy efficiency losing the largest number of jobs across the five major energy sectors. California alone lost 100,308 energy jobs and was second behind Texas in the greatest number of energy jobs lost. (See Table 2 above for job losses between 2019 and 2020.) Energy job losses were lower than other industries impacted by the pandemic. The California Energy Employment report states that critical investments in infrastructure can reignite job growth in the energy sector which outpaced the overall economy before the pandemic.

Future Workforce Needs

To achieve building decarbonization goals, California will need to have a trained workforce and access for people living in disadvantaged communities and coming from low-income households to be a part of that workforce. Rising Sun's Julia Hatton commented that "green jobs" must provide family-sustaining wages, benefits, career advancement, a voice for the worker, safety, and accessibility. In addition, a successful workforce development program must provide training, career services, case management (removing individual barriers, referrals, housing, and so forth), and wrap-around services (such as stipends, mental health care, and trauma-informed care).[136] High-quality jobs must also receive policy and program support, which is part of Governor Newsom's vision for an equitable economic recovery. These objectives describe what is often referred to as a *high-road job plan*.

Supporting high-road jobs aligns goals for equity, job quality, and sustainability. It treats economic growth, income and wealth equality, and environmental protections as complementary, not contradictory, policies. Neha Bazaj from Emerald Cities Collaborative stated not all jobs are created equal and jobs created to implement decarbonization policies

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135 BW Research. 2020. *California Energy and Employment Report*. Prepared for CEC and CPUC, https://www.energy.ca.gov/filebrowser/download/2272.

136 Presentation by Julia Hatton, "Rising Sun Center of Opportunity." July 13, 2021, IEPR Commissioner Workshop on Building Decarbonization, Session 3: Decarbonization and Workforce. https://efiling.energy.ca.gov/getdocument.aspx?tn=238826.

should be high-road jobs. This creation includes a focus on building diversity, improving labor standards, offering contractor and worker training, and livable wages.[137]

Cori Jackson from the UC Davis Lighting and Technology Center identified that current workforce challenges include new technology coupled with an aging workforce choosing retirement over retraining, integrated systems that require cross-disciplinary knowledge, and lack of computer, programming, and cybersecurity curriculum training within the building trades.[138]

Neha Bazaj from Emerald Cities Collaborative stated that the residential construction sector tends to be more low-road, meaning lower pay and fewer job protections, than the commercial sector.[139] However, residential construction jobs are forecasted to compose 40–47 percent of all construction jobs created. Thus, policy makers must ensure that jobs created by residential building electrification contain high-road pathways.

New Technology Training

Proper workforce training is essential to creating high-road careers and ensuring that equipment is properly installed, and GHG emission reduction goals are achieved. The 2019 UCLA report found that construction work like installing new circuits, plumbing, ductwork, appliances, and increasing electricity generation capacity for new electric demands will constitute a large portion of the jobs generated through electrifying California's building stock.[140] The California Workforce Development Board (CWDB) stated that addressing the quality of work performed and developing skill standards can build consumer confidence and

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137 Presentation by Neha Bazaj, "Economic Inclusion in Residential Building Electrification." July 13, 2021, IEPR Com*missioner Worksh*op on Building Decarbonization, Session 3: Decarbonization and Workforce*.* https://efiling.energy.ca.gov/GetDocument.aspx?tn=238789&DocumentContentId=72194.

138 Presentation by Cori Jackson, "Workforce Development Opportunities and Challenges Related to Building Decarbonization." July 13, 2021, IEPR Commissioner Workshop on Building Decarbonization, Session 3: Decarbonization and Workforce.
https://efiling.energy.ca.gov/GetDocument.aspx?tn=238818&DocumentContentId=72223.

139 Comments by Neha Bazaj with "Emerald Cities Collaborative". July 13, 2021, IEPR Commissioner Workshop on Building Decarbonization, Session 3: Decarbonization and Workforce*.*
https://efiling.energy.ca.gov/getdocument.aspx?tn=239943-3.

140 Jones, Betony, Jason Karpman, Molly Chlebnikow, and Alexis Goggans. 2019*. California Building Decarbonization Workforce Needs and Recommendations.* UCLA Lushkin Center for Innovation.
https://innovation.luskin.ucla.edu/wp-content/uploads/2019/11/California_Building_Decarbonization.pdf.

support market growth of new technologies.[141] The CWDB referred to the California Advanced Lighting Controls Training Program certification requirement for lighting control installation projects as one example of standards that can help achieve energy and environmental goals.

Building decarbonization is also technology-heavy and will require manufacturing jobs to produce new equipment.[142] The UCLA report found that additional specialized training is needed for trades that are heavily involved in building decarbonization: electricians, sheet metal and HVAC workers, and plumbers and pipefitters. The clean energy workforce of the future will also need training on working with heat pumps, handling new low-GWP refrigerants, and changing building practices.

Philip Jordan from BW Research highlighted that professionals require only short training programs to install technologies like heat pumps and electric vehicle battery chargers.[143] A professional HVAC technician can complete training in 3 days for the former technology, and a certified electrician can complete 10-day online training for the latter technology. While training in these new technologies is a relatively low burden for seasoned professionals, pathways should also be created for workers outside these sectors.

Community-Focused Training

Economic transition looks different in all communities, and regional partnerships are necessary to enable communities to develop solutions tailored to their needs. To promote this workforce development, communities, workers, stakeholders and contractors should be engaged early in policy development for input and collaboration.[144] Engaging with community-based organizations offers a partner well-positioned to serve the specific needs of individuals in their communities.[145] When these frontline training organizations have formal agreements with

141 Comment by Shrayas Jatkar of the California Workforce Development Board, moderator of workshop panel "Current and Future Workforce and Training Ecosystem," July 12, 2021, IEPR Commissioner Workshop on Building Decarbonization, Session 3: Decarbonization and Workforce. https://efiling.energy.ca.gov/GetDocument.aspx?tn=238791&DocumentContentId=72196.

142 Ibid.

143 Presentation by Philip Jordan, "Overall Projected Clean Energy Job Creation." July 13, 2021, IEPR Commissioner Workshop on Building Decarbonization, Session 3: Decarbonization and Workforce. https://efiling.energy.ca.gov/GetDocument.aspx?tn=238791&DocumentContentId=72196.

144 Presentation by Neha Bazaj, "Economic Inclusion in Residential Building Electrification." July 13, 2021, IEPR Commissioner Workshop on Building Decarbonization, Session 3: Decarbonization and Workforce*.* https://efiling.energy.ca.gov/GetDocument.aspx?tn=238789&DocumentContentId=72194.

145 Jones, Betony, Jason Karpman, Molly Chlebnikow, and Alexis Goggans. 2019. California Building Decarbonization Workforce Needs and Recommendations*.* UCLA Lushkin Center for Innovation. https://innovation.luskin.ucla.edu/wp-content/uploads/2019/11/California_Building_Decarbonization.pdf.

employers, agencies, and apprenticeship programs, better job training and placement outcomes are achieved.

SMUD points to the "Earn and Learn" program as a model that brings training and awareness to communities where workers can participate and benefit from upcoming job opportunities. These types of programs combine learning in the workplace with paid wages, which allow workers to gain relevant experience and develop skills and competencies that are needed to reach building decarbonization goals.[146]

Diversity

Current clean energy workforce demographics fail to represent the diversity of the state. According to the 2021 United States Energy Employment Report, 26 percent of workers in the fuels sector were female as compared to the national workforce average of 48 percent.[147] In this sector, 8 percent of workers were Black or African American compared to the national workforce average of 13 percent.[148] Women were underrepresented by varying degrees in all energy sectors examined, and Black or African American workers were underrepresented in three of the five sectors examined.[149]

Experts provided comments on how diversity can be improved in the building and clean energy workforce. Possible actions to increase diversity include aggregating projects, specifically focusing on workforce within disadvantaged communities, improving gender diversity in the building trades, and developing a database of small, minority- and women-owned contractors.[150] Other methods of increasing workforce diversity include exposing minority workers to jobs in the energy sector.[151] The California Community College system reflects California's diversity, has a strong presence in vocational trades, and can help increase

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146 Sacramento Municipal Utility District comments on the July 13, 2021, IEPR Commissioner Workshop on Building Decarbonization and Workforce. TN 239579. Docket 21-IEPR-06. https://efiling.energy.ca.gov/GetDocument.aspx?tn=239579.

147 NASEO and EFI. *2021 U.S. Energy and Employment Report*. p. 13. https://www.energy.gov/sites/default/files/2021-07/USEER%202021%20Main%20Body.pdf.

148 Ibid.

149 Ibid.

150 Presentation by Neha Bazaj, "Economic Inclusion in Residential Building Electrification." July 13, 2021, IEPR Commissioner Workshop on Building Decarbonization, Session 3: Decarbonization and Workforce. Transcript https://efiling.energy.ca.gov/GetDocument.aspx?tn=238789&DocumentContentId=72194.

151 Jones, Betony, Jason Karpman, Molly Chlebnikow, and Alexis Goggans. 2019. *California Building Decarbonization Workforce Needs and Recommendations*. UCLA Luskin Center for Innovation. https://innovation.luskin.ucla.edu/wp-content/uploads/2019/11/California_Building_Decarbonization.pdf.

equitable access to employment. The Public Policy Institute of California's 2021 report *Improving Career Education Pathways into California's Workforce* found that Black and Latino students, younger students, and men are less likely to complete a college credential. It also found that few students complete a second credential after reenrolling at a community college.[152] These findings suggest that additional support needs to be provided to disadvantaged groups and students seeking to complete a stackable credential.

Getting to an Expanded, Just, Equitable, and Well-Trained Workforce

To get to a clean energy workforce that is diverse, is well-trained, receives a living wage, and includes communities traditionally excluded from participation, California could take potential actions presented in recent research and shared by panelists and commenters at the IEPR workshop on Decarbonization and Workforce, such as:

- Bringing in a more diverse set of workers to fill in for the currently aging workforce.
- Partnering with Minority-Serving Institutions, vocational and technical schools, K-12 schools and school districts, and other community-based organizations that can inform and co-develop workforce development and diversity strategies in local communities.[153]
- Developing contractor standards that require outreach and hiring from disadvantaged communities, enact policies that protect contractors and unions paying workers living wages, and continue apprenticeship programs to ensure workers develop necessary skills — suggested by Randy Young from Sheet Metal Workers.[154]
- Providing career and mentoring opportunities to new entrants to the energy workforce and incumbent workers so they have guidance as they start their career and can

152 McConville, S., S. Bohn, B. Brooks, and M. Dadgar. 2021. *Improving Career Education Pathways into California's Workforce*. Public Policy Institute of California. https://www.ppic.org/wp-content/uploads/improving-career-education-pathways-into-californias-workforce-july-2021.pdf.

153 NASEO. *Energy Sector Workforce Diversity, Access, Inclusion, and the Policy Case for Investment: Recommendations for State Energy Office Action*. https://www.naseo.org/Data/Sites/1/documents/tk-news/workforce-diversity-report_final2%5B2%5D.pdf.

154 Presentation by Randy Young, "Current and Future Workforce and Training Ecosystems." July 13, 2021, IEPR Commissioner Workshop on Building Decarbonization, Session 3: Decarbonization and Workforce. https://efiling.energy.ca.gov/GetDocument.aspx?tn=238787&DocumentContentId=72192.

maximize their potential, as demonstrated by Rising Sun during their IEPR workshop presentation.[155]

- Close collaboration among the state, associations of community-based organizations, labor unions, utilities, and community colleges are necessary to create energy sector pathway opportunities and minimize job losses due to decarbonization.[156]
- Relevant agencies should set terms and conditions on loans, grants, and investments to promote positive labor market outcomes and create public benefits, according to Shrayas Jatkar from CWDB.[157]
- Engaging unions, local building trades councils, and Labor Management Cooperation Committees to develop high-road jobs and minimize job loss.[158]
- Establishing workforce standards for programs and policies.[159]
- Conditioning rebates and incentives for electrification on skill standards or responsible contractor criteria to attract high-performing contractors, ensure work quality, and prevent wage and labor law violations common in the residential construction market.[160]
- The state should guide investments to small businesses in underserved communities as part of workforce development efforts. This will ensure that all communities can participate and benefit from the economic growth of building decarbonization, according to SMUD.[161]

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155 Presentation by Julia Hatton, "Rising Sun Center of Opportunity." July 13, 2021, IEPR Commissioner Workshop on Building Decarbonization, Session 3: Decarbonization and Workforce. https://efiling.energy.ca.gov/getdocument.aspx?tn=238826.

Rising Sun is a California nonprofit working on climate resilience and economic equity in the Bay Area and San Joaquin County. https://risingsunopp.org/.

156 Jones, B., J. Karpman, M. Chlebnikow, and A. Goggans. 2019. *California Building Decarbonization: Workforce Needs and Recommendations*.

157 July 13, 2021, IEPR Commissioner Workshop on Building Decarbonization – Decarbonization and the Workforce, Session 3 transcript. https://efiling.energy.ca.gov/getdocument.aspx?tn=239943-3.

158 Jones, B., J. Karpman, M. Chlebnikow, and A. Goggans. *2019 California Building Decarbonization: Workforce Needs and Recommendations*. https://innovation.luskin.ucla.edu/wp-content/uploads/2019/11/California_Building_Decarbonization-Executive_Summary-1.pdf.

159 Ibid.

160 Ibid.

161 SMUD comments on the July 13, 2021, IEPR Commissioner Workshop on Building Decarbonization and Workforce. TN 239579. Docket 21-IEPR-06. https://efiling.energy.ca.gov/GetDocument.aspx?tn=239579.

CHAPTER 3:
Residential and Commercial Building Decarbonization

Residential and commercial buildings are responsible for about a quarter of greenhouse gas (GHG) emissions in the state.[162] Fossil gas is widely used in both sectors and presents a major obstacle in reducing GHG emissions as the GHG intensity of the electricity system continues to drop. To help inform deployment at the scale needed to achieve deep GHG emission reductions, this chapter reviews:

- The current equipment landscape.
- The costs of decarbonizing existing buildings and constructing new buildings.
- Energy affordability challenges.
- Ongoing research and development.
- Challenges experienced in the equipment supply chain and manufacturers and distributors.

Decarbonization in Residential Buildings

The residential sector in California accounts for 6.1 percent of GHG emissions,[163] predominantly from space and water heating. To double energy efficiency savings by 2030 and reach midcentury climate goals, major changes in the type of equipment installed and used in homes are needed. The 2021 *California Building Decarbonization Assessment* shows that mass deployment of heat pumps for space and water heating is required for deep GHG reductions.[164] Table 3**Error! Reference source not found.** compares average rates of emissions and costs for a selection of end uses.

162 CARB. 2020-2019 GHG Inventory webpage. https://ww2.arb.ca.gov/ghg-inventory-data.

163 Ibid.

164 Kenney, Michael, Nicholas Janusch, Ingrid Neumann, and Mike Jaske. 2021. *California Building Decarbonization Assessment*. California Energy Commission. Publication Number: CEC-400-2021-006-CMF. https://efiling.energy.ca.gov/GetDocument.aspx?tn=239311.

Table 3: Estimated Electrification Equipment Emissions and Costs

Category/ Fuel Type (percent saturation)	**Nameplate Energy Factors**	**Annual Emissions (lbs. CO_2)**	**Annual Operating Costs**	**Up-Front Appliance Costs**
Cooking				
Gas Range/Oven (60)	5k/18.5k Btu	245 - 292	\$32 - \$39	\$1000 - \$2000
Elec. Radiant Cook Top/Oven (28)	1900 W	156 - 282	\$59 - \$93	\$700 - \$900
Elec. Induction Cook Top/Oven (no data)	1476 W	157 - 282	\$45 - \$72	\$2000 - \$3200
Clothes Drying				
Gas Dryer (36)	3.48 CEF	292 - 408	\$39 - \$55	\$700 - \$1000
Electric Dryer (32)	3.93 CEF	49 -61	\$127 - \$157	\$800 - \$1000
Heat Pump Dryer (no data)	5.2 CEF	17 - 18	\$45 - \$47	\$1300 - \$1750
Central HVAC				
Gas Furnace (63)	96 AFUE	1,178 - 2,356	\$157 -\$315	\$2800 - \$4600
Air Conditioner, Split 3.5 ton (70)	18 SEER	90 - 100	\$235 - \$260	\$3300 - \$4300
Heat Pump, Split 3.7 ton (0)	18 SEER 10 HSPF	48 - 103	\$125 - \$267	\$5500 - \$6100
Water Heating				
Gas Storage (65)	0.73 UEF	2,426 - 3,009	\$324 - \$402	\$800 - \$1000
Electric Storage (9)	0.93 UEF	404 - 531	\$1049 - \$1380	\$510 - \$830
Heat Pump Storage (no data)	3.45 - 3.75 UEF	82 - 119	\$213 - \$309	\$1,500 - \$1,700

Notes: Up-Front costs for Central HVAC include installation.

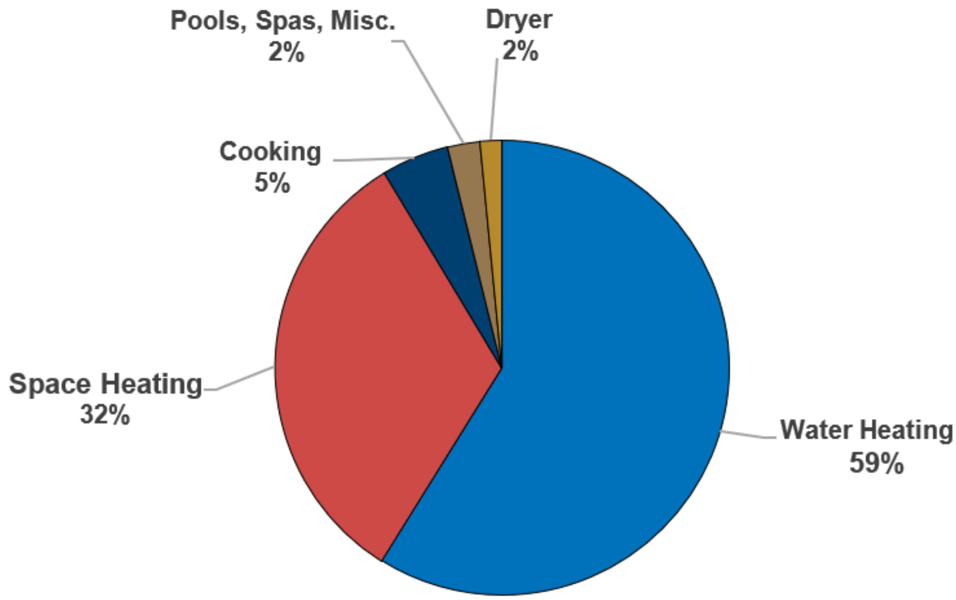
Sources: Percent saturation from 2019 RASS. Annual emissions from U.S. EPA GHG Equivalencies Calculator.

Credit: CEC staff compiled from multiple sources

Gas Equipment Saturation

As of the *2019 Residential Appliance Saturation Study* (RASS),[165] gas consumption in homes is 59 percent water heating, 32 percent space heating, and 5 percent cooking (Figure 14).[166] The remaining home gas appliances account for around 4 percent of total gas use, which includes clothes dryers, fireplaces, and pool or spa heaters.

Figure 14: 2019 Residential Gas End Use Unit Energy Consumption



Source: DNV GL Energy Insights USA, Inc. 2020. CEC, RASS.

The most common gas appliances are also the largest consumers of gas. A complete breakdown of gas use and equipment penetration across single-family, multifamily, and mobile homes is shown in Table 4.

165 The California Residential Appliance Saturation Study (RASS) is a comprehensive study of residential sector energy use. The California Home Energy Survey is the primary data source for the RASS. For more information, see https://www.energy.ca.gov/data-reports/surveys/2019-residential-appliance-saturation-study.

166 Palmgren, Claire, Miriam Goldberg, Ph.D., Bob Ramirez, Craig Williamson, and DNV GL Energy Insights USA, Inc. 2019. *2019 California Residential Appliance Saturation Study*. California Energy Commission. Publication Number: CEC-200-2021-005. https://www.energy.ca.gov/publications/2021/2019-california-residential-appliance-saturation-study-rass.

Table 4: Gas Unit Energy Consumption (UEC) and Appliance Saturation by Dwelling Type

	Single-Family UEC	Single-Family Saturation of Homes with Gas Data	Multifamily UEC	Multifamily Saturation of Homes with Gas Data	Mobile Home UEC	Mobile Home Saturation of Homes with Gas Data
Household Total UEC	443	17,269 homes	241	5,999 homes	300	338 homes
Primary Heat	191	83%	67	63%	136	73%
Auxiliary Heat	59	2%	43	3%	37	<1%
Water Heating	260	94%	252	69%	257	85%
Solar Water Heat	184	<1%	166	0%	174	<1%
Dryer	12	53%	18	28%	17	35%
Range/Oven	25	77%	23	71%	20	82%
Pool Heating	163	5%	178	1%	181	1%
Spa Heating	38	8%	28	1%	38	<1%
Miscellaneous	17	12%	18	6%	27	5%
Household Total UEC for All Homes with Gas Service	434		226		324	

Source: DNV GL Energy Insights USA, Inc. 2020. CEC, *RASS*.

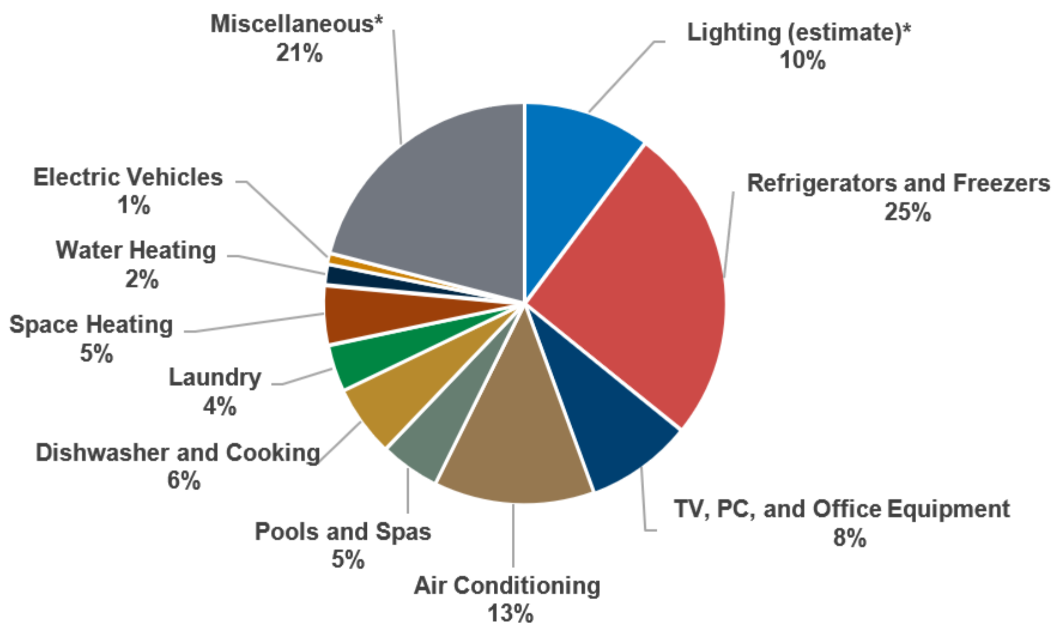
The RASS estimated that statewide, 77 percent of homes use gas for heating, 86 percent use gas for water heating, and 75 percent use gas for cooking. Looking at the type of home, gas use is about 200 therms higher in single-family homes than multifamily units. The biggest contributor to this difference comes from lower gas use for space heating in multifamily units. Another difference is gas water heating, which is 25 percent higher in single- versus multifamily homes (94 percent single-family to 69 percent multifamily). However, a substantial number of apartments and condominiums lack individual water heating. These two differences highlight the nuanced approached to decarbonization that must be taken when dealing with single-family versus multifamily homes. Mobile homes fall in between single-family and multifamily units in terms of gas equipment saturation and use. Regardless of subsector, the same primary end uses must be addressed: space heating, water heating, and cooking.

One challenge decarbonization programs face today is the customer preference for tankless gas water heating. Utility programs show that well over 50 percent of water heater changeouts are from tank to tankless gas. The tankless gas water heaters have an effective useful life of around 20 years. Less than 1 percent of gas equipment switched to electric during the 2019 program cycle.[167] The opportunity to convert gas tank water heaters to electric is still present as the RASS shows more than 71 percent of single-family and 37 percent of multifamily homes have tank water heaters.

Electric Equipment Saturation

Homes in California consume electricity across dozens of different end uses. Most consumption powers refrigeration and freezers (25 percent), air conditioning (13 percent), lighting (10 percent), and computers, televisions, and office equipment (8 percent) as shown in Figure 15. There are also differences between single-family and multifamily homes in energy usage. The 2019 RASS estimated single-family homes consume more electricity than other residences. Some of the common appliances that drive this increase are space heating, air conditioning, and water heating.

Figure 15: 2019 Electricity Usage by End Use



Source: DNV GL Energy Insights USA, Inc. 2020. CEC, *RASS*.

167 DNV GL and NMR Group Inc. on behalf of the CPUC. 2019. *Impact Evaluation of Water Heating Measures Residential Sector – Program Year 2019*. http://calmac.org/publications/CPUC_Group_A_Report_Water_Heating_PY_2019_Final_CALMAC.pdf.

Today, homes have low penetration of electric water heating (6 percent) and heat pump space conditioning (4 percent), and fewer than half of homes have electric cooking (47 percent). The 2019 RASS also showed that primary electric space heating saturations in single-family and multifamily homes have changed very little compared to the 2003 and 2009 studies, although the penetration of electric space heating becomes greater the larger the size of the multifamily building. Electric water heating saturation decreased slightly from the 2003 and 2009 study. Electric dryer saturation increased slightly for single family and multifamily homes. Electric range and oven saturation increased as well although more noticeably in the multifamily homes.

The RASS reported that the age of central air conditioners varies, but more than 50 percent are 9 years or older. This finding presents a decarbonization opportunity if the replacement of these units coincides with electrification of space heating as well.

Costs of Residential Decarbonization

To reach midcentury climate goals, both newly constructed buildings and existing buildings need to take advantage of efficient electric equipment. The *California Building Decarbonization Assessment* estimated the marginal abatement cost[168] for various electrification measures of new and existing buildings of -$17 for heating, ventilation, and air conditioning (HVAC); $96 for water heating; and $592 for other appliances in the moderate electrification scenario.[169] Within newly constructed buildings, there are potential cost savings to builders and buyers by going all-electric. Building retrofit costs will vary because of the diversity of the building stock and climate zones.

New Construction

In developing the 2022 Energy Code heat pump measures, the California Energy Commission (CEC) found that heat pump space conditioning and water heating equipment cost less than the equivalent gas equipment in single-family homes.[170] Table 5 summarizes the cost comparison over a 30-year period. The table does not include costs that are constant across

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168 *Marginal abatement cost* measures the costs and savings of reducing, in this case, carbon dioxide equivalent (CO2e) emissions.

169 Marginal abatement costs include the annualized incremental technology costs over the life of the equipment and the operational fuel costs (or savings) of using the equipment.

Kenney, Michael, Nicholas Janusch, Ingrid Neumann, and Mike Jaske. 2021. *California Building Decarbonization Assessment*. CEC. Publication Number: CEC-400-2021-006-CMF. https://efiling.energy.ca.gov/GetDocument.aspx?tn=239311.

170 CEC. 2022 Energy Code Update Rulemaking. July 2021. Docket 21-BSTD-01. https://efiling.energy.ca.gov/GetDocument.aspx?tn=238850&DocumentContentId=72258.

the base case and proposed scenario, such as refrigerant piping, ducting, and maintenance. The costs also do not include labor for system installation. Labor costs for installing two systems such as an air-conditioning system and a gas-fired furnace would likely be greater than installing a single heat pump system.

Table 5: Average Per Home Costs for HVAC System

Item	Air Conditioner with Gas Furnace	Heat Pump	Incremental Cost for Heat Pump
HVAC Equipment	$2,582	$2,275	($307)
Gas Piping	$200	$0	($200)
Flue and Pad	$350	$0	($350)
Electrical circuits	$0	$150	$150
Replacement	$2,050	$2,275	$225
Total	$5,182	$4,700	($482)

Note: Single-Zone Air Conditioner with Gas Furnace Compared to Single-Zone Heat Pump – New Construction

Source: CEC

These costs include data from distributors of different brands of space-conditioning equipment.[171] Across the three brands, the proposed heat pump space-conditioning system ranged from $125 to $441 less than the baseline of installing an air conditioner with gas furnace. Costs not applicable to heat pump systems include gas piping to the appliance and an exhaust flue from the appliance. The cost of gas piping is assumed at $200 per gas appliance and flue costs are $350 per home, based on conservative estimates collected through interviews with mechanical contractors and designers.[172] Heat pumps require an additional 240-volt, 20-amp circuit for electric resistance backup at an estimated $150 cost.

For single-family domestic water heating, CEC analysis shows that a heat pump water heater (HPWH) is less expensive over a 30-year period than instantaneous gas water heating.[173] Though water heater equipment and replacement costs for the HPWH are greater, savings for

171 Cost data for three brands for which there was information for a 14 SEER air conditioner with 0.80 AFUE furnace were used as the baseline system, excluding cost data for higher-efficiency furnaces. The proposed system was a single-zone 14 SEER, 8.2 HSPF heat pump system.

172 Ibid.

173 City of Palo Alto 2019 Title 24 Energy Reach Code Cost Effectiveness Analysis

Equipment costs were updated with 2021 Home Depot and supplyhouse.com data. Supplyhouse.com webpage, https://www.supplyhouse.com/.

installation, exhaust flue, and maintenance result in a total cost savings of $186. Instantaneous gas water heaters require regular chemical flushing every two years to remove mineral buildup and cleaning of inducer fan motors at an estimated cost of $205 per occurrence. HPWHs do not require maintenance from a professional service provider. Table 6 summarizes the costs for the base case instantaneous gas water heater and proposed HPWH over a 30-year analysis period.

Table 6: Average Per Home Costs for Domestic Hot Water System

Item	Instantaneous Gas Water Heater	HPWH	Incremental Cost of HPWH
Water Heater	$1,306	$1,370	$64
Installation	$1,017	$945	($72)
Gas Piping	$200	$0	($200)
Flue	$313	$0	($313)
Electrical	$331	$500	$169
Replacement	$1,162	$2,315	$1,153
Maintenance	$1,979	$0	($1,979)
Total	$6,308	$5,130	($1,178)

Note: Instantaneous Gas Water Heater Compared to Heat Pump Water Heater

Source: CEC staff

Analysis done in support of the utility codes and standards program found the cost of a new single-family, all-electric home is $3,000 to $30,000 less than a mixed-fuel home.[174] Most of the cost savings are due to avoided gas infrastructure. Similarly, a 2019 Study found that the capital costs to build all-electric single-family homes are several thousand dollars less expensive than mixed-fuel homes. The capital costs per unit to build all-electric multifamily buildings were also several thousand dollars cheaper everywhere except in Climate Zone 3 (San Francisco). [175]

174 Prepared by Frontier Energy for the PG&E Codes and Standards Program. 2019 Energy Efficiency Ordinance Cost-Effectiveness Study: Low-Rise Residential. August 2019. p. 16. https://efiling.energy.ca.gov/GetDocument.aspx?tn=234020-6&DocumentContentId=66846.

175 E3. *Residential Building Electrification in California: Consumer Economics, Greenhouse Gases and Grid Impacts*. April 2019. https://www.ethree.com/wp-content/uploads/2019/04/E3_Residential_Building_Electrification_in_California_April_2019.pdf.

Cost savings in multifamily buildings are more complex but may yield substantial savings when compared with traditional mixed-fuel buildings.[176] Analysis done for the IOU Codes and Standards program indicates the lifetime costs for all-electric new multifamily units are negative; thus, they are cheaper to operate than a mixed-fuel unit.[177]

Multifamily buildings were also evaluated as part of the 2022 Energy Code development for heat pump measures[178]. Table 7 summarizes the HVAC system total installed cost per dwelling unit in a multifamily building and compares a split system air conditioner paired with a gas furnace against different types of heat pump systems. The analysis was done for multiple building prototypes. The installed cost includes the equipment and materials, labor, and soft costs such as overhead, markup, design, and permitting costs.

Heat pump systems are less expensive to install than the baseline split system air conditioner with gas furnace, both due to lower equipment cost as well as lower labor costs. This is because the baseline system includes two separate devices, a split DX cooling system and a gas-fired furnace heating system, whereas the proposed system is a single system that provides both cooling and heating. Additionally, unlike single family residential buildings, there are limitations to where a gas furnace can be placed in multifamily buildings due to constraints on open combustion devices and the need for venting. Therefore, the installation costs for a both gas furnace and air conditioner are higher in multifamily buildings than in single family. The baseline system costs account for gas piping to the gas furnace, whereas the single zone heat pump system costs account for additional electrical capacity. The gas piping costs are for gas pipelines from the building main meter to individual gas furnaces serving each dwelling unit and do not include cost savings from eliminating the gas infrastructure to the building.

For all scenarios modeled, the proposed heat pump system costs less than the baseline split system air conditioner with gas furnace.

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176 Prepared by Frontier Energy for the PG&E Codes and Standards Program. August 2019. *2019 Energy Efficiency Ordinance Cost-Effectiveness Study: Low-Rise Residential*. p. 16. https://efiling.energy.ca.gov/GetDocument.aspx?tn=234020-6&DocumentContentId=66846.

177 Ibid.

178 CEC. 2022 Energy Code Update Rulemaking. May 2021. Docket 21-BSTD-01. https://efiling.energy.ca.gov/GetDocument.aspx?tn=237692&DocumentContentId=70915.

Table 7: Average Per Dwelling Unit Installed Costs for HVAC System: Split System Air Conditioner with Gas Furnace Compared to Heat Pump

Building Prototype, Heat Pump Type	Installed Cost – Baseline Split System with Gas Furnace	Installed Cost – Proposed Heat Pump System described in Building Prototype	Incremental Cost per Dwelling Unit
2-story Garden Style, Single-Zone Heat Pump	$20,750	$14,018	($6,732)
3-story Loaded Corridor, Single-Zone Heat pump	$22,516	$16,368	($6,118)
5-story Mixed Use, Single-Zone Heat Pump	$22,405	$15,371	($7,034)
10-story Mixed Use, Single-Zone Heat Pump	$22,435	$15,304	($7,131)
5-story Mixed Use, Ductless Mini-split Heat Pump	$22,405	$19,802	($2,604)
10-Story Mixed Use, Ductless Mini-split Heat Pump	$22,435	$19,102	($3,332)
5-story Mixed Use, Variable Refrigerant Flow Heat Pump	$22,405	$17,606	($4,800)
10-story Mixed Use, Variable Refrigerant Flow Heat Pump	$22,435	$17,008	($5,427)

Source: CEC

Existing Building Retrofits

The costs of retrofitting existing homes can vary greatly depending on the scale of the retrofit and barriers to electrification. There are four levels of effort to consider when planning a retrofit: equipment, building infrastructure, distribution system, and operating costs.

1. **Low- or zero-emission equipment**: Installation of equipment includes costs for new zero-emissions appliance(s), required ducting or system material, labor, permitting, and disposal fees.
2. **Building infrastructure**: Building infrastructure upgrades include costs for service panel replacement, new wiring and material, plumbing, structure, and permitting. These upgrade costs are contingent on the panel capacity to accommodate added load from converted fossil fuel equipment to electric. One CPUC study showed that at least 65 percent of existing buildings would need some type of infrastructure upgrade (wiring, plumbing, or electrical panel upgrades) to install a heat pump water heater. Further, 90 percent of building owners indicated that they would make such a change out only when existing equipment failed or was near end of life.[179]

   Existing homes built before 1990 may require structural rehabilitation or weatherization measures before installing new low- or zero-carbon equipment. The costs vary according to building type and vintage and equipment choices.

   Most homes built prior to 1990 have service panels with 100-amp capacity or smaller that may need to be replaced. Research conducted on behalf of the CPUC found that nearly 20 percent of heat pump water heater projects funded by investor-owned utility (IOU) incentives required electric panel upgrades.[180] Additionally, nearly 65 percent of projects incurred additional costs for wiring and plumbing. According to SMUD, fuel switching a storage water heater from gas to electric adds about $500 due to added wiring and installing a condensate drain.[181] The costs to rewire an entire single-family home range between $500 and $2,200 based on variables such as labor, permitting requirements, and materials.[182]

   However, space conditioning heat pump systems are a different situation. A heat pump system can provide space heating and cooling to a home. The highest efficiency systems include demand-flexible controls that conserve energy for customers and

179 Sadhasivan, Getachew, Trapp, Abraham. 2021. *Impact Evaluation of Water Heating Measures - Residential Sector - Program Year 2019*. CPUC. CALMAC ID: CPU0233.01, p. 9. http://www.calmac.org/publications/CPUC_Group_A_Report_Water_Heating_PY_2019_Final_CALMAC.pdf.

180 DNV and NMR Group Inc. on behalf of the CPUC. 2019. *Impact Evaluation of Water Heating Measures – Residential Sector – Program Year 2019*. http://calmac.org/publications/CPUC_Group_A_Report_Water_Heating_PY_2019_Final_CALMAC.pdf.

181 "SMUD Residential Electrification Projects Costs." September 2020. https://efiling.energy.ca.gov/Lists/DocketLog.aspx?docketnumber=19-DECARB-01.

182 Cutrona, Salvatore. "Electrical Wiring Cost." March 2021. *Home Advisor*. https://www.homeadvisor.com/cost/electrical/install-electrical-wiring-or-panel/.

provide grid benefits. Thus, it provides an overall cost advantage of about $3,000[183] when compared to replacing a combined gas furnace and split air-conditioning systems.

In cases where building infrastructure upgrades are required, this cost advantage would diminish substantially. Average service panel upgrades costs range from $2,744 and $4,256 throughout California.[184] Replacing service panels requires relocating old circuits to the new panel before it is energized. It can also take weeks before the utility is available to come and switch the supply from the old panel to the new one forcing consumers to possibly choose between timeliness and reducing GHG emissions. All these factors contribute to making infrastructure a barrier to all-electric conversion.

3. **Distribution System**: Electrical distribution upgrades include costs for electrical hardware, wiring, and material across distribution circuits. As the electric grid undergoes transformation from a centralized, fossil-fuel-powered system toward a grid that is dynamic with zero-emissions, the distribution system will require investment in upgraded equipment. Historically, the cost of equipment upgrades to the distribution system are passed through to customers as part of their retail electricity rate. As residential zero-emissions retrofits drive an increase in on-site electrical appliances, retail rates will reflect the system upgrades required to support these load changes. These distribution upgrades become necessary investments to promote a zero-emissions future. The CEC noted the potential for infrastructure and rate cost impacts in the *California Building Decarbonization Assessment*: "The significant increases in demand caused by building decarbonization will likely necessitate additional investment in distribution and transmission infrastructure compared to what is already planned for the base load forecast. For transmission costs, avoided capacity costs developed for the avoided cost calculator were used. These provide a cost per kilowatt (kW) of load growth that can be applied to demand forecast scenarios to estimate incremental revenue requirements."[185]
4. **Operating Costs:** The cost of operating the new equipment must also be considered by the consumer. Replacing gas equipment for electric equivalents may result in

183 E3. April 2019. Residential Building Electrification in California: Consumer Economics, Greenhouse Gases and Grid Impacts. https://www.ethree.com/wp-content/uploads/2019/04/E3_Residential_Building_Electrification_in_California_April_2019.pdf.

184 Ibid.

185 Kenney, Michael, Nicholas Janusch, Ingrid Neumann, and Mike Jaske. 2021. California Building Decarbonization Assessment. CEC. Publication Number: CEC-400-2021-006-CMF. Chapter 4, "Electricity Price Impacts," p. 78. https://efiling.energy.ca.gov/GetDocument.aspx?tn=239311.

increased utility bills. As discussed in chapter 1, electricity rates are expected to increase moving forward which adds to this concern.

Decarbonization for Low-Income Households

Low-income households face additional barriers to decarbonization compared to middle- and high-income households. These barriers include greater energy burden,[186] poorer housing conditions, lack of access to capital, potential lack of access to programs, and lack of control of the decision if they rent. Together, these barriers create a high bar that must be reached to participate in decarbonization.

Energy Burden

Low-income residents face growing energy burden, that is, a significant portion of their income goes to energy costs. Nearly one in three United States households face some form of energy insecurity, or risk of disconnection.[187] Figure 16 breaks down the energy burden in California counties as of 2018, highlighting that inland and rural areas see higher rates of burden. The *2019 Annual Affordability Report*[188] found that roughly 11.2 percent of low-income households in California spend more than 35 percent of their disposable income on *bundled services* — electricity, gas, water, and communications services combined.[189] The report also found that areas with the highest service costs tend to have relatively low incomes. The map below shows the average energy burden across California counties. While this does not show the impacts to low-income communities within a given county, it is clear the inland and mountainous portions of the state have higher energy burden than the coastal regions. Even within coastal communities, the energy burden experienced by low-income households is often three times greater than non-low-income households.

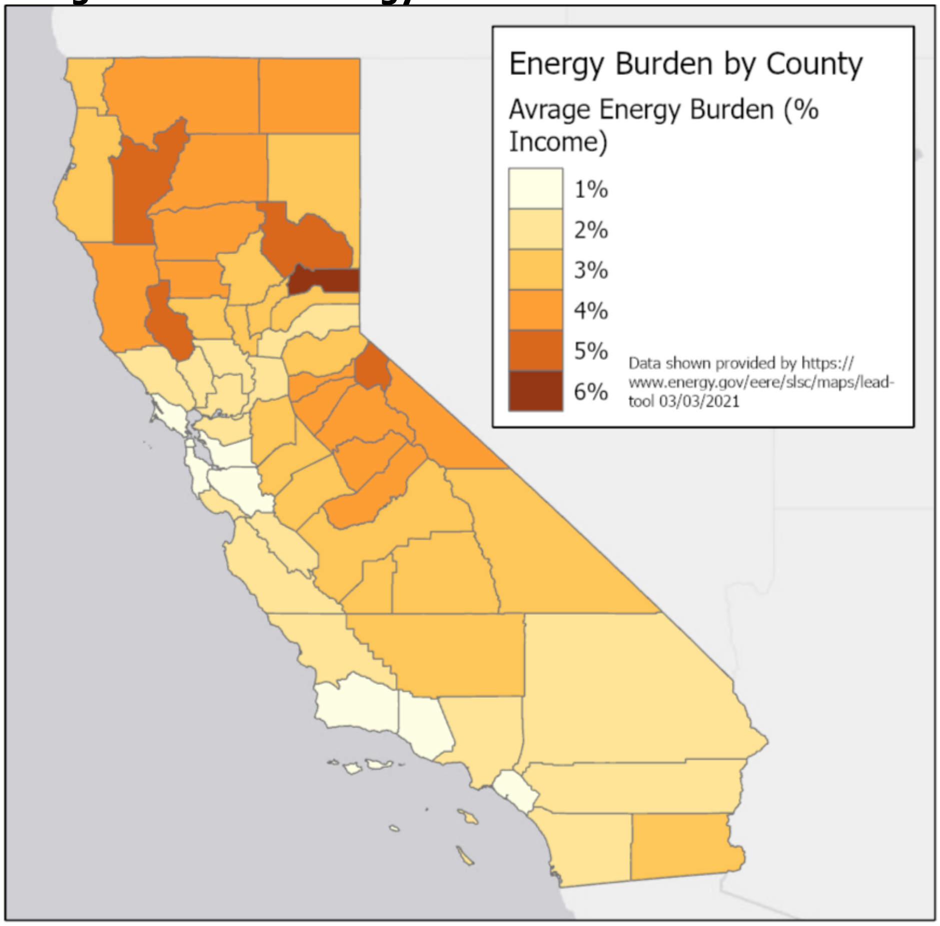
186 *Energy burden* refers to the percentage of household income spent on energy costs.

187 Berry, Chip, Carolyn Hronis, and Maggie Woodward. "One in Three U.S Households Faces a Challenge in Meeting Energy Needs." Energy Information Administration. 2018. https://www.eia.gov/todayinenergy/detail.php?id=37072.

188 Jain, Ankit, Bridget Sieren-Smith, Jefferson Hancock, Jeremy Ho, and Wylen Lai. *2019 Annual Affordability Report*. April 2021. https://www.cpuc.ca.gov/-/media/cpuc-website/industries-and-topics/reports/2019-annual-affordability-report.pdf.

189 Low-income households are defined as households at the twentieth percentile of the regional income distribution. The twentieth percentile was selected for analysis in this report because it represents households that are low-income, but do not qualify for assistance programs like the California Alternate Rates for Energy (CARE) program.

Figure 16: 2018 Energy Burden in California Counties



Source: Low-Income Energy Affordability Data Tool Map Export. https://www.energy.gov/eere/slsc/maps/lead-tool.

Future iterations of the California Public Utilities Commission's (CPUC's) *Annual Affordability Report* will investigate the extent to which assistance programs such as the California Alternate Rates for Energy (CARE) and Family Electric Rate Assistance (FERA) programs are being effectively used in areas where low-income households spend a high portion of their disposable income on essential services. The report also encourages the CPUC to use the affordability metrics of the report to identify regions for targeted assistance as well as the previously identified disadvantaged communities.

Further, CPUC staff at the CPUC's Rates and En Banc Hearing on June 10, 2021, estimated annual energy increases of 3.5 to 4.7 percent for 2021–2030.[190] This financial picture shows the challenge of low-income households to pay for rent, buy groceries, pay bills, let alone to invest in energy-saving measures. Further, moderate- or middle-income residents do not necessarily have disposable income to invest in energy projects. Decarbonization policy and financing solutions must recognize the financial constraints households face.

Research and Development

The CEC is funding research and development projects in residential buildings that focus on improving their efficiency and reducing GHG emissions. These projects include advancing building envelope technologies, improving the efficiency of major energy using systems, and using low-global-warming potential refrigerants in mechanical systems.

- **Improving building envelopes**: This research aims to advance envelope measures to minimize technology and implementation costs while reducing heating and cooling energy use and costs for building occupants. One such project is researching the benefits of triple-pane windows in retrofit situations that can reduce energy use and increase comfort for occupants of multifamily and single-family homes.[191]
- **Advancing energy efficiency**: Research has focused on implementing and demonstrating technologies or combinations of technologies to maximize energy savings and cost-effectiveness and reduce greenhouse gas emissions. Examples include evaluating cost-effective bundles of efficiency measures for existing low-income multifamily homes[192] and testing next-generation air-conditioning systems tailored to California's climate.[193]
- **Demonstrating use of low-GWP refrigerants**: Reducing hydrofluorocarbon (HFC) emissions is essential for the success of building decarbonization. Current commonly used refrigerants, such as R-410A or R-134a have global warming potentials of 2,088 and 1,410, respectively based on the IPCC's Fourth Assessment Report. One research

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190 Jain, Ankit, Bridget Sieren-Smith, Jefferson Hancock, Jeremy Ho, and Wylen Lai. April 2021. *2019 Annual Affordability Report*. https://www.cpuc.ca.gov/-/media/cpuc-website/industries-and-topics/reports/2019-annual-affordability-report.pdf.

191 EPC-19-033, https://www.energy.ca.gov/filebrowser/download/730.

192 EPC-15-053, https://www.energizeinnovation.fund.

193 EPC-14-021, https://www.energizeinnovation.fund.

project is testing low-GWP ammonia and carbon-dioxide-based heat pumps in multifamily and small commercial spaces.[194]

- **Reducing fossil gas use:** The CEC is also funding projects to reduce gas use in buildings through use of solar thermal technologies or measures to improve operational efficiencies, especially in buildings with central plants.
- **Testing and demonstrating novel electric technologies**: Most HVAC and water-heating systems in both single-family and multifamily residential buildings use gas. Research projects have focused on solutions that reduce the cost of deployment of decarbonization measures. Examples include large capacity central heat pump water heaters,[195] combination HVAC and water heating systems, and improved air-to-air heat pumps with high-efficiency heat exchangers that use low-GWP refrigerants.[196]
- **Low-income and disadvantaged communities**: The CEC's research program supports several efforts to address some of the challenges of decarbonizing the low-income housing sector. These efforts include overcoming the need for panel upgrades to achieve electrification of HVAC and water-heating systems, maintaining or improving occupant comfort, and ensuring housing and energy services are affordable. For instance, one research project is demonstrating advanced envelope and efficiency improvements in all-electric manufactured homes that are fire-resistant and will meet or exceed the state's Title 24 requirements.[197] The finished home will be installed in a low-income or disadvantaged community. Another project is demonstrating use of 120-volt electric HVAC heat pumps and large-capacity carbon dioxide water heaters that avoided having to upgrade electric panels in a multifamily complex located in a disadvantaged community.[198]

Decarbonization in Commercial Buildings

The commercial sector[199] in California contributes 7 percent of GHG emissions.[200] The major sources of GHG emissions are water heating, space heating, and cooking. The greatest

194 EPC-19-014, https://www.energizeinnovation.fund.

195 EPC-19-030, https://www.energy.ca.gov/filebrowser/download/723.

196 EPC-18-019, https://www.energizeinnovation.fund.

197 EPC-19-043, https://www.energy.ca.gov/filebrowser/download/732.

198 EPC-15-053, https://www.energizeinnovation.fund.

199 For the purposes of the report, the definition of *commercial* includes hotels and motels.

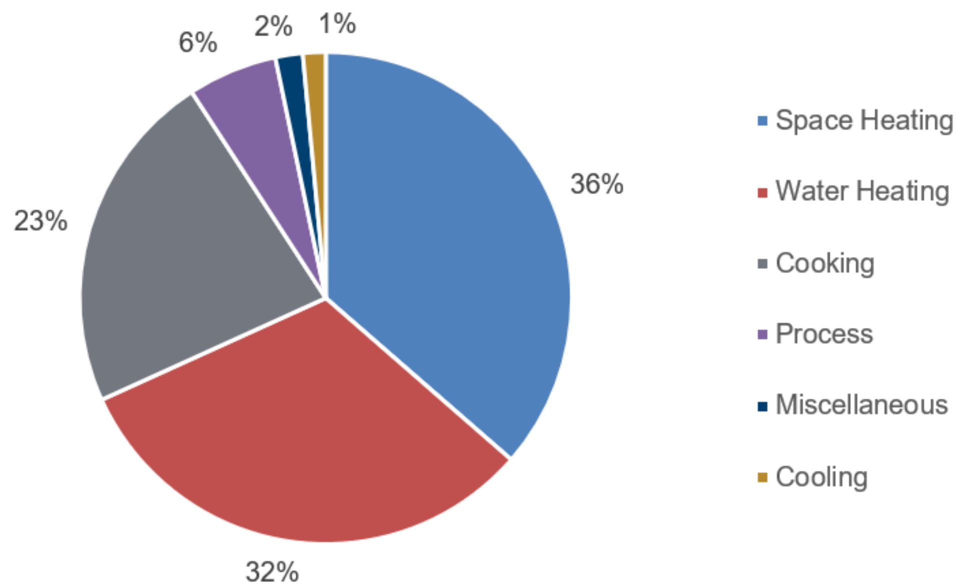
200 CARB GHG Emissions Inventory webpage, https://ww2.arb.ca.gov/ghg-inventory-data.

opportunity for decarbonization comes from electrifying those end uses, as well as introducing lower-GWP refrigerants. Large offices and retail spaces are the greatest consumers of electricity (32 percent), while restaurants and hospitals account for 38 percent of gas use. The most recent data for energy use in the commercial sector is the *2006 Commercial End Use Survey*.[201] The next iteration of this survey finishes data collection this year, and the final report is expected in 2022.

Gas Equipment Landscape

Gas use in commercial buildings is split mostly among space heating (36 percent), water heating (32 percent), and cooking (23 percent). The diversity of this sector means that there are many other processes that may also use gas. However, these processes account for about 6 percent of commercial consumption.

Figure 17: Commercial Gas Consumption by End Use



Source: CEC, Commercial End Use Survey

The commercial sector uses water heaters of varying sizes, which makes substitution for electric water heaters more challenging. Heat pump water heaters capable of meeting the

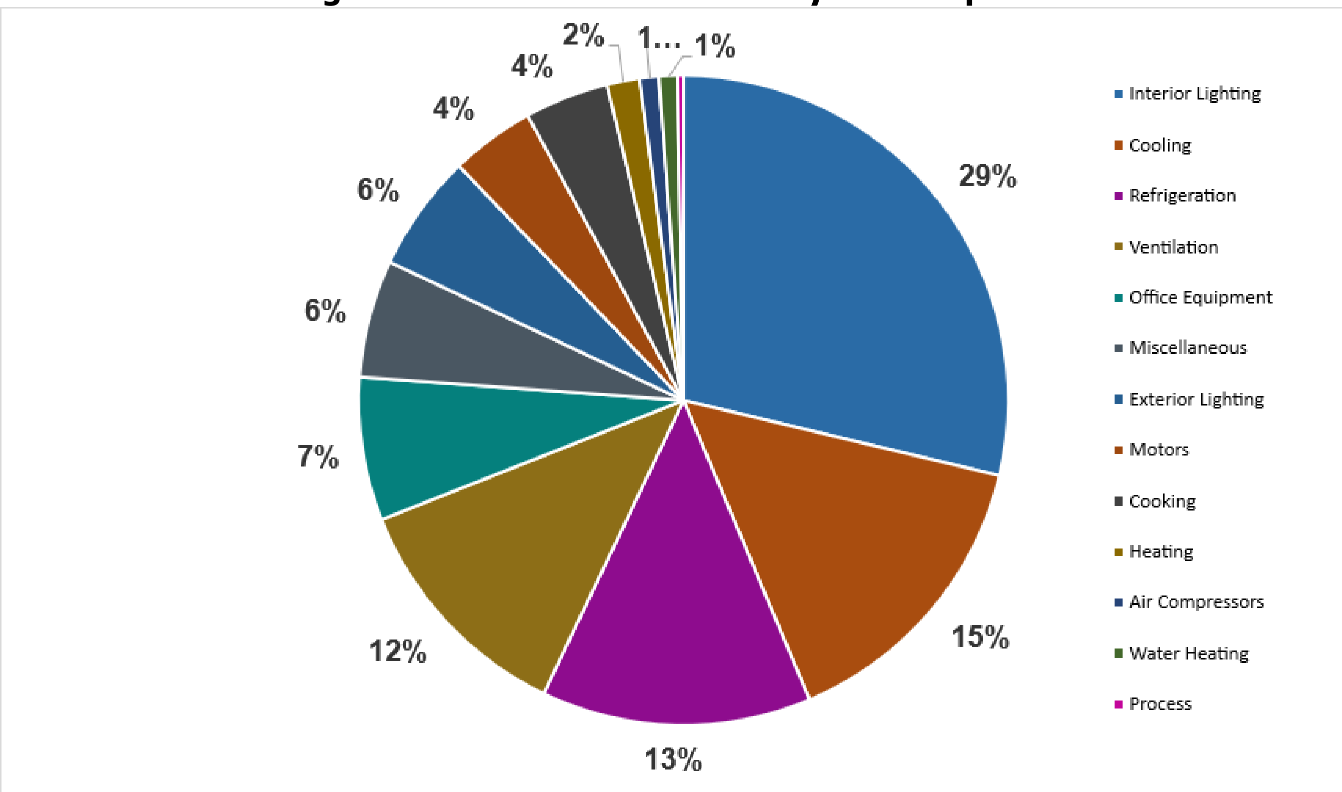
201 CEC. *Commercial End Use Survey*. 2006. https://www.energy.ca.gov/data-reports/surveys/california-commercial-end-use-survey.

needs of commercial buildings are available but have not reached significant market penetration.

Electric Equipment Landscape

Electricity use in commercial buildings is dominated by interior lighting (29 percent), air conditioning (15 percent), refrigeration (13 percent), and ventilation (12 percent), which together make up about 59 percent of usage. Similar to gas end uses in this sector, there are numerous end uses that make up the remaining 41 percent of electricity consumption.

Figure 18: Commercial Electricity Consumption



Source: CEC, Commercial End Use Survey

The significant amount of energy used for refrigeration (13 percent of electricity usage) also comes with added GHG emissions due to high-GWP refrigerants. Commercial refrigeration contributed 9 million metric tons of carbon dioxide equivalent emissions in 2019, which was equivalent to 2 percent of the statewide emissions.[202] The emissions from this sector will come down as more energy is met by renewable sources and the refrigerants in use are substituted to lower-GWP alternatives.

Costs of Commercial Decarbonization

The commercial building sector covers numerous types of buildings from hospitals, offices, schools, to retail. Consequently, there are a wide variety of technologies in use with a range of costs to decarbonize. The *California Building Decarbonization Assessment* estimated the marginal abatement cost of new and existing commercial building electrification ranges from -$163 to -$11 depending on the aggressiveness of the scenario.[203] The cost to decarbonize water heating and HVAC was -$386 per metric ton and -$164 per metric ton, respectively, in the moderate electrification scenario. Commercial food service and appliance decarbonization has positive costs per metric ton, $209 and $576 respectively. However, these latter two end uses have much smaller GHG emission reduction potential when compared to space and water heating.[204]

New Construction

A study supporting the utility codes and standards program found that all-electric new commercial construction has mostly lower upfront costs compared to a mixed-fuel building.[205] The cost reductions were due to avoided gas infrastructure, including planning, service extension, meter, and plumbing, even when the cost of additional wiring and panel capacity were included. The only exception was in all-electric office building construction. Incremental costs for new commercial buildings were also mostly negative across climate zones and in some cases when adding upfront costs through solar photovoltaic (PV), battery storage, and technologies more efficient than code.

202 CARB. Current California GHG Emission Inventory Data webpage. https://ww2.arb.ca.gov/ghg-inventory-data.

203 Kenney, Michael, Nicholas Janusch, Ingrid Neumann, and Mike Jaske. 2021. *California Building Decarbonization Assessment*. California Energy Commission. Publication Number: CEC-400-2021-006-CMF. https://www.energy.ca.gov/publications/2021/california-building-decarbonization-assessment.

204 Ibid.

205 TRC and Energy Soft for PG&E Codes and Standards Program. 2019. *2019 Nonresidential New Construction Reach Code Cost Effectiveness Study*. p. 1. https://localenergycodes.com/download/74/file_path/fieldList/2019%20NR%20NC%20Cost%20Effectiveness%20Report.

For the 2022 Energy Code, CEC staff performed analysis to develop heat pump baseline requirements.[206] Several types of commercial buildings were modeled, such as small offices, retail buildings, warehouses, and schools. Equipment capacity and number of units were matched to the different building type models.

There are significant avoided costs when installing a heat pump in comparison to air conditioning with gas because construction did not require gas piping from the main service to each of the rooftop units. This cost was estimated by contractors with direct experience with commercial HVAC installations. Heat pump units were overall more expensive than air conditioning with gas units, but the avoided costs made up the differences. Table 8 summarizes the cost comparison.

Table 8: Incremental Cost of Heat Pumps in New Commercial Buildings

Building Type	Small Office	Small Retail	Medium Retail	Large Retail	Small School	Warehouse
Number of Units in Model	5	4	6	19	23	1
Heat Pump Equipment Cost	$818	$654	$982	$3,108	$3,763	$164
Avoided Gas Line Cost	($5,544)	($4,841)	($6,247)	($25,746)	($18,193)	($2,733)
Incremental Cost	($4,726)	($4,187)	($5,265)	($22,638)	($12,730)	($2,569)

Source: CEC

Existing Building Retrofits

Upgrading existing commercial buildings has various upfront incremental costs. Similar to existing homes, costs vary by building size, age, existing panel size, and specific equipment in

206 Prepared by Roger Hedrick, John Arent, Nikhil Kapur, and Rahul Athalye of NORESCO for the CEC. *Heat Pump Baseline for Non-Residential and High-Rise Residential Buildings – Feasibility Analysis*. https://efiling.energy.ca.gov/GetDocument.aspx?tn=238849&DocumentContentId=72257.

Cost data were collected for rooftop packaged air conditioning units using gas and compared with equivalent rooftop packaged heat pump units. The cost data components included equipment costs, labor, and installation costs. Material or labor costs for items that are the same in both the current gas baseline and the proposed heat pump baseline, such as crane rental and curb construction, were not included. Equipment cost data were taken from multiple distributor sources and from several direct quotes from manufacturers for equipment with nominal capacity in the range of 2 to 30 tons.

need of replacement. Work done to support the IOU Codes and Standards Program found costs ranged from a few thousand dollars to more than $40,000.[207]

Research and Development

The Electric Program Investment Charge (EPIC) and the Natural Gas Research and Development (R&D) program have supported multiple projects that further decarbonization in the commercial building sector. These projects include guidebooks to decarbonize healthcare-related buildings, development of cost-effective measure packages to achieve zero-net energy, and demonstration of heat pump gas technology. As an example, the health care sector is the highest gas consumer within the commercial building sector. The CEC's research programs have supported several research efforts in this area including mechanical ventilation, dehumidification and reheating of supply air, and development of a guidebook to help health care buildings to decarbonize. The CEC also supported the deployment of integrated precommercial energy efficiency technologies in big-box retail stores, grocery stores, office buildings, and public buildings.

Supply Chain and Equipment Challenges

The CEC heard from program implementers, builders, manufacturers, and distributors about the supply chain and available decarbonization equipment during an IEPR workshop June 22, 2021.[208]

Equipment Availability

The success of decarbonization hinges on the scale to which heat pumps can be introduced. To date, heat pumps are a small percentage of the existing stock and are not the first option many turn to when replacing water heaters or furnaces. One reason is the lower availability of heat pumps in box stores and through contractors.

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207 TRC and Energy Soft for PG&E Codes and Standards Program. 2019. 2019 Nonresidential New Construction Reach Code Cost Effectiveness Study. p. 1. https://localenergycodes.com/download/74/file_path/fieldList/2019%20NR%20NC%20Cost%20Effectiveness%20Report.

208 June 6, 2021, IEPR Commissioner Workshop Building Decarbonization Equipment, Technology, and Supply Chain Session 1 transcript. https://efiling.energy.ca.gov/getdocument.aspx?tn=239219.

June 6, 2021, IEPR Commissioner Workshop Building Decarbonization Equipment, Technology, and Supply Chain Session 2 transcript. https://efiling.energy.ca.gov/getdocument.aspx?tn=239220.

At the IEPR workshop on building electrification, panelist Panama Bartholomy of the Building Decarbonization Coalition identified the low availability of electric appliances as a barrier to building electrification.[209]

Another issue for existing homes is the existing wiring for 240-volt appliances which may prevent installing new electric appliances without costly upgrades. To solve this issue, researchers, manufactures, and contractors have been collaborating and testing new 120-volt heat pumps that can be installed and run off existing wiring.

Low-GWP Heat Pumps

As electrification and the number of heat pumps installed increase, refrigerant usage will also increase. To continue toward achieving reduced GHG emissions, the refrigerants used in heat pump equipment will need to have a low GWP. The availability and cost of using low-GWP refrigerants are a consideration for decarbonization policy.

Heat Pump Water Heaters

The Advanced Water Heating Initiative (AWHI), led by the New Buildings Institute, is a collaborative, market transformation effort to catalyze a rapid transition to high-efficiency, grid-connected heat pump water heaters.[210] The central heat pump water heating workgroup of AWHI is developing high-performing products, which includes the use of low-GWP or lower-GWP refrigerants. The workgroup has identified five low-GWP or lower-GWP products that will go through the Technology Innovation Model, which involves working with manufacturers and providing supporting research to bring products from research and demonstration to commercial availability. There are a handful of heat pump water heaters that use carbon dioxide (CO_2) (GWP equal to 1) as a refrigerant. Table 9 lists the limited heat pump water heater products available or in development with low-GWP refrigerants.

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209 Ibid.

210 Advanced Water Heating Initiative webpage, https://www.advancedwaterheatinginitiative.org/.

Table 9: Low-GWP or Lower-GWP HPWH Products

Refrigerant	GWP	Product Availability
R744 (CO_2)	1	SanCO_2, WaterDrop, Mitsubishi QAHV, Lync Likely more being developed for the U.S. market More available in other international markets
R290 (propane)	4	None are available in the United States due to specific refrigerant regulations Several available in other international markets
R513	573	Likely one or more in development by a U.S. manufacturer
R32	675	None yet on the market in the U.S. Available in international markets

Source: AWHI

Heat Pump HVAC

With the California Air Resources Board's (CARB's) HFC Regulation, air-conditioning and heat pump manufacturers will need to manufacture equipment with lower-GWP refrigerants (GWP less than 750) beginning in 2023.[211] (See Chapter 2 for more information.) There are room/window air conditioning products available in the United States that use lower-GWP refrigerants but no other systems that use them.

A2L Refrigerants

A challenge of implementing low-GWP refrigerants is that lower-GWP refrigerants that are most viable in the near future are mildly flammable. Flammability refers to the heat of combustion and burning velocity of refrigerants when leaked out of equipment. These refrigerants are a class of refrigerants referred to by the American Society of Heating, Refrigeration, and Air Conditioning Engineers (ASHRAE) as *A2L refrigerants*. A2L refrigerants are prohibited in residential and commercial buildings for most direct air conditioning applications due to their mild flammability. A2L refrigerants are permitted in small amounts in hermetically sealed equipment and in indirect systems where the refrigerant is contained in a

211 CARB. Prohibitions on Use of Certain Hydrofluorocarbons in Stationary Refrigeration, Chillers, Aerosols-Propellants, and Foam End Uses Regulation webpage, https://ww2.arb.ca.gov/rulemaking/2020/hfc2020.

machinery room. Studies have been conducted by the nationally accredited codes and standards setting bodies, federal, and state governments as well as the Air-conditioning, Heating, and Refrigeration Institute[212] and partners to test the safety of A2L refrigerants in buildings for additional applications and to inform building codes and industry standards accordingly. For health and safety purposes, products containing A2L refrigerants have charge (amount of refrigerant) limits, must be installed in properly sized rooms, and may be required to have a leak detection system with sensors, emergency shut-off and ventilation. upon detection (See UL Standard 60335-2-40 and ASHRAE 15.) Allowing A2L refrigerants at common charge levels in homes and businesses for direct air conditioning applications will require changes to the California Mechanical Code (CMC).[213] (The CMC is based on the International Association of Plumbing and Mechanical Officials' Uniform Mechanical Code (UMC).)[214] The International Association of Plumbing and Mechanical Officials is considering the allowance of A2L refrigerants in the UMC that may allow for the use of A2L refrigerants in California buildings as early as July 1, 2024, via amendments to the CMC.

Inexpensive Induction Stoves

At the June 22, 2021, Integrated Energy Policy Report (IEPR) workshop, panelist Brandon De Young of De Young Properties commented that electrification costs (for example HPWH, induction cooking) are a smaller issue than originally thought, but still a concern. Dan Cronin, with the United States Environmental Protection Agency's ENERGY STAR® program offered that while the residential market is small, most manufacturers offer induction cooking, and utility incentives/promotions are available in California and other states.[215]

Heat Pump Clothes Dryers

At the June 22, 2021, IEPR workshop,[216] Mr. Cronin with the U.S. EPA's ENERGY STAR program indicated that ENERGY STAR's most efficient 2021 clothes dryers use heat pump or

212 AHRI Flammable Refrigerants Research Initiative webpage, https://www.ahrinet.org/resources/research/ahri-flammable-refrigerants-research-initiative.

213 DGS Building Standards Commission webpage for California Building Standards Code, https://www.dgs.ca.gov/BSC/Codes.

214 Uniform Mechanical Code webpage, https://codes.iapmo.org/home.aspx?code=UMC.

215 A list of induction cooktop lending programs is available at https://www.buildingdecarb.org/kitchen-electrification-group-resource-directory.html.

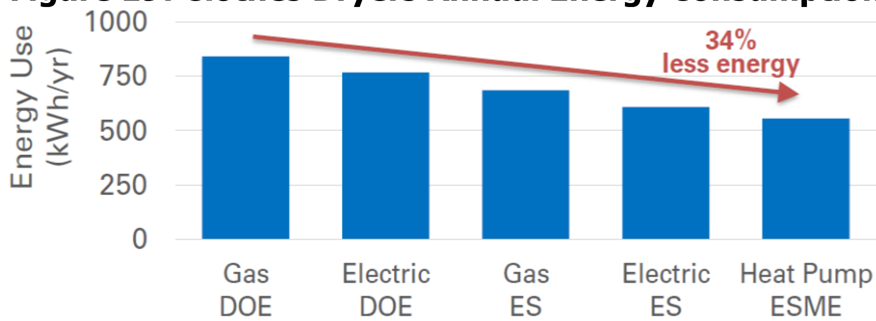
216 Dan Cronin. 2021. *Presentation - Heat Pump Clothes Dryers and Emerging Technologies* https://efiling.energy.ca.gov/Lists/DocketLog.aspx?docketnumber=21-IEPR-06. TN # 238357.

June 22, 2021, workshop transcript for session 2. https://efiling.energy.ca.gov/Lists/DocketLog.aspx?docketnumber=21-IEPR-06. TN # 239220.

hybrid heat pump technology. As of October 2021, 23 models from 8 brands are commercially available; however, fewer than 1 percent of households have a heat pump dryer. When introduced in 2012, the long drying cycle was a barrier to consumers. The drying cycle has now been reduced to 35 minutes in some models. The no-venting requirement provides flexibility in where to place the laundry equipment. Development of advanced clothes drying technologies is ongoing, General Electric has an ultrasonic dryer in development, and Samsung is developing a thermoelectric heat pump clothes dryer.

Similar to other types of heat pump equipment, heat pump dryers contain refrigerant. Most models available on the global and national market use high-GWP refrigerant R-134A, which has a GWP of 1430. There is a need for research and development to expand the market to include dryers with low-GWP refrigerants.

Figure 19: Clothes Dryers Annual Energy Consumption



Credit: ENERGY STAR

More Electric Panel Size Options

Building electrification may require electrical panel upgrades to support increased electrical loads as households replace gas appliances with high-efficiency electrical appliances, such as heat pump water heaters. At the June 22, 2021, IEPR workshop, Ram Narayanamurthy with Electric Power Research Institute emphasized the need for innovative solutions. As an example, he described how smart panels that automatically coordinate the operation of large loads within a building can prevent the need for electric service upgrades in some existing buildings, providing valuable load flexibility that reduces impacts on electric infrastructure. .

Innovative approaches that allocate existing panel capacity more efficiently and support increased household electrical loads without requiring panel upgrades can increase the affordability of building electrification. This can be accomplished by selecting low-wattage heat pumps and other equipment to meet the capacity of the existing electric panel, or by using equipment control devices that prioritize urgent loads and offer compatibility with existing household electrical infrastructure. As an example, controls can be used to pause a heat pump water heater or electric vehicle (EV) charger automatically while an induction stove is drawing electricity for cooking.

Manufacturer and Distributor Challenges

According to Helen Walter-Terrinoni of the Air-Conditioning, Heating, and Refrigeration Institute (AHRI), due to the COVID-19 pandemic, the heating, ventilation, air-conditioning, and refrigeration industry is plagued by the same supply chain shortages that other industries are currently facing. The pandemic has created challenges that significantly impact the ability to redesign equipment to meet new regulatory requirements. Furthermore, severe weather and raw material and component shortages are exacerbating these supply chain shortages. A collaboration of manufacturing associations composed of AHRI, Association of Home Appliance Manufacturers, North American Association of Food Equipment Manufacturers, and National Electrical Manufacturers Association, drafted the Joint Association Supply Chain white paper[217] to the Department of Commerce and United States Trade Representative illustrating the supply chain disruptions that are lowering the competitiveness of their combined industries and hindering their members' manufacturing capabilities in the United States.

Supply chains follow market demand, and HPWHs comprise about 5 percent of California's total residential water heater market.[218] Until there's a clear market signal for growth, supply chain constraints will continue to persist.

Manufacturers view regulatory uncertainties about future climate goals as another challenge to supply chains. Manufacturers believe regulatory clarity specific to zero-carbon equipment requirements would be one solution to this challenge. Ankur Maheshwari of HVAC equipment manufacturer Rheem identified new construction as being a low-hanging fruit and opined it should be considered as a driver to push market adoption.[219]

Manufacturers are experiencing atypical stress with global commodities, such as steel, which has seen costs double since Summer 2020. As a result, manufacturers are seeing and paying higher than normal commodity costs. Steel and other commodities are essential to manufacturing consumer heating and cooling equipment. When manufacturers experience constraints to their supply chains, and cost increases to key commodities, there are downstream pricing impacts. Josh Greene, vice president of government and industry affairs at A. O. Smith, stated, "Similarly, as the transition to more heat pumps both for space heating

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217 Supply Chain Disruptions Affect Viability of U.S. Manufacturing Sector white paper, https://www.automation.com/en-us/assets/white-papers/white-paper-supply-chain-disruptions-manufacturing.

218 Palmgren, Claire, Miriam Goldberg, Ph.D., Bob Ramirez, Craig Williamson, DNV GL Energy Insights USA, Inc. 2021. *2019 California Residential Appliance Saturation Study* (RASS). Publication Number: CEC-200-2021-005. https://www.energy.ca.gov/publications/2021/2019-california-residential-appliance-saturation-study-rass.

219 Ankur Maheshawari. 2021. *Presentation – Rheem* https://efiling.energy.ca.gov/Lists/DocketLog.aspx?docketnumber=21-IEPR-06 and June 22, 2021, IEPR workshop on Building Decarbonization- Equipment, Technology, and Supply Chain transcript for session 1. https://efiling.energy.ca.gov/getdocument.aspx?tn=239219.

and water heating — and again, regardless of installation or application — begins to ramp up, there will be supply chain pressure on compressors, components, electronics, amongst other things.”

CHAPTER 4: Funding Decarbonization

California must make significant investments in retrofits and newly constructed buildings to enable and accelerate the building decarbonization needed to meet state climate goals. Various studies have estimated California needs to invest billions of dollars to decarbonize buildings over the next two decades to achieve midcentury climate goals.

The *California Building Decarbonization Assessment* estimated the net cost to decarbonize buildings by 2030 ranges from $3 billion to nearly $40 billion.[220] The Energy Futures Initiative estimates incremental costs of $1.5 billion to build only all-electric homes after 2020 until 2030.[221] The Building Decarbonization Coalition has also estimated that a grant-only approach to low- to moderate-income household decarbonization would require a cumulative public and ratepayer investment over 25 years on the order of $72 billion to $150 billion.[222]

The scale of needed investments presents affordability barriers and constraints that vary across building types and locations, discussed in more detail in Chapter 3. Low- and moderate-income households and disadvantaged communities face particularly onerous barriers to implementing energy efficiency and building decarbonization measures. Stakeholders recommend that financing programs be based on the guiding principles of addressing affordability, striving for equity, maximizing impact, minimizing risk, and reducing complexity to address the challenges faced by residents, property owners, and businesses across California.[223]

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220 Kenney, Michael, Nicholas Janusch, Ingrid Neumann, and Mike Jaske. 2021. *California Building Decarbonization Assessment*. California Energy Commission. Publication Number: CEC-400-2021-006-CMF. https://www.energy.ca.gov/publications/2021/california-building-decarbonization-assessment.

221 Energy Futures Initiative. 2019. *Pathways for Deep Decarbonization in California*. p. 188. https://energyfuturesinitiative.org/s/EFI_CA_Decarbonization_Full-b3at.pdf.

222 Mast, Bruce, Holmes Hummel, and Jeanne Clinton. June 2020. *Towards an Accessible Financing Solution, Building Decarbonization Coalition*. p. 14. http://www.buildingdecarb.org/uploads/3/0/7/3/30734489/bdc_junewhitepaper_designdraft.pdf.

223 Southern California Edison comments on the July 13, 2021, IEPR Commissioner Workshop on Building Decarbonization and Workforce. TN 239023. Docket 21-IEPR-06. https://efiling.energy.ca.gov/GetDocument.aspx?tn=239023&DocumentContentId=72454.

Funding Strategies

The high and variable costs to decarbonize California's nearly 14 million homes and more than 7 million square feet of commercial space requires decision makers to look at existing and new funding streams. They must consider how funds can be layered and distributed through a lens of affordability and equity. Delivering comprehensive financing solutions will help scale successful programs and enable new options that will overcome barriers Californians face and accelerate building decarbonization to meet the state's climate goals.

This section discusses funding sources for financing building decarbonization, which includes a combination of federal funds, the state general fund, cap and trade, utility surcharges, philanthropic grants, bonds, private financing, and new funding mechanisms. Most importantly, providing the necessary funding will require a concerted effort to coordinate across public and private entities.

Federal Funds

The federal government helps fund building decarbonization in California via loans, grants, bonds, tax incentives, rebates, and stimulus. These funds flow through programs administered by state agencies and local governments and directly to participants in California.

The United States Department of Energy (U.S. DOE) funds the Weatherization Assistance Program (WAP), which is administered by the California Department of Community Services & Development (CSD). The program provides services for cost-effective energy efficiency improvements in low-income households. Participating households save on average $283 each year in energy costs. A national evaluation of the WAP program determined the non-energy benefits of the program have returned $2.78 for every dollar invested. In total, program participants experienced a $514 annual reduction in out-of-pocket medical expenses and total household benefits of $14,148 on average.[224]

The Low Income Home Energy Assistance Program (LIHEAP) is funded by the U.S. Department of Health and Human Services and administered by CSD. It assists low-income households with heating and cooling energy costs, manages energy crises, provides free energy efficiency upgrades to low-income households, and offers education on energy efficiency best practices. The Coronavirus Aid, Relief, and Economic Security Act allocated an additional $49 million in California to supplement its LIHEAP grant, which totaled $204 million for the federal fiscal year 2019–2020.

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224 U.S. DOE. DOE/EE-2124. "Weatherization Assistance Program Fact Sheet." January 2021. https://www.energy.gov/sites/default/files/2021/01/f82/WAP-fact-sheet_2021_0.pdf.

The U.S. DOE's State Energy Program provides grant funding and technical assistance to state agencies to advance state-led energy initiatives and increase energy affordability through energy efficiency, offer renewable technologies, and demonstrate new innovative building technologies that advance building decarbonization.

The United States Environmental Protection Agency (U.S. EPA) recently announced new initiatives that will accelerate building decarbonization across residential, commercial, and industrial sectors. One such initiative, the ENERGY STAR Home Upgrade program, will focus on combining energy efficiency and electrification measures that deliver the greatest amount of greenhouse gas (GHG) emissions reductions and net energy savings. The program will partner with existing and new energy efficiency programs to accelerate building decarbonization with a focus on underserved households.[225]

Existing federal tax credits and deductions encourage developers to build new energy-efficient homes and businesses to invest in on-site renewables. The Energy Act of 2020 extends a tax credit for homeowners who install energy-efficient improvements and renewables. It also reinstates an inflation-adjusted tax deduction for commercial building owners who install energy efficiency improvements.

State Funds

In California, energy efficiency and decarbonization programs are largely funded on the statewide level via the general fund, Greenhouse Gas Reduction Fund (GGRF), bonds, and the Public Purpose Program surcharge on ratepayer's utility bills.

The GGRF is funded by proceeds from CARB's Cap-and-Trade Program.[226] The state's share of the auction proceeds is deposited into the GGRF, which the Legislature appropriates to state agencies to implement California Climate Investments programs. California Climate Investments programs reduce GHG emissions in California with a focus on the most disadvantaged communities. A portion of these programs include energy efficiency and building decarbonization, such as the Low-Income Weatherization Program (LIWP) administered by CSD.

225 U.S. EPA press release. May 17, 2021. "Through Public-Private Partnerships, EPA Helps to Advance Efficiency and Reduce Emissions of American Homes and Buildings." https://www.epa.gov/newsreleases/through-public-private-partnerships-epa-helps-advance-efficiency-and-reduce-emissions.

226 The Cap-and-Trade Program is a market-based system that establishes an annual declining limit – or cap – on about 80 percent of statewide greenhouse gas (GHG) emissions from the largest polluters ("covered entities") in the state. Covered entities must obtain allowances equal to their emissions. Allowances are purchased at quarterly auctions, which generates proceeds. The state's share of auction proceeds is deposited into the GGRF.

Electricity rates are another source of funding for energy efficiency programs. Utilities recover fixed costs associated with electricity generation, transmission, distribution, Public Purpose Program, and the state surcharge via charges on customers' utility bills. (See example electricity rate breakdown in Chapter 1.) The Public Purpose Program surcharge is authorized by the California Public Utilities Commission (CPUC) and funds programs that are, in part, designed to advance and achieve the state's climate and equity goals. While this surcharge may provide a funding source for decarbonization efforts, it must be balanced given average electric rates for investor-owned utilities (IOUs) in California are above the national average and are expected to outpace the rate of inflation over the next decade as utilities invest in transmission and distribution infrastructure and implement wildfire mitigation measures.[227] Further, as the market for distributed energy resources[228] matures, there is a potential cost shift toward those unable to access these technologies. If these fixed costs were funded by the state or through an income-based fixed charge on customers' utility bills, rates could be reduced to benefit low- and moderate-income households who carry a higher energy burden.[229]

Public-Private Partnerships

Public- and ratepayer-funded programs alone are unlikely to accelerate building decarbonization at the scale needed to meet statewide decarbonization goals. Recent efforts have explored the role of private capital and financing to support and accelerate building decarbonization. One pathway is through "green banks," mission-driven and self-sustaining public or nonprofit financial institutions that leverage public funds to mobilize private investment in sustainable and clean energy infrastructure. In the last decade, these institutions have experienced rapid growth. In 2020, green banks drove $1.69 billion in total investment across the nation, in large part because of increased demand for clean energy and energy efficiency improvements during the COVID-19 pandemic.[230]

227 CPUC. May 2021. *Utility Costs and Affordability of the Grid of the Future: An Evaluation of Electric Costs, Rates, and Equity Issues Pursuant to P.U. Code Section 913.1*. https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/office-of-governmental-affairs-division/reports/2021/senate-bill-695-report-2021-and-en-banc-whitepaper_final_04302021.pdf.

228 DER examples include rooftop photovoltaic, storage, and demand flexibility.

229 Borenstein, Severin, Meredith Fowlie, and James Sallee. February 2021. *Designing Electricity Rates for An Equitable Energy Transition*. University of California, Berkeley, Energy Institute at Haas. https://haas.berkeley.edu/wp-content/uploads/WP314.pdf.

230 American Green Bank Consortium. May 2021. *Green Banks in the United States: 2021 U.S. Green Bank Annual Industry Report With Data From Calendar Year 2020*. https://greenbankconsortium.org/annual-industry-report.

The California State Treasurer's Office partially acts as a green bank and operates the California Alternative Energy and Advanced Transportation Authority (CAEATFA) and the California Pollution Control Financing Authority, which administer programs that help residents, businesses, industry, and government implement, in part, energy efficiency projects and renewable energy. The California Lending for Energy and Environmental Needs, within the California Infrastructure and Economic Development Bank (iBank), provides financing to local governments and public institutions for energy efficiency, renewables, and energy storage projects through direct public loans or tax-exempt bonds.

Green bonds can be issued by the public or private sector to provide a significant source of capital for statewide and community-scale sustainable infrastructure projects, including building decarbonization. Municipal green bond issuances across the nation have grown in the last decade since they were first issued. In 2019, municipalities issued roughly $9 billion in green bonds nationwide. A Milken Institute report published September 2020,[231] builds on previous work with the State Treasurer's Office. The report advocates implementing standardized metrics in planning a project to better understand the value provided by green bonds to further increase the attractiveness of these bonds. In the context of building decarbonization, these metrics could include GHG mitigation, avoided costs — such as those provided by the CPUC's Avoided Cost Calculator — grid resiliency, improved energy efficiency, and embodied carbon. Quantifying non-energy benefits can provide additional metrics. A key recommendation from the report and shared by Southern California Gas Company (SoCalGas) is that the state should provide a supporting role for municipalities interested in issuing green bonds through technical assistance and financial means.[232]

In other states, the Connecticut Green Bank was able to attract $312 million in total investment by leveraging $36 million in public funds in 2020.[233] It also began issuing a green municipal bond, the Green Liberty Bond, which provides funding to support energy efficiency and solar photovoltaic (PV) projects. The New York Green Bank deployed $303.5 million toward renewables and energy efficiency projects, a portion of which will benefit low- and

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231 Brennan, Maressa. September 2020. Growing the US Green Bond Market: Lab 2. Milken Institute. https://milkeninstitute.org/report/growing-us-green-bond-market-lab-2.

232 SoCalGas comments on the July 12, 2021, IEPR Commissioner Workshop on Financing Building Decarbonization Session 2. TN 239044. Docket 21-IEPR-06. https://efiling.energy.ca.gov/GetDocument.aspx?tn=239044.

233 Connecticut Green Bank's webpage, https://www.ctgreenbankbonds.com/connecticut-green-bank-ct/i6126.

moderate-income communities in 2020. The commitments are expected to attract up to $800 million in additional private investments.[234]

The success and growth of green banks and bonds have generated significant interest on the federal level with ongoing legislation to create the Clean Energy and Sustainability Accelerator, which would partner with state green banks, community development financial institutions, and other stakeholders to accelerate decarbonization with a focus on equity and affordability.[235]

As the programs discussed in this section demonstrate, it is possible to leverage private capital and promote public-private partnership by creating the proper value proposition to attract investment.

Funding Deployment Mechanisms

There are existing and innovative pathways for building decarbonization financing programs to distribute the funds discussed in the previous section. Table 10 provides an overview of financing models and mechanisms that support building decarbonization.

Table 10: Existing and Innovative Approaches to Financing Building Retrofits

Financing Models & Mechanisms	Description
Loans	Traditional personal or business loans. Requires minimum credit scores, debt-to-income ratio. Can be secured with property for improved loan terms. Generally excludes low-income households, tenants, and commercial buildings with severe capital and debt limitations.

234 American Green Bank Consortium. *Green Banks in the United States: 2021 U.S. Green Bank Annual Industry Report With Data From Calendar Year 2020*. May 2021. https://greenbankconsortium.org/annual-industry-report.

235 Clean Energy and Sustainability Accelerator Act, H.R. 806. 2021. https://www.congress.gov/bill/117th-congress/house-bill/806/.

Zurofsky, Adam, Jeffrey Schub, John Rhodes, Tony Curnes, and Sam Calisch. *A Plan to Accelerate Climate Action and Environmental Justice by Investing in Household Electrification at the Local Level*. May 2021. https://www.rewiringamerica.org/rewiring-communities-report.

Financing Models & Mechanisms	Description
Revolving Loan Funds Green Banks Community Development Financial Institutions (CDFIs)	Mission-driven institutions designed to fund clean energy and sustainable infrastructure projects. Initial funds can be drawn from several sources (such as public funds, ratepayer funds, bonds, or philanthropic grants). Revenue from outstanding loans is used to fund additional loans and achieve institutional goals. CDFIs are private institutions that provide financial services to disadvantaged communities.
Green Bond	A special type of bond that earmarks use of proceeds for projects that have positive environmental or climate benefits. Used to raise large amount of funds ($25 million+) (for example, funds for a green bank) Large government, commercial, industrial, and community-scale projects. Tax incentives can lower cost of capital.
Credit Enhancements Loan Loss Reserves	Reserve funds that mitigate risk to lenders in case of default. Provide credit enhancement and improved loan terms for borrowers.
Interest Rate Buydown	Subsidy of financing costs by a third-party (such as a public fund) that reduces interest rate paid by borrower.
Property Assessed Clean Energy	Loan secured by a property lien. Usually repaid via property taxes. The property lien is assumed by the new owner if there is a change in property ownership. Excludes tenants and can create negative outcomes for low- and moderate-income households.

Financing Models & Mechanisms	Description
On-Bill Financing On-Bill Repayment	Costs of qualifying projects are financed by utility investments or a third-party lender. Financing is repaid via utility bill. Default can result in utility service shut-off. Addresses split incentive barrier.
Tariff On-Bill	Utility invests in qualifying projects. Cost recovery via a tariff on the customer's bill. The tariff is attached to the meter and does not follow the building owner or tenant if they move. Addresses split incentive barrier. Default can result in utility service shutoff.
Direct Install	Qualified measures are provided at low- or no-cost and directly installed by the utility or a third-party implementer. Economies of scale could deliver additional cost savings by retrofitting several adjacent buildings.
Tax Equity	Qualified project costs are offset by tax incentives that are transferred to the installer or a third-party that finances the project in exchange for ownership. Commonly used to finance renewable energy projects.
Energy Savings Performance Contract	An Energy Service Company installs and maintains energy efficiency equipment and recovers costs via associated energy savings. Typically provides guaranteed savings. Appropriate for large complex projects by government agencies, hospitals, universities, and schools.

Financing Models & Mechanisms	Description
Energy Services Agreement (ESA)	ESA provider provides upfront capital and manages project and maintenance via a third-party contractor. ESA provider retains ownership of installed equipment for duration of contract term. Additional measures can be installed/updated during contract term. Pay-for-performance incentive via actual energy savings compared to baseline. Appropriate for multifamily, commercial, and industrial buildings. Addresses split incentive barrier in commercial buildings.

Source: U.S. DOE. Establish Financing (https://www.energy.gov/eere/slsc/establish-financing); Better Buildings, U.S. DOE. Energy Efficiency Project Financing (https://betterbuildingssolutioncenter.energy.gov/alliance/market-solutions/energy-efficiency-project-financing)

Many existing energy efficiency programs rely on future energy savings to recover the project installation costs of building retrofits. In buildings that require extensive infrastructure retrofit or remediation, energy savings from energy efficiency improvements will not always offset the financing costs, which can create negative financial outcomes for participants.[236] Other building decarbonization measures, such as electrification, do not always provide bill savings and in some cases could increase a customer's bill.[237] Tenants who pay the operating costs of energy could risk an increase in their utility bills with building electrification, which would shift the cost burden of building decarbonization to tenants. These are challenges that must be addressed so all California residents can benefit from the clean energy transition.

236 Steinmetz, Leo. May 2021. *Financing Energy Efficiency for Low- and Moderate-Income Homeowners in Contra Costa County*. https://www.contracosta.ca.gov/DocumentCenter/View/70938/Steinmetz-APA---Financing-Energy-Efficiency-for-LMI-Homeowners-in-Contra-Costa-County?bidId=.

237 Association for Energy Affordability, July 12, 2021, IEPR Commissioner Workshop Financing Decarbonization Session 2 transcript https://efiling.energy.ca.gov/getdocument.aspx?tn=239943-2.

An ongoing CPUC rulemaking proceeding (R.20-08-022) is investigating innovative financing mechanisms and programs to encourage large-scale investments toward deep building decarbonization by leveraging IOU ratepayer funds.[238] This proceeding has been structured to evaluate existing programs administered by CAEATFA and the IOUs and to explore new financing program proposals. The proceeding aims to address barriers of building decarbonization with a focus on affordability and equity, expand IOU ratepayer-funded programs beyond energy efficiency, and provide consumer protections for participants. The CPUC recently adopted a decision allowing CAEATFA to expand its programs statewide on the condition that it is able to source non-ratepayer funds.

Incentive Layering

Incentive layering will be key for whole-building decarbonization. The CPUC is investigating how energy efficiency, distributed energy resources, decarbonization, and low-income program funds can be used together.[239] This investigation also invites coordination amongst programs — for example, electrification with efficiency, such as incentives for advanced air conditioning combined with weatherization to reduce the load. Stakeholders have expressed that regulatory barriers, in some cases, prevent full program participation and do not recognize the full societal benefits that building decarbonization can provide. Whenever possible, stacking or layering incentives upstream with a single point of contact will streamline the process for participants.[240]

For example, participants who enrolled in both Marin Clean Energy's (MCE's) Low-Income Families and Tenants (LIFT) pilot program and the Multifamily Energy Savings program were able to avoid up to 80 percent of upfront costs, which extends the reach and benefits of both programs to address funding gaps that were previously unmet.[241]

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238 Deep decarbonization is defined by the Deep Decarbonization Pathways Project as reducing United States GHG emissions by at least 80 percent from 1990 levels by 2050 via technical and policy pathways that require systemic changes to the energy economy.

239 CPUC. R.19-01-011 Phase II Staff Proposal. https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M345/K591/345591050.PDF.

240 CPUC. Workshop on Incentive Layering for Building Decarbonization (July 2020). https://www.cpuc.ca.gov/about-cpuc/divisions/energy-division/building-decarbonization/workshop-on-incentive-layering-for-building-decarbonization.

241 DNV Energy Systems. 2021. *MCE Low-Income Families And Tenants Pilot Program Evaluation*. https://www.mcecleanenergy.org/wp-content/uploads/2021/07/MCE-Low-Income-Families-and-Tenants-Pilot-Program-Evaluation.pdf.

The CPUC has adopted a set of guiding principles for incentive layering, which applies to several building decarbonization programs, including the BUILD program, TECH initiative, the Wildfire and Natural Disaster Resiliency Rebuild (WNDRR) program, the HPWH subprogram of SGIP, and other EE programs authorized by CPUC. These guiding principles center on "ease of participation, complementary incentives, non-duplicative attribution of program benefits, and ongoing coordination among program administrators and implementers." Of note, the decision allows consideration of program incentives throughout the supply chain and funding to be directed beyond equipment and installation costs, such as panel upgrades and workforce education and training. The decision designates the TECH Initiative implementer to act as a single point of contact and facilitate the implementation of these guiding principles through coordination and data sharing across eligible programs. The implementer may also consider approaches to layer incentives with programs beyond the CPUC's jurisdiction.[242]

Co-Benefits

The benefits of building decarbonization include short- and long-term societal benefits in the form of improved health and safety, increased comfort,[243] fewer utility-scale power plants, improved indoor and outdoor air quality, socioeconomic stimulant for statewide and local economies, jobs, and mitigated or positive impacts on climate change. Building decarbonization will also help California reach its climate goals.

Quantifying the non-energy co-benefits creates new value streams that can be layered with new and existing incentives. This would help overcome current affordability and equity barriers and ensures costs of building decarbonization are not shifted towards renters and low- and moderate-income households.[244]

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242 CPUC. Decision on Incentive Layering, The Wildfire and Natural Disaster Resiliency Rebuild Program, Data Sharing, Rate Adjustments for Electric Heat Pump Water Heaters, and Propane Usage. (D.21-11-002), November 9, 2021. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M421/K107/421107786.PDF.

243 Hayes, Sara, Cassandra Kubes, and Christine Gerbode. May 2020. *Making Health Count: Monetizing the Health Benefits of In-Home Services Delivered by Energy Efficiency Programs*. ACEEE. https://www.aceee.org/sites/default/files/pdfs/h2001.pdf.

California Department of Community Services and Development. November 2020. *Low-Income Weatherization Program (LIWP) Impact Report*. https://csd.ca.gov/Shared%20Documents/LIWP-Impact-Report-November-2020.pdf.

244 Mast, Bruce, Ardenna Energy, LLC, Holmes Hummel, Clean Energy Works, and Jeanne Clinton. July 2020. *Towards an Accessible Financing Solution: A Policy Roadmap With Program Implementation Considerations for Tariffed On-Bill Programs in California*. Building Decarbonization Coalition. https://www.buildingdecarb.org/uploads/3/0/7/3/30734489/bdc_whitepaper_final_small.pdf.

The *Assembly Bill 1232 Report & Action Plan*[245] recommends a "healthy home" three-tiered model approach for multifamily and low-income energy efficiency programs that recognize the health co-benefits created by energy efficiency building retrofits. It assesses how the LIWP for Multifamily Properties (LIWP Multifamily) program fits within this model and could be expanded to provide additional funding and increase health and safety services to the low-income multifamily sector. It identifies additional measures, if made eligible, that could provide added health benefits. It also recommends tracking mechanisms and metrics to quantify health co-benefits that could be used to source additional funds for LIWP Multifamily. With additional funding, the program could expand to provide integrated energy-plus-health services that combines energy and public health goals.

Accelerating building retrofits in California requires creative use of the mechanisms and approaches discussed to achieve decarbonization goals and address affordability and equity barriers faced by California's residents, businesses, and communities.

State Funds Deployment

California has many pathways to fund and finance decarbonization. These are offered by state agencies, utilities, air districts, and private entities. Below are some examples of key state decarbonization initiatives.

BUILD and TECH

As stated earlier, Senate Bill 1477 (Stern, Chapter 378, Statutes 2018) required the CPUC, in consultation with the California Energy Commission (CEC), to create two incentive programs — Building Initiative for Low-Emissions Development (BUILD) and Technology and Equipment for Clean Heating (TECH). These two programs will use gas corporation Cap-and-Trade Program allocated allowance auction proceeds to promote the installation of low-emission and near-zero-emission space- and water-heating technologies in new and existing homes. The programs will promote clean emission technology and work to accelerate market adoption by coordinating with manufacturers, distributors, and contractors. Also, SB 1477 addresses energy equity challenges by reserving a minimum 30 percent of total program funding for new housing in low-income and disadvantaged communities.

In January 2019, the CPUC issued a building decarbonization order instituting rulemaking (OIR) proceeding (R.19-01-011).[246] The CPUC and CEC hosted several interagency and agency

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245 California Department of Community Services and Development. January 2021. *AB 1232 Report & Action Plan*. https://www.csd.ca.gov/Shared%20Documents/AB1232-Report.pdf.

246 CPUC Order Instituting Rulemaking Regarding Building Decarbonization webpage. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M264/K629/264629773.PDF.

workshops, with a final decision adopted in March 2020.[247] The decision (D. 20-03-027) established:

- BUILD: $80 million targeted to technical assistance and incentives for low-income residential all-electric new construction to reduce greenhouse gas emissions. The CEC is the program administrator, issued an implementation plan in 2020, and will be providing technical assistance awards and financing incentives in early 2022. The program will also promote energy equity by requiring that tenants and occupants have bill savings.
- TECH: $120 million with a focus on market adoption of low-emissions space- and water-heating technologies, upstream and midstream activities, for existing single- and multifamily homes. Energy Solutions is the program implementer, and is providing comprehensive guidance on product incentives, workforce development and training opportunities, and quick-start grants.[248] The program will also be exploring tariff-billed financing and is addressing consumer awareness through The Switch is On.[249]

Local Government Challenge

In 2017, the Local Government Challenge, managed by the CEC using American Recovery and Reinvestment Act (ARRA) funds, awarded $7.2 million for Energy Innovation Challenge grants and $3 million for Small Government Leadership Challenge grants. Program goals included energy innovation, small government leadership, climate action planning, and replicability. The program provided grants to 13 local governments to conduct and implement energy efficiency projects and planning. As of September 2021, 11 of the 13 recipients have completed their projects.

One notable building decarbonization project, the Del Mar Civic Center Energy Enhancement Project, installed a solar PV and energy storage system. The solar PV and energy storage system saved the city more than $20,000 in utility bill costs. Outreach efforts were conducted

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247 CPUC Decision Establishing Building Decarbonization Pilot Programs webpage. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M331/K772/331772660.PDF.

248 *Quick-start grants* fund scalable projects, partnerships, and strategies that accelerate deployment of heat pump space & water heating technologies.

249 "Switch is On" is a public information campaign and webpage (https://www.switchison.org/) supporting residential consumers who are considering all-electric conversion. The project is led by the Building Decarbonization Coalition, in partnership with community choice aggregators, municipal utilities, and energy efficiency organizations. The Switch is On webpage provides consumer-friendly information, including all-electric appliance options, electrical system upgrades, costs, and a contractor finder.

to disseminate project results and inspire replication among other local government and commercial sites.

Low-Income Weatherization Program

CSD administers the LIWP funded by the GGRF. LIWP is a direct-install program that funds energy efficiency upgrades and renewable energy systems for affordable multifamily properties. The LIWP goals are to reduce GHG emissions and lower the energy costs in low-income households. The program has been well-received by stakeholders and identified as a model program. However, the program is oversubscribed with a waiting list that consists of more than 14,000 units and is scheduled to end in 2022 based on available funding.[250]

A recent study on targeted electrification in California pointed to the LIWP as a model program for decarbonization.[251] The authors believe the LIWP is one of a handful of programs showing how GHG reductions can be done successfully in low-income and disadvantaged communities. However, new funding for this program has not been allocated since 2019, and there is a long wait list for participation.

As discussed earlier in this chapter, the *Assembly Bill 1232 Report & Action Plan* identifies a pathway to scale the program and implement cross-referrals with public health agencies that could make the case for additional funding from other sources, possibly from the health sector as demonstrated by the Washington State Weatherization Plus Health program.[252]

CAEATFA

CAEATFA collaborates with public and private partners to provide financing solutions for implementing energy efficiency measures, renewables, and manufacturing technologies that align with California's climate goals. It administers the California Hub for Energy Efficiency Financing (CHEEF) programs, which use IOU ratepayer funding to leverage private capital. These programs provide improved loan terms for residential, commercial, and affordable housing customers to cover the upfront costs of deep energy efficiency upgrades. Up to 30

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250 California Department of Community Services and Development. January 2021. Assembly Bill 1232 Report & Action Plan. https://www.csd.ca.gov/Shared%20Documents/AB1232-Report.pdf.

251 Harwood, Meghan, Sean Newlin, Kiki Velez, and Michelle Vigen Ralston. The Flipside Report: A White Paper on Targeted Geographic Electrification in California's Gas Transition. Building Decarbonization Coalition. p. 15. https://www.buildingdecarb.org/uploads/3/0/7/3/30734489/the_flipside_report_-_targeted_electrification_for_gas_transition.pdf.

252 California Department of Community Services and Development. January 2021. Assembly Bill 1232 Report & Action Plan. https://www.csd.ca.gov/Shared%20Documents/AB1232-Report.pdf.

percent of financing can be applied toward non-energy efficiency measures to provide project flexibility.

The GoGreen Home Energy Financing program, a CHEEF program, enrolled 447 new loans in 2020, which represents $7.1 million in financing and a 64 percent increase compared to 2019. Low- and moderate-income census tracts accounted for 61 percent of loans and 54 percent of the total dollar amount. Disadvantaged communities received 21 percent of loans to implement energy efficiency upgrades.

The CPUC has granted CAEATFA an additional $75.2 million in IOU ratepayer funding to operate CHEEF through June 30, 2027. CAEATFA is also conditionally authorized to incorporate non-IOU ratepayer funding to expand the reach of CHEEF programs beyond IOU territories. CAEATFA has been directed to submit a letter within 180 days of the decision to indicate how it plans to source and allocate non-ratepayer funds.[253]

Self-Generation Incentive Program (SGIP)

The CPUC-administered SGIP offers rebates for installing distributed energy technologies in residential and nonresidential locations with an added incentive for qualified equity and equity resilience projects. The CPUC recently authorized (D.20-01-021) an additional $1 billion through 2024 for the program and is considering offering incentives for heat pump water heaters.[254]

Energy Savings Assistance

The Energy Savings Assistance program provides energy efficiency improvements and education at no cost to IOU customers living in residential and multifamily properties and who qualify for CARE rates. The program was reauthorized (CPUC D. 21-06-015) through 2026 with $2.2 billion in additional funds and is expected to treat 1.1 million households. The decision also approved Energy Savings Assistance funding for electrification so long as it passes the revised fuel substitution test.[255] (See description of the Low-Income Families and Tenants Pilot Program below.)

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253 CPUC. Decision Extending California Hub For Energy Efficiency Financing Programs And Conditionally Approving Use Of Plateform For Non-Ratepayer Funded Programs (D.21-08-006), August 5, 2021. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M398/K319/398319629.PDF.

254 CPUC. Order Instituting Rulemaking Regarding Policies, Procedures and Rules for the Self-Generation Incentive Program and Related Issues (R.20-05-012), June 8, 2020, https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M339/K524/339524901.PDF.

255 CPUC. Fuel Substitution in Energy Efficiency. https://www.cpuc.ca.gov/about-cpuc/divisions/energy-division/building-decarbonization/fuel-substitution-in-energy-efficiency.

Climate Catalyst Revolving Loan Fund

Assembly Bill 78 (Committee on Budget, Chapter 10, Statutes of 2020) established the Climate Catalyst Revolving Loan Fund, administered by the iBank, which has a goal to provide low-cost financing for low-carbon technology and infrastructure projects.[256] While the budget plan is still being developed, the fund may source capital from federal and state funds, green bonds, and private capital to accelerate the implementation of projects and technologies that will help California reach its climate goals.

Wildfire and Natural Disaster Resiliency Rebuild Program

The WNDRR program was authorized by the CPUC in November 2021. The WNDRR is funded by the PPP charge and includes $50 million applied over ten years. It will provide incentives for the rebuild of all-electric single-family homes and multifamily buildings that were destroyed by wildfire or other natural disasters. Although the specific incentive structure has yet to be determined, added equity incentives may be available for low-income households and disadvantaged communities. The WNDRR may also offer additional incentives for measures that offer increased GHG emission reductions, such as above code energy efficiency buildings, energy storage systems, and grid responsive measures.[257]

Utility and Local Incentives

LIFT Pilot Program

The LIFT program launched as an Energy Savings Assistance pilot program in 2017 using a $3.5 million grant from the CPUC and was reauthorized through 2023. It is administered by MCE and was developed to address gaps in the market for income-qualified multifamily tenants and property owners.

During Phase 1 of the LIFT program, 865 households, 97 percent of which were income-qualified households, received upgrades resulting in energy savings of 50 kWh and 32 therms per dwelling unit. Ninety-four percent of income-qualified households were outside disadvantaged communities. Seventy-six percent of program participants received two or more qualified upgrades by also participating in MCE's Energy Savings for Multifamily Properties

256 iBank. 2021. California Climate Catalyst Program. https://ibank.ca.gov/climate-financing/climate-catalyst-program/.

257 CPUC. Decision on Incentive Layering, The Wildfire and Natural Disaster Resiliency Rebuild Program, Data Sharing, Rate Adjustments for Electric Heat Pump Water Heaters, and Propane Usage. (D.21-11-002), November 9, 2021. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M421/K107/421107786.PDF.

program. LIFT participants who installed heat pump water heaters (HPWHs) realized average annual savings of $192 per unit.[258]

Some of the lessons learned and recommendations that MCE identified to expand the program include:

- Streamlining the experience for participants by providing a single point of contact to reduce the burden on tenants and property managers.
- Quantifying perceived non-energy benefits that could bring additional value to the program.
- Layering and stacking additional incentives, such as SGIP and TECH, that could maximize benefits to households.
- Considering expanded technologies, such as lower wattage heat pumps, to reduce costs on panel upgrades and electrification upgrades.

Southern California Edison Building Electrification Pilot

Southern California Edison (SCE) is approved to initiate a pilot program to electrify high-usage, income-qualified single-family households in disadvantaged communities.[259] SCE expects participating households to save energy, reduce air pollution, improve indoor air quality, and receive other health and economic benefits. SCE has received $40.8 million over five years to treat 3,130 homes. The program will offer heat pumps for space and water heating, and clothes drying, and other electric measures such as induction cooktops.

Sacramento Municipal Utility District Low-Income Electrification

Sacramento Municipal Utility District (SMUD) has set a goal to electrify all buildings in its service territory by 2045 and all low-income customers by 2040. In response, SMUD launched the Low-Income Electrification program in 2019 as a direct installation program with the goal electrifying every end use in qualified single-family homes, regardless of age or condition of existing equipment.

Direct installation of equipment has delivered significant savings on project costs. Given additional resources, a direct installation program could potentially scale to include all

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258 DNV Energy Systems. 2021. *MCE Low-Income Families And Tenants Pilot Program Evaluation*. https://www.mcecleanenergy.org/wp-content/uploads/2021/07/MCE-Low-Income-Families-and-Tenants-Pilot-Program-Evaluation.pdf.

259 CPUC. June 3, 2021. Decision 21-06-015, Decision on Large Investor-Owned Utilities and Marin Clean Energy's CARE, Energy Savings Assistance, and FERA Program Applications. p. 382.

customers and realize additional volume savings if implemented on a neighborhood scale to allow simultaneous electrification of adjacent homes.[260]

Air Districts

Spread throughout California are 35 air districts that regulate and enforce local air quality (Figure 20).

260 July 12–13, 2021, IEPR Commissioner Workshop on Building Decarbonization: Consumers, Financing, and Workforce. Session 1 webpage, https://www.energy.ca.gov/event/workshop/2021-07/session-1-iepr-commissioner-workshop-building-decarbonization-consumers-and. Session 2 webpage, https://www.energy.ca.gov/event/workshop/2021-07/session-2-iepr-commissioner-workshop-building-decarbonization-financing. Session 3 webpage, https://www.energy.ca.gov/event/workshop/2021-07/session-3-iepr-commissioner-workshop-building-decarbonization.

SMUD comments on July 12–13, 2021, IEPR Commissioner Workshop on Building Decarbonization: Consumers, Financing, and Workforce. https://efiling.energy.ca.gov/GetDocument.aspx?tn=239579&DocumentContentId=73012.

Figure 20: California Air Districts

Source: California Air Resources Board (CARB)

Recent work has been done by some air districts to improve building conditions and replace gas appliances to reduce GHG emissions. For example, the South Coast Air Quality Management District ran a program in Coachella upgrading residential building envelopes and insulation in disadvantaged communities.[261] This program directly invested in upgrading buildings at no cost to the occupant to improve the local air quality. Air districts also have an opportunity to use their regulatory authority to limit nitrous oxide, or NOx, emissions from

261 South Coast Air Quality Management District's Home Weatherization Program webpage, http://www.aqmd.gov/home/programs/community/home-weatherization-program.

buildings. The primary source of these emissions is gas-burning equipment, thus setting caps would push more buildings toward electrification.

CARB Funding Wizard

Finding the right source of funding can be very challenging for people, companies, and governments. CARB set up the Funding Wizard with this in mind. It is a searchable database of grants, loans, rebates, and incentives for clean energy projects.[262] Past CEC reports, such as the *2019 California Energy Efficiency Action Plan*, have pushed for a centralized database of energy efficiency and decarbonization opportunities, which this provides.[263]

Industrial and Agricultural Funding Programs

Funding for industrial and agricultural decarbonization projects and technologies has come from the California Climate Investments Program, which is funded by cap-and-trade dollars and administered by CARB. This program puts billions of dollars to work reducing GHG emissions, strengthening the economy, and improving public health and the environment — especially in disadvantaged communities.[264] Examples of programs funded that are associated with the industrial and agriculture sectors include those administered by the CEC (Renewable Energy for Agriculture Program and the Food Production Investment Program) and California Department of Food and Agriculture (State Water Efficiency and Enhancement Program[265] and the Dairy Digester Research and Development Program[266]). Some of these programs are discussed in Chapter 5.

Other funding programs for industrial and agricultural projects focused on energy efficiency and decarbonization include those offered by energy and water utilities and governmental agencies. Utility programs focus on providing incentives for implementing specific commercially available technologies related to research and development. Governmental funding programs typically focus on research and development activities. Federal programs can be found by going to the Grants.gov website.[267] Detailed information on the CEC's research and development programs and others are contained in Chapter 5.

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262 CARB. Funding Wizard webpage, https://fundingwizard.arb.ca.gov/web/.

263 Kenney, Michael, Heather Bird, and Heriberto Rosales. 2019. *2019 California Energy Efficiency Action Plan*. California Energy Commission. Publication Number: CEC400-2019-010-SF.

264 CARB. California Climate Investments webpage, https://ww2.arb.ca.gov/our-work/programs/california-climate-investments.

265 CDFA State Water Efficiency and Enhancement Program webpage, https://www.cdfa.ca.gov/oefi/sweep/.

266 CDFA Dairy Digester Research and Development Program webpage, https://www.cdfa.ca.gov/oefi/ddrdp/.

267 The Grants.gov webpage is available at https://www.grants.gov/web/grants/home.html.

Program Considerations for Equity

California will need to ensure that funding and financing options cater to the needs of households and businesses within rural regions of the state and Native American Tribes. They face complex barriers not experienced by other households and businesses. The *California Building Decarbonization Assessment* calls for coordination with local community-based organizations and direct investment in these communities. Through this activity, cycles of energy burden and historical lack of program access can begin to be undone.[268]

More detail on the barriers and needs of rural communities as well as Native American Tribes is available in the *California Building Decarbonization Assessment*.[269]

SoCalGas' comments submitted to the IEPR Workshop docket note, "…[T]he low-income program [ESA] must adapt and evolve, to appeal to customers that are unwilling to participate in the current ESA Program design. For example, one major barrier is language for undocumented customers and customers in the Asian community. The ESA program quarterly study indicates only five percent of participants in the ESA program are of Asian descent while Asians make up 11 percent of the total customer population in SoCalGas' service territory." [270]

The utility also identified an income barrier to participation in the low-income program: "There exists a barrier to participation in the low-income program, which is dependent on customer/household income levels. This barrier to entry precludes income-ineligible households of disadvantaged communities requiring energy savings as they may be unable to pay for the costs of energy efficient equipment. We recommend directing more funds for rebates/incentives to specifically target income-ineligible households in disadvantaged communities. Targeting these households not only achieves energy savings, but also enhances public health and safety for families most in need notwithstanding income levels."[271]

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268 Kenney, Michael, Nicholas Janusch, Ingrid Neumann, and Mike Jaske. 2021. California Building Decarbonization Assessment. California Energy Commission. Publication Number: CEC-400-2021-006-CMF. https://www.energy.ca.gov/publications/2021/california-building-decarbonization-assessment. pp. 116–117.

269 Ibid., pp. 118–120.

270 Southern California Gas Company Comments on the July 12–13, 2021, IEPR Commissioner Workshop on Building Decarbonization – Consumers, Financing, and Workforce. TN 239044. Docket 21-IEPR-06. https://efiling.energy.ca.gov/GetDocument.aspx?tn=239044.

271 Ibid.

CHAPTER 5: Embodied Carbon

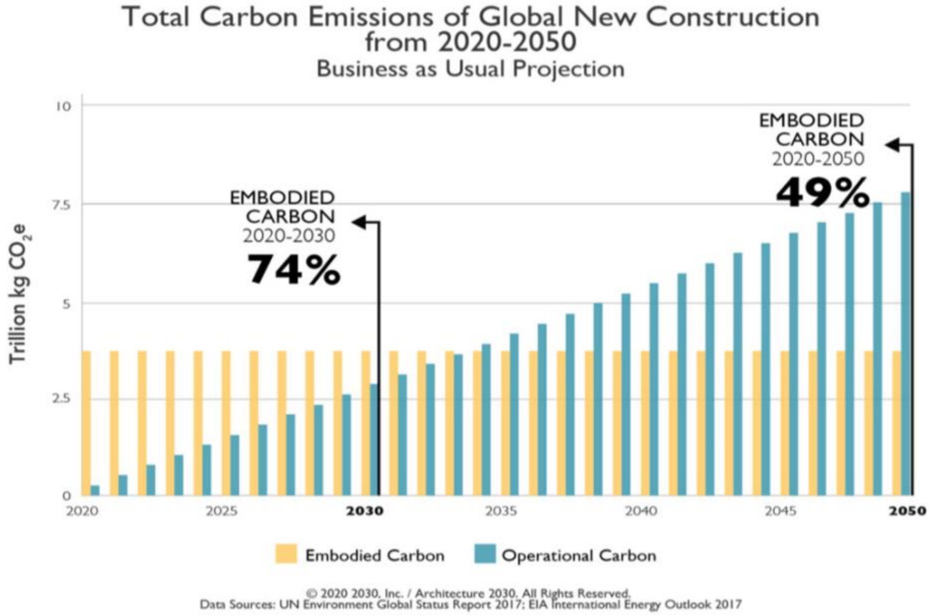
Embodied Carbon Defined

As buildings become increasingly energy-efficient, optimize operations to time-based signals, and incorporate renewable sources of electricity, embodied carbon — or the greenhouse gas (GHG) emissions directly tied to the materials and appliances within buildings — will represent an increasing amount of the total environmental footprint of these buildings. These emissions will need to be accounted for when assessing the total impact of buildings and related operations on the environment.

Embodied carbon refers to the GHG emissions resulting from the extraction, manufacturing, transportation, installation, maintenance, and disposal of building materials.[272] As shown in Figure 21, embodied carbon includes GHGs from building materials included in building structures, enclosures, and finishes. From a climate change perspective, the impact of GHG emissions from construction products is locked-in and immediate. Unlike operational emissions generated from cooking, heating water, and space conditioning — which are generated over time and can be limited by building standards and renewable energy sources — embodied carbon from building materials makes direct impacts to the atmosphere today.

272 Carbon Leadership Forum. Embodied Carbon 101. Version December 17, 2020. https://carbonleadershipforum.org/embodied-carbon-101/.

Figure 21: Total Carbon Emissions of Global New Construction From 2020–2050 (Business-as-Usual Projection)



Source: Architecture 2030

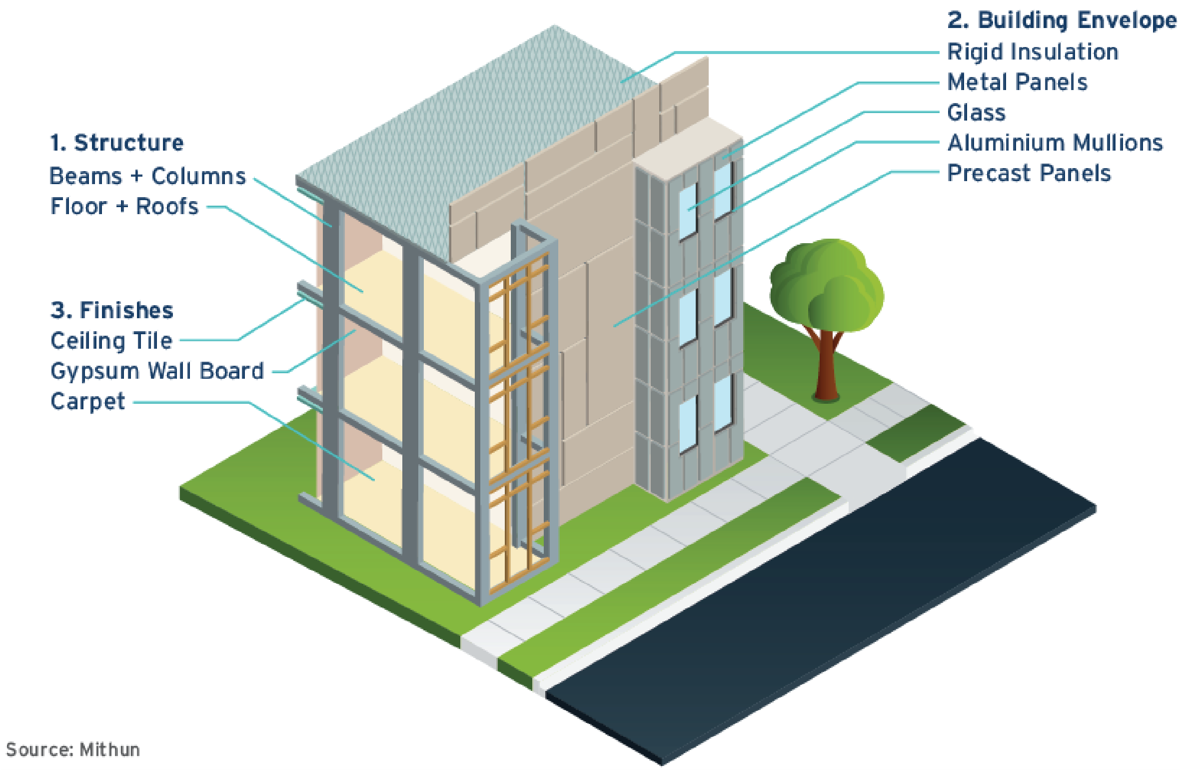
Embodied carbon emissions have a large global impact. According to a 2018 study by the Embodied Carbon Review titled *Embodied Carbon Reduction in 100+ Regulations and Rating Systems Globally*, embodied carbon is increasingly recognized in European and American energy efficient and green building rating systems.[273] Embodied carbon is less recognized, however, in the Middle East, African, and Asia-Pacific regions, where much of global development currently occurs and a surface area the size of Paris is built every five days.[274] While most efforts in place globally to address the issue are still voluntary, many have been, and are increasingly very effective and have moved discussion and research to action, instigating policy initiatives to address embodied carbon.

273 Castro, Rodrigo, Erica Terranova, Tytti Bruce-Hyrkäs, and Panu Pasanen. November 2018. *The Embodied Carbon Review: Embodied Carbon Reduction in 100+ Regulations and Rating Systems Globally*. www.oneclicklca.com/embodied-carbon-review.

274 World Economic Center. 2021. *Decarbonizing Value Chains: The Build Environment, Executive Roundtable Summary*. Available at WEC-RT-Summary-Sept-2021-Built-Environment_final.pdf.

This event brought together 36 senior sustainability and building experts from seven countries, of which 61 percent came from global companies and 39 percent from think tanks, non-governmental organizations, and service providers.

Figure 22: Typical High-Embodied Carbon Structural Elements, Building Envelope Materials, and Finish Materials



Source: Mithun

Embodied carbon is calculated at either the whole-building or individual-material level. At the whole-building level, it is assessed through a *life-cycle* or *carbon* analysis. For the life-cycle analysis, the most common assessments are *cradle-to-gate* and *cradle-to-grave*:

- *Cradle-to-gate* includes the GHG emissions from extracting or harvesting the raw materials, finishing or manufacturing them, and transportation. Transportation includes moving materials from extraction to manufacturing and finally to the project site where the product is to be installed.
- *Cradle-to-grave* includes the GHG emissions from all stages the material goes through, from initial extraction or harvesting, to finishing or manufacturing, to transportation, and also includes carbon generated during construction, use within the building, and finally, end of life as either demolition or a recycled material.

Most current studies and calculations typically include only upfront embodied carbon or cradle-to-gate, as the GHG emissions from use within the building and end of life are still difficult to quantify.

At the individual-material level, building material manufacturers of structural, interior, finish, and furnishing products are increasingly providing environmental product declarations (EPDs) that include the embodied carbon calculation. EPDs are independently verified and registered documents detailing information about the life-cycle GHG emissions (typically cradle-to-gate) associated with the product manufacture. The Carbon Leadership Forum maintains an extensive library of EPDs. According to Kate Simonen, head of the Carbon Leadership Forum (CLF) and a co-presenter at the August 26, 2021, Integrated Energy Policy Report (IEPR) Commissioner Workshop on Embodied Carbon, CLF provides a free, Embodied Carbon in Construction Calculator (EC3). The EC3 tool, "allows owners, green building certification programs, and policymakers to assess supply chain data to create EPD requirements and set embodied carbon limits and reductions at the construction material and project scale."[275] As reported at the August 2021 workshop, EC3 had EPDs for more than 40,000 products and was being used by more than 15,000 individuals.[276] As of October 29, 2021, the number of EPDs had increased to 70,000, and more than 17,000 people were using EC3.[277]

Embodied Carbon in Building Materials

In new building projects, on average, up to 50 percent of total GHG emissions, considered over a 30-year building life, are from the embodied carbon associated with the initial construction, and approximately 70 percent of that is from just six materials — concrete and steel (by far the most significant),[278] flat glass, insulation, masonry, and wood products.[279] There are however significant variations in estimations of the contribution of embodied carbon to the lifetime emissions from a building that warrant further analysis and contextualization for California.

275 Carbon Leadership Forum's Member-Led Initiatives webpage, https://carbonleadershipforum.org/what-we-do/initiatives/ec3/. Accessed October 25, 2021.

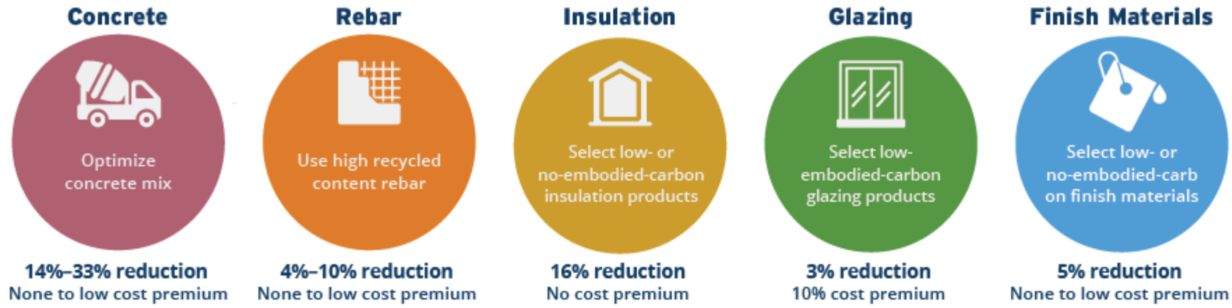
276 Comments by Kate Simonen with the Carbon Leadership Forum. August 26, 2021, IEPR Commissioner Workshop on Building Decarbonization Session 1 transcript. p. 70, Lines 6–9. https://efiling.energy.ca.gov/getdocument.aspx?tn=240146.

277 Email correspondence with Kate Simonen dated October 29, 2021.

278 Presentation by Webly Bowles with New Buildings Institute at the July 22, 2021, New Buildings Institute webinar. "Solving for the 11 Percent Embodied Carbon Footprint in the Build Environment." https://newbuildings.org/event/solving-for-the-11-embodied-carbon-in-the-built-environment/.

279 Ibid.

Figure 23: Top Categories for Reducing Embodied Carbon



Source: RMI

Steel

Globally, according to the World Steel Association, rebar accounts for 44 percent of steel in buildings, sheet products account for 31 percent, and structural steel accounts for 25 percent.[280] Steel production increased by 11.6 percent in 2020 and continues to grow. The most typical production method is blast furnace — basic oxygen furnace steelmaking — and results in 1.73 tons of carbon dioxide (CO_2) emissions per ton of steel.[281]

Efforts are underway to reduce the carbon footprint of steel beyond the current practice of recycling.[282] Tata Steel in the Netherlands is planning to use underwater carbon capture and storage to reduce CO_2 steel manufacturing impact by an estimated 30 percent.[283] European steel manufacturers SSAB and ArcelorMittal are beginning, and planning, to utilize hydrogen, produced via water electrolysis using renewable energy, as a fuel source for manufacturing steel. SSAB produced a first batch of this steel in July 2021 and is marketing it as HYBRIT,

280 Worldsteel Association's Steel in Buildings and Infrastructure webpage, https://www.worldsteel.org/steel-by-topic/steel-markets/buildings-and-infrastructure.html.

281 Blaine Brownell. 2021. "Working Toward a Carbon-Free Steel." *Architect Magazine*. https://www.architectmagazine.com/technology/working-toward-a-carbon-free-steel_o.

282 Hoffman, Christian, Michel Van Hoey, and Benedikt Zeumer. June 3, 2020. "Steel Players Across the Globe, and Especially in Europe, are Increasingly Facing a Decarbonization Challenge." McKinsey & Company. https://www.mckinsey.com/industries/metals-and-mining/our-insights/decarbonization-challenge-for-steel.

283 Tata Steel press release, "Tata Steel Plans to Develop Largest CO_2 Capture Installation in the World." https://www.tatasteeleurope.com/corporate/news/tata-steel-plans-to-develop-largest-CO2-captur-installation-in-the-world.

"the world's first fossil-free steel."[284] While low-emission steel is currently 20 percent to 50 percent[285] more expensive than conventional steel, the Net-Zero Steel Initiative[286] expects the price to become competitive and will advocate for government support and policy interventions to support that transition at COP26 in Glasgow.[287] The Net-Zero Steel Initiative is a project of the Mission Impossible Partnership, an international alliance of climate and industry leaders focused on "supercharging" decarbonization. The initiative is working across the entire value chain of the world's highest-emitting industries — aluminum, concrete/cement, chemical, steel, transport, aviation, shipping, and trucking — in the next 10 years.

Concrete and Cement

Concrete is the most used building material worldwide. Concrete accounts for 6–10 percent of global CO_2 emissions; however, most those emissions (77 percent)[288] are attributable to cement. Cement is the binding material, along with water, that holds concrete together. Cement makes up only about 10–15 percent of concrete, so it accounts for an outsized proportion of GHG emissions from the material. Cement is made by heating a mixture of materials such as limestone and clay to a temperature of about 1,450 degrees Celsius (2,700 degrees Fahrenheit) to form a substance known as *clinker*. Clinker is then ground and mixed with other additives to make cement. Because of the high temperature requirements, producing clinker is one of the most energy- and carbon-intensive industrial processes in the world. Fossil fuels — typically coal — are used to achieve the high heat needed. The GHG

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284 SSAB's HYBRIT technology webpage, https://www.ssab.com/fossil-free-steel/hybrit-a-new-revolutionary-steelmaking-technology.

285 Mission Possible Partnership. 2021. *Steeling Demand: Mobilizing Buyers to Bring Net-Zero Steel to Market Before 2030.* https://www.energy-transitions.org/wp-content/uploads/2021/07/2021-ETC-Steel-demand-Report-Final.pdf.

286 Mission Possible Partnership's Net-Zero Steel Initiative webpage, https://missionpossiblepartnership.org/action-sectors/steel/.

287 Mission Possible Partnership. 2021. *Steeling Demand: Mobilizing Buyers to Bring Net-Zero Steel to Market Before 2030.* p. 35. https://www.energy-transitions.org/wp-content/uploads/2021/07/2021-ETC-Steel-demand-Report-Final.pdf.

COP26 is also known as the 2021 United Nations Climate Change Conference and is being held in Glasgow, Scotland between October 31, 2021 and November 12, 2021.

288 Cao, Zhi, Eric Masanet, Anapam Tiwari, and Sahil Akolawala. 2021. *Decarbonizing Concrete: Deep Decarbonization Pathways for the Cement and Concrete Cycle in the United States, India, and China*. Industrial Sustainability Analysis Laboratory, Northwestern University. https://www.climateworks.org/report/decarbonizing-concrete/. p. 3.

emissions associated with cement result from the combustion of fossil fuels that generate the heat needed for its production and the chemical reactions that occur during production.

Existing methods to reduce emissions from cement include using supplementary cementitious materials (SCM)[289] such as limestone that can be substituted for a portion of cement (up to 15 percent according to ASTM). Other SCMs are fly ash, slag, pozzolanic materials including recycled glass, and even rice husks, although some of these alternatives, while effective, are becoming scarce. (For example, fly-ash is a by-product of coal-fired generation and is becoming less available as coal-fired power plants are replaced by cleaner fuels.) A new technology under development replaces natural limestone with carbonate rocks produced using CO_2. Alternative fuels, such as hydrogen, if used in cement production could also eliminate a portion of GHG emissions.[290]

Construction scheduling is a simple solution that can also make a difference. A longer set time allows a concrete mix with less cement to reach strength comparable to a faster drying high cement mix.

Additional Products

Glass, insulation products, masonry, and wood all, to a lesser extent than concrete and steel, contribute to embodied carbon, but can also, depending upon the product, contribute to a solution. Wood, for example, is a significant carbon sink,[291] it captures more carbon from the environment than it releases. Wood is composed of roughly 50 percent carbon. Where it is available, it is increasingly being used as a structural material in 'mass timber', replacing concrete and steel cross laminated timber, glue laminated timber (also known as "glulam"), and dowel laminated timber. Other carbon-rich, plant-based materials such as bamboo, straw, hempcrete, and cellulose, already in limited use, are currently being developed into more available products for the commercial construction market.

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289 SCMs are materials that, when used in conjunction with portland cement, portland limestone cement or blended cements, contribute to the properties of hardened concrete through hydraulic and/or pozzolanic activity. This reduces the amount of cement and therefore carbon that results from concrete production.

290 Czigler, Thomas, Sebastian Reiter, Patrick Schulze, and Ken Somers. 2020. *Laying the Foundation for a Zero-Carbon Cement*. McKinsey & Company. https://www.mckinsey.com/industries/chemicals/our-insights/laying-the-foundation-for-zero-carbon-cement.

291 A carbon sink is anything that typically absorbs more carbon from the atmosphere than it releases. Examples include plants, soil, and the ocean.

Embodied Carbon Research and Goals

Around the United States and the world, numerous organizations, think tanks, and universities are researching embodied carbon. Some examples include:

- **CLF:**[292] Housed at the University of Washington, Seattle, and working since 2009 to accelerate a transformed, decarbonized building industry. CLF is a resource for embodied carbon research, building case studies, life cycle assessment (LCA) specifications, EPDs, toolkits, and the EC3 tool.
- **New Buildings Institute (NBI):**[293] NBI has been working for 25 years to achieve both zero energy and zero carbon in the built environment through research, education, and most importantly, policy and code development. NBI's Getting to Zero Resource Hub[294] includes information about guides, models, research, case studies, and educational webinars on carbon-neutral buildings.
- **Structural Engineers Institute (SEI):**[295] SEI issued the SE2050 Commitment to reduce and eliminate embodied carbon in structural systems by 2050. Currently in a data gathering phase, more than 60 major national and international structural engineering firms are participating, both preparing Embodied Carbon Action Plans and reporting on project data.
- **Architecture 2030:**[296] A nonprofit thought leader and offshoot of the American Institute of Architects (AIA), Architecture 2030 has challenged American architectural firms to commit to designing 100 percent of buildings to a zero-emissions standard by 2050. This expands its founding goal of designing all new buildings and major renovations to net-zero-energy by 2030.
- **Buro Happold:**[297] Buro Happold is an integrated engineering firm committed to having all its projects be zero-carbon by 2050. In step with Architecture 2030, the firm has further challenged all engineering firms to commit to building all projects to a zero-carbon standard by 2050.

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292 Carbon Leadership Forum webpage, https://carbonleadershipforum.org/.

293 New Buildings Insitute webpage, https://newbuildings.org/.

294 New Buildings Institute's Getting to Zero Resource Hub webpage, https://newbuildings.org/resource/getting-to-zero-resource-hub/.

295 American Society of Civil Engineers webpage, https://www.asce.org/.

296 Architecture 2030 webpage, https://architecture2030.org/.

297 Buro Happold webpage, https://www.burohappold.com/.

Tools and Resources

LCAs, also known as *carbon assessment tools,* are the standard for determining the impact of embodied carbon. Green building rating systems, originally developed to encourage energy, water, and resource efficiency, are now also requiring LCAs. Examples of rating systems and tools follow.

Voluntary Rating Systems

- **BREEAM:**[298] BREEAM is a green building rating and certification system that is carbon-based. Developed in the United Kingdom and used in Canada and to a limited extent in the United States, it includes LCA requirements
- **Leadership in Energy and Environmental Design (LEED):**[299] The United States Green Building Council (USGBC) developed, and with the Green Building Certification Institute (GBCI) implements LEED, a green building rating and certification system with versions for new residential and nonresidential buildings, schools, and existing buildings. The most commonly used green building rating system in the United States, LEED includes LCA requirements.
- **Living Building Challenge:**[300] Living Future Institute's Zero Carbon and Living Building certification systems contain rigorous rating criteria. Living Buildings are rated based on the benign and positive relationship to nature, water, energy, materials, health, community, and beauty.

LCA Tools

- **Athena Institute:**[301] The nonprofit Athena Sustainable Materials Institute offers a range of free LCA software tools and EcoCalculators for a variety of construction applications. The roots of Athena go back to work that began at Canada's national wood products research institute in 1989. A consortium team researched and produced data for structural and envelope building materials in alignment with then-evolving European ISO standards for LCA.

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298 BREEAM USA webpage, https://www.breeam.com/usa/.

299 U.S. Green Building Council's webpage, https://www.usgbc.org/leed.

300 International Living Future Institute's Living Building Challenge webpage, https://living-future.org/lbc/.

301 Athena Sustainable Materials Institute webpage, http://www.athenasmi.org/.

- **One Click LCA:**[302] One Click LCA is a for-profit European based carbon assessment and LCA tool that integrates with many voluntary and mandatory rating systems and LCA reporting requirements.
- **Tally®:**[303] Tally is an Autodesk® application that allows architects and engineers to coordinate the environmental impact of building and whole-building LCA with the Revit® architectural design platform.
- **eConLCA:**[304] A European-based LCA tool, eConLCA compiles country-specific construction products databases into a single multinational application and helps project developers comply with LEED, BREEAM, and other green building rating systems.
- **EarthShift Global:**[305] EarthShift Global is both an LCA software tool and an LCA training services resource for a wide variety of industries and clients.
- **EC3:**[306] The CLF EC3 tool is a free resource that allows benchmarking, assessment, and information needed to reduce embodied carbon, focused on the upfront supply chain emissions of construction materials.

Databases

- **Carbon Smart Materials Palette®:**[307] Developed by Architecture 2030, the Carbon Smart Materials Palette is designed to support LCAs and EPDs and provide guidelines for low- and no-carbon material selections and specifications.
- **EPD Registry™:**[308] The registry is an international construction products database containing EPDs and toolkits for low-carbon construction products throughout Europe, South America, Australia, and New Zealand.

302 One Click LCA webpage, https://www.oneclicklca.com/.

303 Link to KT Innovations' Tally application, https://apps.autodesk.com/RVT/en/Detail/Index?id=3841858388457011756&appLang=en&os=Win64.

304 The EPD Registry's eConLCA tool webpage, https://www.theepdregistry.com/econlca/.

305 EarthShift Global webpage, https://earthshiftglobal.com/.

306 Link to Carbon Leadership Forum's EC3 tool, https://carbonleadershipforum.org/what-we-do/initiatives/ec3/.

307 Carbon Smart Materials Palette webpage, https://materialspalette.org/palette/.

308 The EPD Registry webpage, https://www.theepdregistry.com/.

Embodied Carbon Policy Action

California

A first in the nation and widely emulated, the Buy Clean California Act[309] (Public Contract Code Sections 3500–3505) is an innovative program establishing limits on embodied carbon emissions and construction materials procured by the state for public construction projects. The law requires the California Department of General Services (DGS) to publish, by January 1, 2022, acceptable maximum GWP limits for the following eligible materials: structural steel, concrete reinforcing steel (rebar), flat glass, and mineral wool board insulation. Daniel Garza, senior procurement engineer at DGS and co-coordinator for Buy Clean California, discussed the program at the August 26, 2021, IEPR workshop on embodied carbon. State building projects under contract after July 1, 2022, will be required to provide EPDs demonstrating that building products meet the GWP limits being established by DGS in consultation with CARB.[310]

To address fossil fuel use in cement production, Senate Bill 596 (Becker, Chapter 246, Statutes of 2001) requires CARB to release a plan for achieving cement carbon neutrality by the summer of 2023, with a goal of cutting emissions by 40 percent below 2019 levels in seven years. Reaching net-zero emissions in steel, cement, concrete, and other building products will, as in other carbon-intensive sectors, require a commitment and collaboration from producers, customers, and regulators, with strong demand-side signals to demonstrate there is a market for low-carbon products.

Challenges to Implementation of Embodied Carbon Reductions

At the August 26, 2021, IEPR commissioner workshop, Rebecca Dell, industry program director at ClimateWorks Foundation, discussed some of the challenges California faces reducing embodied carbon from buildings. Foremost, the mild climate, increasing renewable electricity supply, and relatively efficient building stock mean that operational energy is a small percentage of total building energy use, compared to the embodied energy in new construction. Without education, for the building industry and general public, about the contribution of embodied carbon, operational energy statistics give a false impression of low overall carbon impact in the built environment.

California is also home to eight coal-fired cement kilns. While reaching carbon neutrality in that industry is feasible, it will be difficult, given the high temperatures needed for cement

309 DGS webpage for the Buy Clean California Act, https://www.dgs.ca.gov/PD/Resources/Page-Content/Procurement-Division-Resources-List-Folder/Buy-Clean-California-Act.

310 August 26, 2021, IEPR Commissioner Workshop on Building Decarbonization: Embodied Carbon and Refrigerants Session 1 transcript, p. 36. https://efiling.energy.ca.gov/getdocument.aspx?tn=240146.

production.[311] Building material manufacturing also produces additional air-polluting emissions and may contaminate water and generate other waste products.[312]

Despite these challenges, organizations and jurisdictions in California have made progress in reducing embodied carbon from buildings. For example, in 2008, Siegel & Strain studied GHG emissions from the building materials and overall construction process on one of their projects, the Portola Valley Town Center. The result showed 449 tons carbon dioxide equivalent (CO_2e) overall. Although this was primarily a wood-framed building, the concrete used in the foundation was the largest source of emissions, accounting for about 38 percent overall. The largest sources of GHGs were:[313]

- Concrete (172 tons).
- Metals such as rebar, structural steel, roofing (59 tons).
- Wood framing (36 tons).
- Insulation (28 tons from expanded polystyrene insulation and 13 tons from batt insulation).
- Gypsum board (22 tons).

Marin County developed and adopted a first-in-the-nation low-carbon concrete building ordinance.[314] This ordinance took effect January 1, 2020, and requires limits to cement content or an increase in the use of cement alternatives such as fly ash or pozzolans in public and private concrete applications. An exception is allowed if the developer can demonstrate to the building official that concrete with high early strength is required, in which case the cement content may be increased by 30 percent. Examples include precast, prestressed concrete; beams; slabs above grade; and shotcrete. Batch certificates or EPDs or both are required to demonstrate compliance with the ordinance.

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311 Cao, Z., E. Masanet, A. Tiwari, and S. Akolawala. 2021. *Decarbonizing Concrete: Deep Decarbonization Pathways for the Cement and Concrete Cycle in the United States, India, and China*. Industrial Sustainability Analysis Laboratory, Northwestern University. https://www.climateworks.org/wp-content/uploads/2021/03/Decarbonizing_Concrete.pdf.

312 CARB. Pollution Mapping Tool. https://www.arb.ca.gov/ei/tools/pollution_map/.

313 Presentation by David Kaneda with New Buildings Institute at the July 22, 2021, New Buildings Institute webinar. "Solving for the 11 Percent Embodied Carbon Footprint in the Built Environment." https://newbuildings.org/event/solving-for-the-11-embodied-carbon-in-the-built-environment/.

314 County of Marin's Low-Carbon Concrete Requirements webpage, https://www.marincounty.org/depts/cd/divisions/sustainability/low-carbon-concrete.

Stakeholder Suggestions to Advance State Policy on Embedded Carbon

Presenters at the August 26, 2021, IEPR commissioner workshop on embodied carbon provided suggestions for how California could further account for and reduce embedded carbon from California's buildings. For example, Siegel and Strain, a California-based architectural firm, is committed to low-carbon construction. In his presentation to the August 26, 2021, IEPR Commissioner Embodied Carbon workshop, firm Principal Henry Siegel, American Institute of Architects, advocated for the following policy actions:[315]

- Create incentives to renovate existing buildings and reuse building materials and infrastructure to reduce operating and embodied emissions. He pointed out that existing buildings, are key as they are often inefficient and "from an embodied carbon standpoint, we can't afford to replace them all. [And] we can't afford to leave them alone."
- Use low-carbon materials in building upgrades, starting with lowering emissions from concrete.
- Conduct comprehensive energy and carbon benchmarking and audits for large buildings. Also, develop EPDs for building renovation and retrofits.
- Develop a Home Energy Score for residential buildings at the point of sale.
- Implement rigorous performance revisions to Title 24, Part 10, the California Existing Building Code.
- "Reboot" CALGreen to include exemplary low-carbon design and construction criteria.

Bruce King, author of *The New Carbon Architecture*,[316] echoed Henry Siegel's call for existing building renovation and reuse. Further, Mr. King advocated for manufacturing building products from indigenous, plant-based materials such as straw, hemp, and algae. He suggested that the goal is not just reducing carbon from buildings, but eventually storing and "drawing down" 15 gigatons of carbon a year by 2050.[317]

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315 August 26, 2021 IEPR Commissioner Workshop Embodied Carbon Session 1 Pages 83 – 90 TN 240146 transcript https://efiling.energy.ca.gov/getdocument.aspx?tn=240146.

316 Ecological Building Network webpage on The New Carbon Architecture, https://www.ecobuildnetwork.org/projects/new-carbon-architecture.

317 August 26, 2021, IEPR Commissioner Workshop on Building Decarbonization: Embodied Carbon and Refrigerants Session 1 transcript, p.64, Lines 14–25.

Policy Initiatives Outside California

Jurisdictions outside of California are also taking action to reduce embodied carbon. Examples include:

- **Vancouver, British Columbia**: Requires an LCA and an embodied carbon report from projects requesting rezoning. (This is a reporting requirement only; there are no performance targets.)[318]
- **Portland, Oregon:** City projects must provide EPDs that disclose the volume of emissions from concrete.[319]
- **Quebec and British Columbia, Canada**: "Wood First"[320] and "Wood Charter"[321] initiatives for midrise buildings encourage the use of wood construction technologies.
- **Denver, Colorado:** The City of Denver contracted with Lotus Engineering and Sustainability to conduct a study titled, *Denver's Building Sector Embodied Carbon Emissions*[322] that was published in June 2021. The city is currently working to develop code requirements to address embodied carbon.
- **World Business Council for Sustainable Development (WBCSD):** The WBCSD developed the Building Carbon System Framework tool[323] to provide a common language to promote collaboration and achieve decarbonization across the full life cycle of buildings. An intensive and comprehensive whole-building life-cycle assessment was conducted in collaboration with Arup on six European buildings using the WBCSD Framework to test the tool. The key outcomes from this collaboration are the need to:
    - Commit to WBLCA on all projects.

318 City of Vancouver. *Green Buildings Policy for Rezoning- Process and Requirements*. Effective July 22, 2010. https://bylaws.vancouver.ca/Bulletin/bulletin-green-buildings-policy-for-rezoning.pdf. p. 14.

319 City of Portland, Oregon's Current Sustainable Procurement Initiatives webpage, https://www.portland.gov/omf/brfs/procurement/sustainable-procurement-program/sp-initiatives.

320 Victoria, British Columbia, Canada's Wood First Act. October 29, 2009. https://www.bclaws.gov.bc.ca/civix/document/id/complete/statreg/00_09018_01.

321 Quebec's "The Wood Charter: Taking Stock" publication, https://mffp.gouv.qc.ca/wp-content/uploads/BilanCharteduBois_anglais.pdf.

322 Denver Climate Action, Sustainability & Resiliency, Lotus Engineering & Sustainability. 2021. Denver's Building Sector Embodied Carbon Emissions. https://www.denvergov.org/files/assets/public/climate-action/documents/hpbh/nze/denvers-building-sector-embodied-carbon-emissions-june-2021.pdf.

323 World Business Council for Sustainable Development's Net-Zero Buildings: Where Do We Stand? publication, https://www.wbcsd.org/Programs/Cities-and-Mobility/Sustainable-Cities/Transforming-the-Built-Environment/Decarbonization/Resources/Net-zero-buildings-Where-do-we-stand.

- Develop consistent and transparent carbon intensity and benchmark data.
  - Define explicit targets.
  - Define net-zero buildings.
  - Establish wider collaboration.
- **Denmark:** A co-presenter at the August 26, 2021, IEPR commissioner workshop, Harpa Birgisdottir, Senior Researcher at the Danish Building Research Institute, outlined the path that Denmark has followed since 2011 to reach the mandatory building CO_2 emission levels that will go into effect in 2023.[324] The process includes:
  - Rigorous and increasing building efficiency targets.
  - Voluntary green building rating system with low-carbon targets.
  - Focus on LCAs and education for building professionals.
  - Research including in depth CO_2 LCA case studies of 60 buildings/building types.
  - Mandatory and higher Voluntary CO_2 thresholds to become effective in 2023.

In California and abroad, there is enormous potential for innovation and use of low-carbon products in the built environment. Further research and development are needed, as well as collaboration with other jurisdictions, to develop best practices for reducing embodied carbon in buildings. Also, city planners, designers, and architects could benefit from greater clarity around low-carbon label claims and material-neutral embodied carbon standards.

Embodied Carbon Code Development

NBI is currently working to develop embodied carbon building material code language[325] for the next version of the International Building Code (IBC) and the International Residential Code, both of which are due January 10, 2022.

The basic structure that NBI proposes is to require EPDs for specific products, and to require that a smaller subset of materials meet low-embodied carbon requirements through two options, one of which is a material GWP limit. NBI is also working within the ASHRAE 189.1 process to include similar language there.

NBI drafted preliminary code language, now in Beta format, currently being reviewed and field tested by a small number of jurisdictions around the country, including the City of Denver.

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324 August 26, 2021, IEPR Commissioner Workshop on Building Decarbonization: Embodied Carbon and Refrigerants Session 1 transcript, pp. 25–32.

325 Codes for Climate resources web page, https://www.codesforclimate.org/resources/.

The draft language suggests three broad approaches, EPD reporting, material requirements, and whole building LCAs:

EPD Reporting:

- Require Product-specific Type lll EPDs for:
  - 100 percent of concrete and steel products.
  - 75 percent for flat glass, insulation, masonry units, and wood products.

Material Approach:

- Require GWP limits for:
  - Concrete kg-CO_2e/m^3 based on compressive strength.
  - Structural steel kg-CO_2e/pound.
  - Structural steel recycled content.

Whole Building LCA:

- Reporting only, or with proscribed LCA targets that must be met.

The City of Denver[326]

Working with NBI, Denver is planning to have its draft embodied carbon building code ready for public review by the summer of 2022 and will then begin moving it through the legislative process.

Current Challenges in California

According to Rebecca Dell, Industry Program Director at ClimateWorks Foundation, and the moderator and key presenter at the August 26 IEPR Commissioner Embodied Carbon workshop, California faces significant challenges in addressing embodied carbon.

Foremost, the mild climate, clean renewable electricity supply, and relatively efficient building stock mean that, in new construction, operational energy is a smaller overall percentage of total building energy use than the embodied energy in building materials. To meet the state's carbon reduction goals, it is imperative that the state address embodied carbon in building materials.

326 City of Denver, Colorado. 2022 Building and Fire Code and Denver Green Code Adoption Process. https://www.denvergov.org/Government/Agencies-Departments-Offices/Community-Planning-and-Development/Building-Codes-Policies-and-Guides/Building-and-Fire-Code-Adoption-Process.

Also, California is also home to eight coal-fired cement kilns, and while reaching carbon neutrality in that industry is feasible, it will be difficult, given the high temperatures needed for cement production.[327]

Building material manufacturing also produces additional air polluting emissions, as well as contaminated water and waste products.[328]

327 Climateworks Foundation. March 16, 2021. "Decarbonizing Concrete: Deep Decarbonization Pathways for the Cement and Concrete Cycle in the United States, India, and China." https://www.climateworks.org/report/decarbonizing-concrete/.

328 CARB. Pollution Mapping Tool. https://www.arb.ca.gov/ei/tools/pollution_map/.

CHAPTER 6: Industrial and Agricultural Decarbonization

Although decarbonization of the industrial and agricultural sectors largely involves changes in processes or technologies, the strategies for decarbonization are similar to those for decarbonizing homes and businesses.

The industrial and agricultural sectors account for roughly 21 percent and 7.6 percent, respectively, of California's greenhouse gas (GHG) emissions.[329] Industrial emissions are primarily due to fuel combustion from sources that include refineries, oil & gas extraction, cement plants, and cogeneration emissions attributed to thermal energy output. Process emissions, such as from clinker production in cement plants and hydrogen production for refinery use, and fugitive emissions (for example GHGs released from chemical reactions during manufacturing processes) also contribute significantly to the total emissions for this sector and are estimated to account for more than half of the industrial GHG emissions.[330] Of the agricultural emissions, around 71 percent are emitted from livestock.[331] While no single solution will decarbonize the agricultural and industrial sectors, further research and development is needed to expand the opportunities available.

Decarbonization in the Industrial Sector

California's robust industrial sector plays a significant role in making the state's economy the world's fifth largest with $3.2 trillion gross domestic product (GDP) in the first quarter of 2021. The state also ranked first in the nation in manufacturing GDP in 2020. In 2020, the industrial sector accounted for more than 10 percent of California's total GDP and employed more than 7.5 percent of the workforce (1.2 million employees). California's top three manufacturing sectors by value are (1) computer and electronic products, (2) chemicals, and (3) food, beverage, and tobacco products. California also produces petroleum products, aerospace and

329 California Air Resources Board (CARB). July 28, 2021. California Greenhouse Gas Emissions for 2000 to 2019, Trends of Emissions and Other Indicators.
https://ww3.arb.ca.gov/cc/inventory/pubs/reports/2000_2019/ghg_inventory_trends_00-19.pdf.

330 Based on data from California Greenhouse Gas Emissions for 2000 to 2019, Trends of Emissions and Other Indicators (https://ww3.arb.ca.gov/cc/inventory/pubs/reports/2000_2019/ghg_inventory_trends_00-19.pdf). (See Table 13.) Assumes 60 percent of cement GHG emissions is process related and 100 percent of the other emissions from release of GHG during chemical processing.

331 Ibid.

transportation equipment, durable goods, cement, glass, wood, fabricated metal products, machinery, motor vehicles and parts, as well as electrical equipment and appliances.[332]

California's industrial sector consumes 23 percent of the total energy used in the state and accounts for more than 30 percent of the state's gas consumption.[333] Industry is the second-largest contributor of GHG emissions in California (second to the transportation sector), contributing 21 percent of the state's GHG emissions.[334]

According to a study by the Energy Futures Initiative, gas accounts for 55 percent of the total energy consumption in the industrial sector, followed by petroleum (29 percent), electricity (11 percent), renewables (3 percent), and coal (2 percent), as of 2016 (Figure 24).[335] Gas consumption by industrial users has remained relatively constant since 1996, with an annual consumption of about 700 billion cubic feet.[336] The two largest industrial consumers of gas in California are manufacturing (39 percent) and oil and gas production (34 percent). Chemicals, food, and cement make up two-thirds of the gas use within manufacturing.[337]

332 Bureau of Economic Analysis. U.S. Department of Commerce 2021 First Quarter Dataset.

National Association of Manufacturers. 2021 California Manufacturing Data webpage, https://www.nam.org/state-manufacturing-data/2021-california-manufacturing-facts/.

333 United States Energy Information Administration (U.S. EIA). California state profile and energy estimates webpage, https://www.eia.gov/state/?sid=CA.

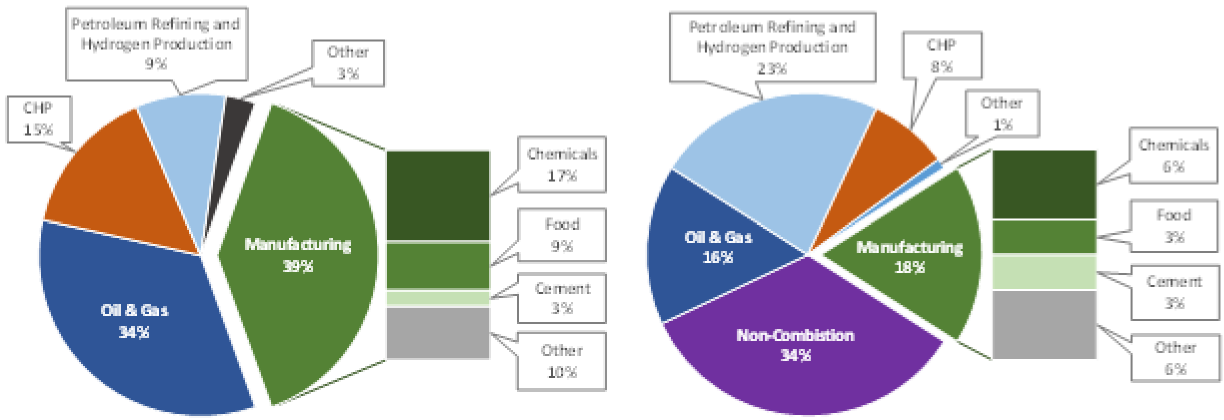
334 CARB. July 28, 2021. California Greenhouse Gas Emissions for 2000 to 2019, Trends of Emissions and Other Indicators. https://ww3.arb.ca.gov/cc/inventory/pubs/reports/2000_2019/ghg_inventory_trends_00-19.pdf.

335 Energy Futures Initiative. 2019. Optionality, Flexibility, and Innovation. https://static1.squarespace.com/static/58ec123cb3db2bd94e057628/t/5ccb4cf87817f7881c4c58e6/1556827401738/FINAL+OFI.pdf.

336 U.S. EIA. Natural Gas Consumption by End Use for California in 2021. https://www.eia.gov/dnav/ng/ng_cons_sum_dcu_SCA_a.htm.

337 Energy Futures Initiative. 2019. Optionality, Flexibility, and Innovation. https://static1.squarespace.com/static/58ec123cb3db2bd94e057628/t/5ccb4cf87817f7881c4c58e6/1556827401738/FINAL+OFI.pdf.

Figure 24: Gas Use (Left) and GHG Emissions (Right), by Industrial Subsector



Data from 2016. Source: Energy Futures Initiative (2020)

Roughly 200 industrial facilities, out of more than 700 reporting entities, are required to report to CARB through its Regulation for the Mandatory Reporting of Greenhouse Gas Emissions.[338] Those reporting entities above the Cap-and-Trade Program thresholds are also subject to the requirements of the Cap-and-Trade Regulation. A list of industrial sectors with the highest GHG emissions along with the number of facilities is in Table 11.

Table 11: Industry Sectors With the Highest GHG Emissions in California

Emissions Rank	Sector	Million Metric Tons Carbon Dioxide Equivalent (MMT CO_2e)	# Facilities
1	Refinery (with or without a Hydrogen Plant)	31	20
2	In-State Electricity Generation	26	166
3	Oil and Gas Production	17	59
4	Cement Plant	7.8	8
5	Cogeneration	5.2	32
6	Hydrogen Plant	3.3	7
7	Food (Other Combustion Source)	2.4	86

338 CARB. Mandatory GHG Emissions Reporting webpage, https://ww2.arb.ca.gov/our-work/programs/mandatory-greenhouse-gas-emissions-reporting.

Emissions Rank	Sector	Million Metric Tons Carbon Dioxide Equivalent (MMT CO_2e)	# Facilities
8	Mining (Other Combustion Source)	1.8	7
9	Wood & Paper (Other Combustion Source)	0.8	18
10	Glass (Other Combustion Source)	0.69	10
11	Chemicals (Other Combustion Source)	0.67	20
12	Metals (Other Combustion Source)	0.60	19
13	Materials (Other Combustion Source)	0.34	15

Source: CARB, Annual Summary of GHG Emissions, 2020; Guidehouse, 2021

A 2018 decarbonization report by E3 investigated a variety of mitigation scenarios to achieve a 40 percent reduction in GHG emissions by 2030 and 80 percent reduction by 2050, relative to 1990 emissions. E3's report[339] indicates that to meet the statewide GHG emissions reduction goals by 2050 the following reductions are needed, relative to 2015 usage:

- 20 percent reduction in total industrial, nonpetroleum, energy demand
- 90 percent reduction in refinery and oil and gas extraction energy demand

End Uses

Energy usage within California's industrial sector varies due to the numerous processes and equipment that are used to manufacture the vast range of products. A breakdown of the average energy consumption by application in industrial facilities is shown in Figure 25. In the plot, total fuel-fired (red) and electrical (blue) uses are shown in separate graphs, while the y-axis is percentage of the combined total plant energy.

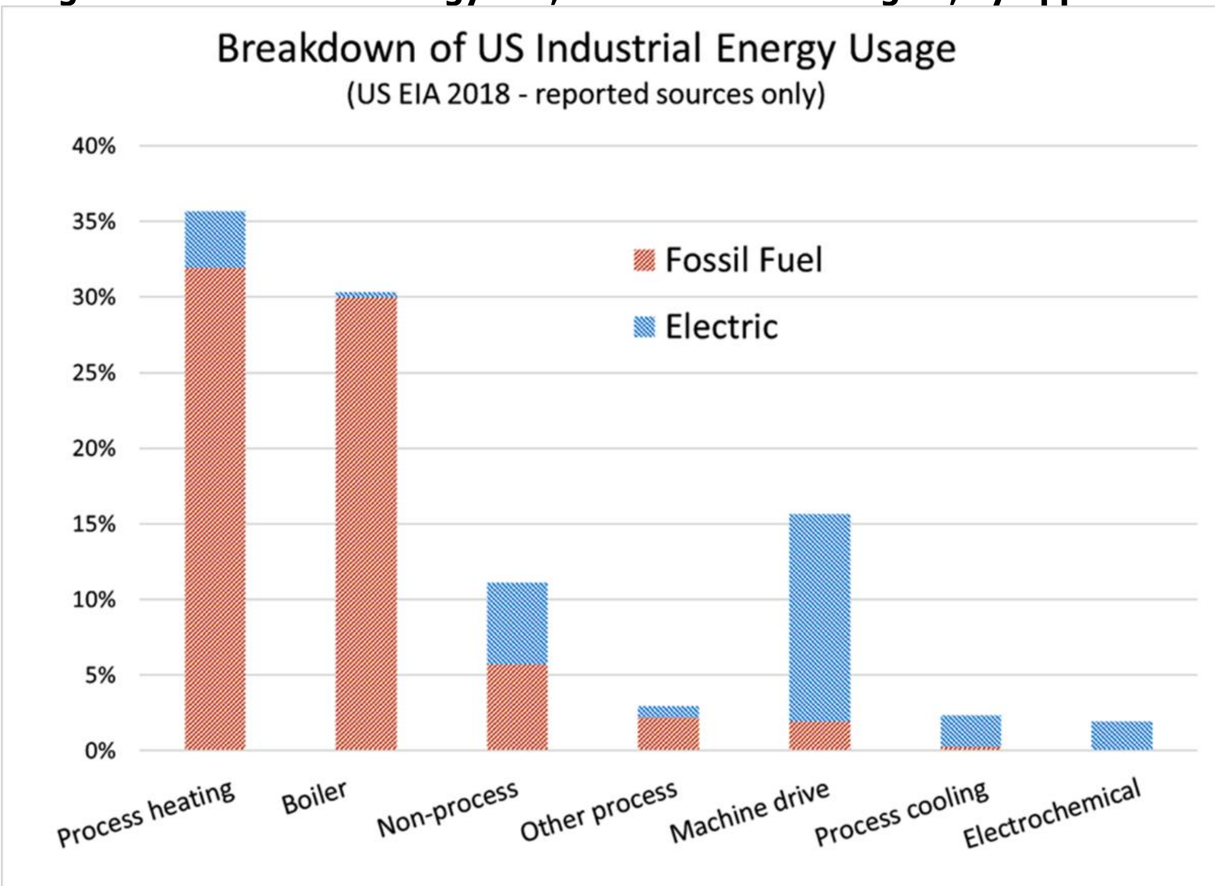
Direct and indirect heating accounts for about 85 percent of industrial gas use in California. Industrial heating processes include drying, heat treating, curing, and forming, calcining, smelting, and other industrial operations.[340] Typical industrial heating equipment includes boilers, furnaces, ovens, dryers, heaters, kilns, evaporators, and catalytic or thermal oxidizers,

339 Mahone, Amber, Zachary Subin, Jenya Kahn-Lang, Douglas Allen, Vivian Li, Gerrit De Moor, Nancy Ryan, and Snuller 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.

340 Thiel, Gregory P., and Addison K. Stark. March 17, 2021. "To Decarbonize Industry, We Must Decarbonize Heat." *Joule*. https://www.sciencedirect.com/science/article/abs/pii/S2542435120305754.

which produce heat mostly via gas combustion. Machines drives, heating, cooling, and electrochemical reactions account for the bulk of electricity use in industrial plants.

Figure 25: Industrial Energy Use, Western Census Region, by Application



Source: U.S. EIA, 2018 Manufacturing Energy Consumption Survey; Guidehouse 2021

Challenges and Barriers to Industrial Decarbonization

Industrial decarbonization is hindered by the diversity of industrial processes, the lack of real-world data on emerging technologies, and several technical and economic challenges. The discussion of barriers and opportunities described below draws on input from participants of the August 3, 2021, Integrated Energy Policy Report (IEPR) Commissioner Workshop to Accelerate Industrial Decarbonization.

Capital Costs

Economics are a key driver for decision-making in manufacturing and industry. Industrial equipment is capital-intensive, and industrial plants are designed and built to be operated for extended periods. Replacing equipment with more energy efficient technologies, switching fuels, or incorporating other decarbonization methods require upfront costs.

Operating Costs

Like capital costs, the operating cost of a fuel is critical when considering fuel switching. The cheaper price of methane compared to electricity discourages fuel switching away from methane.

Infrastructure

New infrastructure will be required for decarbonization, such as additional electricity generation and delivery infrastructure to support electrification, or construction of pipelines for decarbonization efforts involving green hydrogen or carbon capture and utilization or sequestration, respectively.

Disruption to Process

For the industrial sector, energy efficiency or decarbonization upgrades often necessitate shutting down processes, thereby disrupting goods production. Such upgrades may be accomplished only in narrow time frames when the process or section of the building is shut down for maintenance. This means that efficiency upgrades and financing must be planned well in advance.

Heterogeneity and Deep Integration

The industrial sector has a variety of subsectors that manufacture a range of products using unique methods and equipment, sometimes at the same plant. The variation within the industrial sector does not lend itself to drop-in replacement technologies that are broadly applicable within and across subsectors. Custom utility programs exist to resolve this, but barriers to defining a proper baseline or justifying the incentive often result in the window of opportunity passing.

Risk Aversion and Awareness

Industry is risk-averse and slow to change, which is understandable given the cost of facilities and the requirements to operate safely, maintain product quality, and operate profitably. Uncertainty remains about what the best and most cost-effective decarbonization strategies are, and few want to risk adopting novel decarbonization strategies in the industrial sector if they have not been fully proven and evaluated. Some industrial plant managers may not be aware of opportunities for efficiency gains and energy savings, and smaller plants may not have dedicated energy managers. Wayne Nastri of the South Coast Air Quality Management District stated, "We have got to deploy technologies that are proven."[341]

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341 August 3, 2021, IEPR Commissioner Workshop to Accelerate Industrial Decarbonization transcript. https://efiling.energy.ca.gov/getdocument.aspx?tn=240048. p. 85.

Regulatory and Permitting Requirements

Industrial plant managers have noted regulatory and permitting requirements are some of the most challenging barriers when considering implementation of large-scale decarbonization technologies (for example, renewable generation, energy storage, microgrids, electrification of fossil-fueled equipment). Steve Coppinger from CalPortland stated that any time equipment is changed to improve efficiency, emissions could be altered, and this triggers a new permitting process that is time-consuming and will "hold us up from what we'd like to accomplish."[342] Interconnection, departing load charges, electrical infrastructure upgrades, permitting, and the California Environmental Quality Act (CEQA) are often cited as time-consuming, cost-prohibitive, and potential reasons for not implementing the project. These issues affect nearly all large-scale energy projects and are not unique to industrial plants. A discussion of barriers and potential solutions for many of these issues can be found in the *2020 IEPR Update, Volume II — The Role of Microgrids in California's Clean and Resilient Energy Future*.[343]

Status, Potential, and Opportunities for Decarbonization in Industry

Although a range of options are available to decarbonize the industrial sector, an effective decarbonization strategy will require tailored solutions that consider the unique challenges and opportunities in each subsector. As discussed at the August 3, 2021, IEPR workshop on industrial decarbonization, the varied needs within the industrial sector make decarbonizing challenging as there is no one-size-fits-all solution.[344]

Emissions reduction pathways are available, however, and encompass a range of opportunities within specific subsectors. These subsectors include cement, chemicals and allied products, food products, industrial combined heat and power, landfills, oil and gas production and processing, petroleum refining, and hydrogen production. California's industrial sector has opportunities to reduce GHG emissions and energy use through a combination of technologies and practices as discussed below.

342 Ibid., p. 50.

343 Bailey, Stephanie, David Erne, and Michael Gravely. 2021. *Final 2020 Integrated Energy Policy Report Update, Volume II: The Role of Microgrids in California's Clean and Resilient Energy Future, Lessons Learned From the California Energy Commission's Research*. California Energy Commission. Publication Number: CEC-100-2020-001-V2-CMF. https://www.energy.ca.gov/data-reports/reports/integrated-energy-policy-report/2020-integrated-energy-policy-report-update.

344 This challenge for its decarbonizing the industrial sector was raised by Bob Gemmer (U.S. DOE), Dr. Asfaw Beyene (San Diego State University IAC), Dr. Ahmad R. Ganji (San Francisco State University IAC), Elizabeth Dutrow (United States Environmental Protection Agency) and others. August 3, 2021, IEPR Commissioner Workshop to Accelerate Industrial Decarbonization, Session 1: Programs and Policies transcript. https://efiling.energy.ca.gov/getdocument.aspx?tn=240047.

Increasing Energy Efficiency

Opportunities for reducing emissions in the industrial sector include implementing energy efficiency measures. These measures focus on improving the energy efficiency of existing equipment and systems either through direct equipment replacement, improving operation and maintenance practices, or implementation of controls to minimize unnecessary operation of equipment. The result is reduced energy use and cost, reduced GHG emissions, and increased operating efficiency.

Addressing Risk Aversion

Improving awareness of the available cost-effective measures to decarbonize industrial plants, providing financial support, and developing the workforce needed for implementation, including dedicated energy managers are critical.[345] During the IEPR workshop on industrial decarbonization, representatives of the U.S. DOE underscored that because industrial plant managers are risk-averse and hesitant to invest in technologies with paybacks longer than two to three years, they are most likely to adopt technologies that receive financial support from the state, federal government, or utilities. Programs advancing industrial decarbonization, including demonstrating technologies and offering financial support for decarbonization, are discussed below.

Advancing Strategic Energy Management

Strategic energy management (SEM) is a growing program design that targets industry energy use. SEM programs focus on supporting customers to implement behavioral, retrocommissioning, energy efficiency, and operational savings measures.[346] The California investor-owned utilities (IOUs) identified SEM as a key strategy to reducing energy consumption and increasing efficiency savings.[347] Through this program, a utility or third-party

345 These ideas were supported by workshop participants from New York State Energy Research & Development Agency (Patrick O'Shei); United States Department of Energy (U.S. DOE, represented by Bob Gemmer); Southern California Edison (SCE, represented by Derek Okada); San Diego State University IAC (Dr. Asfaw Beyene); and others. August 3, 2021, IEPR Commissioner Workshop to Accelerate Industrial Decarbonization, Session 1: Programs and Policies transcript. https://efiling.energy.ca.gov/getdocument.aspx?tn=240047.

346 AESC. February 22, 2018, press release: "AESC and Cascade Energy Bring Strategic Energy Management to Southern California," http://www.aesc-inc.com/aesc-cascade-energy-bring-strategicenergy-management-southern-california/.

347 Presentation by Colleen Breitenstein, "Doubling Energy Efficiency Savings Workshop: Industrial & Agricultural Sector." June 7, 2018, IEPR Commissioner Workshop on Doubling Energy Efficiency Savings. https://efiling.energy.ca.gov/GetDocument.aspx?tn=223676&DocumentContentId=53830.

implementer provides the processes and systems needed to incorporate energy considerations and energy management into daily operations.[348] The key is to continuously monitor and evaluate ways to improve efficiency and upgrade assets.

Recovering Waste Heat

Industrial waste heat is generated energy from industrial processes that is not put into any practical use and is lost, wasted, and exhausted into the environment. Use of industrial waste heat is one of the most promising sources of zero-carbon heat. Recovering the waste heat can be conducted through various recovery technologies such as recuperator; regenerators (furnace regenerators, rotary regenerators, heat wheels, passive air preheaters, and regenerative and recuperative burners); high temperature heat pumps; plate heat exchangers; and economizers (waste heat boilers) in the steel, iron, food, and ceramic industries.[349] There is much interest in using waste heat recovery technologies to generate electricity, thereby increasing overall efficiency and contributing to the decarbonization of industrial sectors.

Various research and demonstration projects are in progress or the concept phase. The future research activities are mainly directed toward:[350]

- Optimization and development of heat pump components and systems (for example heat exchangers, heat storage, waste heat boilers, and compressors) to accommodate for temperatures and pressures that are higher than currently available.
- Increasing cycle efficiency, for example, through use of multistage systems.
- Scale-up of heat pump models to maximize the economic feasibility for industrial applications.
- Development of environmentally friendly synthetic refrigerants with low global warming potential (GWP) and use of natural refrigerants, such as hydrocarbons or water.

Presentation by Erin Brooks, "Agricultural and Industrial Energy Efficiency." June 7, 2018, IEPR Commissioner Workshop on Doubling Energy Efficiency Savings. https://efiling.energy.ca.gov/GetDocument.aspx?tn=223678&DocumentContentId=53832.

348 U.S. Department of Energy. Data Driven, Strategic Energy Management- State and Local Solution Center webpage, https://www.energy.gov/eere/slsc/data-driven-strategic-energy-management.

349 Jouhara, Hussam, Navid Khordehgah, Sulaiman Almahmoud, Bertrand Delpech, Amisha Chauhan, and Savvas A. Tassou. June 2018. "Waste Heat Recovery Technologies and Applications." *Elsevier*. https://www.sciencedirect.com/science/article/pii/S2451904918300015.

350 Gaur, Ankita Singh, Desta Z. Fitiwi, and John Curtis. January 2021. "Heat Pumps and Our Low-Carbon Future: A Comprehensive Review." *Elsevier*. https://www.sciencedirect.com/science/article/abs/pii/S221462962030339X.

Deploying Distributed Energy Resources

Another approach is to deploy into a plant distributed energy resources that incorporate renewable energy, distributed generation, demand-side management, energy storage, and thermally activated technologies. The aim is to maximize efficiency, reduce GHG emissions, and enhance energy reliability, security, and resiliency without sacrificing performance.

Advancing Green Hydrogen

Fuel switching from fossil fuels to green hydrogen could offer a zero-carbon alternative for industrial processes and eliminate GHG emissions from gas combustion in higher-temperature process heating (>800° Celsius or 1,472° Fahrenheit) which is technically and economically challenging for direct electrification. Production and use of green hydrogen for industrial applications in lieu of direct electrification can reduce the burden on electric ratepayers by reducing the need for investments in transmission and distribution infrastructure and improving grid reliability. These opportunities were highlighted by Patrick O'Shei (New York State Energy Research & Development Agency) and Michael Yee (Southern California Gas Company [SoCalGas]) at the August 3, 2021, IEPR workshop.[351]

The United States Department of Energy (U.S. DOE) has funded efforts focused on reducing the cost of green hydrogen. Interest in hydrogen continues to grow, but the strategy of hydrogen for decarbonization in California is still in the early development stages. Significant research is being done to drive down the costs to enable hydrogen to be cost-competitive.

Developing Carbon Capture, Utilization, and Storage

Carbon capture, utilization, and storage (CCUS) encompasses methods and technologies that capture CO_2 emissions from the source, preventing them from entering the atmosphere, or capture carbon directly from the air. The CO_2 emissions are stored deep underground or converted into marketable industrial and commercial products. CCUS is considered one of the essential components for reducing CO_2 emissions since it can achieve net negative emissions that can offset sectors unable to achieve zero emissions.

CO_2 capture technologies include precombustion, oxy-fuel combustion, post-combustion, and chemical looping. There are several pathways considered to use captured CO_2 to produce chemicals, fuels, plastic, and carbon containing minerals. Currently, CCUS technologies face

351 August 3, 2021, IEPR Commissioner Workshop to Accelerate Industrial Decarbonization, Session 1: Programs and Policies transcript. https://efiling.energy.ca.gov/getdocument.aspx?tn=240047.

issues such as high costs, high energy penalties, and lack of demonstrations of long-term safety and reliability of storage.[352]

During the August 3, 2021, IEPR workshop, Patrick O'Shei pointed out that CCUS appears to be well-suited for the cement industry, while Michael Yee emphasized high potential for CCUS, especially when combined with sustainable biomass-to-energy conversion. Elizabeth Dutrow with the United States Environmental Protection Agency (U.S. EPA) emphasized that, unlike energy efficiency, carbon capture generally is not accompanied by energy savings and economic benefits, and, for that reason appears to be more suitable for the long-term perspective.[353] Further research, development, and demonstration are needed to advance the technology.

Programs Advancing Industrial Decarbonization

California is supporting decarbonization in the industrial sector with a variety of incentive or grant programs, regulatory standards or programs, and research and development programs supported as described below.

Industrial Assessment Centers (IACs)

IACs have been conducting industrial assessments since 1976 with teams at 35 universities around the country. According to the U.S. DOE, "IACs typically identify more than $130,000 in potential annual savings opportunities for every manufacturer assessed, nearly $50,000 of which is implemented during the first year following the assessment."[354] Further, IACs train the "next-generation of energy savvy engineers, more than 60 percent of which pursue energy-related careers upon graduation."[355]

The U.S. DOE IACs at San Francisco State University and San Diego State University have provided no-cost energy audits to medium and small industrial plants.[356] In 2022, San Francisco State University and University of California, Irvine are expected to participate in the

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352 Zhang, Xian, Jing-Li Fan, and Yi-ing Wei. August 2013. "Technology Roadmap Study on Carbon Capture, Utilization, and Storage in China." *Elsevier*. https://www.sciencedirect.com/science/article/pii/S0301421513002425.

353 August 3, 2021, IEPR Commissioner Workshop to Accelerate Industrial Decarbonization, Session 1: Programs and Policies transcript. https://efiling.energy.ca.gov/getdocument.aspx?tn=240047.

354 U.S. DOE. Industrial Assessment Centers webpage, https://www.energy.gov/eere/amo/industrial-assessment-centers-iacs.

355 Ibid.

356 U.S. DOE. Locations of Industrial Assessment Centers webpage, https://www.energy.gov/eere/amo/locations-industrial-assessment-centers.

IAC program. Discussion at the IEPR workshop suggested that most of the participating facilities in California are small to medium-sized.

California Energy Commission (CEC) Administered Research and Development Programs

The CEC has two main research and development programs with funds that support industrial decarbonization: the Electric Program Investment Charge (EPIC)[357] and the Natural Gas Research and Development program.[358] (See Chapter 2.) Industrial research is a subset of these programs and includes:

- **Energy efficiency:** The research objectives are to develop, test, and demonstrate innovative and precommercial energy efficiency technologies or strategies with direct energy efficiency benefits. Projects funded are required to provide data and analysis to estimate direct electricity and cost savings and, if applicable, water savings and other benefits. Examples of projects include process and manufacturing improvements and data center energy efficiency improvements. One successful project demonstrated a novel hyperefficient pump motor unit for hydraulic systems capable of reducing energy consumption up to 80 percent.[359]
- **Energy management:** The research objectives are to develop and deploy energy management systems at industrial and manufacturing plants to identify ways to optimize performance and increase efficiency. One successful project deployed energy management systems to improve the efficiency of air compressor systems at more than 100 facilities in a variety of manufacturing sectors.[360] Another project will deploy energy management systems in dairies targeting a range of process operations and efficiency savings of 20 percent.
- **Advanced refrigeration:** This research focuses on advanced refrigeration technologies and use of low-GWP refrigerants to reduce energy use and GHG

357 CEC. Electric Program Investment Charge program webpage, https://www.energy.ca.gov/programs-and-topics/programs/electric-program-investment-charge-epic-program.

358 CEC. Natural gas program webpage, https://www.energy.ca.gov/programs-and-topics/programs/natural-gas-program.

359 Arciga, Manuel. 2021. *Hyper-Efficient Pump Motor Unit With Fully Integrated Permanent Magnet Motor and Motor Controls With Combined Liquid Cooling*. California Energy Commission. Publication Number: CEC-500-2021-041. https://www.energy.ca.gov/sites/default/files/2021-07/CEC-500-2021-041.pdf.

360 Greenstone, Michael, et al. 2019. *Unlocking Industrial Energy Efficiency Through Optimized Energy Management Systems*. California Energy Commission. Publication Number: CEC-500-2019-060. https://www.energy.ca.gov/sites/default/files/2021-06/CEC-500-2019-060.pdf.

emissions. Examples include development of highly efficient magnetic refrigeration for cryogenic applications applicable to electronics and pharmaceutical sectors,[361] development of anti-ice coatings to improve heat transfer and reduce defrost cycles,[362] demonstration of an energy-efficient chilling system using an ultra-low-charge ammonia refrigerant,[363] and demonstration of a refrigeration system that uses process waste heat to increase efficiency.[364]

- **Industrial heat pumps:** This research focuses on the use of heat pumps to recover waste heat and reduce energy use and GHG emissions. Projects include developing industrial heat pumps capable of providing higher working temperatures, as well as ones that can more efficiently recover lower-grade heat.[365]
- **Large-scale heat recovery systems:** This research demonstrates waste heat recovery systems that are replicable and scalable in various industries to reduce gas use and GHG emissions. Examples include developing low-cost heat exchangers with automated controlled heat extraction and developing a novel lightweight and low-cost polymer (plastic) heat exchanger.[366]

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361 May 13, 2020, CEC Business Meeting, Item 9a. Grant Request Form for General Engineering & Research, L.L.C. https://www.energy.ca.gov/filebrowser/download/278.

362 May 13, 2020, CEC Business Meeting, Item 9e. Nelumbo, Inc., "Advanced Heat Exchanger Coatings to Improve Energy Efficiency of Industrial Refrigeration System." EPC-19-025. https://www.energy.ca.gov/proceedings/2020-business-meetings.

363 Electric Power Research Institute, Inc., "Development and Testing of an Energy Efficient Ultra-Low Charge Ammonia Refrigeration System in a Food Processing Plant." EPC-16-048. Electric Program Investment Charge 2019 Annual Report, https://www.energy.ca.gov/publications/2020/electric-program-investment-charge-2019-annual-report.

364 May 13, 2020, CEC Business Meeting, Item 9a. Institute of Gas Technology dba Gas Technology Institute, "Booster Ejector Enhancement of Compressor Refrigeration Facilites Utilizing Industrial Process Waste Heat." EPC-19-023. https://www.energy.ca.gov/proceedings/2020-business-meetings.

365 May 13, 2020, CEC Business Meeting, Item 9b, The Regents of University of California-Merced, "Stirling Cycle Heat Pumps for Industrial Heat Recovery." EPC-19-022. https://www.energy.ca.gov/proceedings/2020-business-meetings.

May 13, 2020, CEC Business Meeting, Item 9d, Electric Power Research Institute, Inc., "Development of an Advanced High Temperature Heat Pump for the Efficient Recovery of Low-Grade Industrial Waste Heat." EPC-19-024. https://www.energy.ca.gov/proceedings/2020-business-meetings.

366 May 13, 2020, CEC Business Meeting, Item 12b, Trevi Systems, Inc., "Demonstrating Replicable, Innovative, Large-Scale Heat Recovery in the Industrial Sector." PIR-19-005. https://www.energy.ca.gov/proceedings/2020-business-meetings.

- **Demand response:** This research focuses on developing and testing technologies with the potential to achieve at least 20 percent demand reduction and increase operational reliability and efficiency. Projects have targeted municipal water pumping and commercial refrigerated food warehouse.[367]

Research areas under consideration include:

- Improving the energy efficiency and load flexibility of cold storage and refrigeration systems.
- Advancing industrial carbon capture and utilization, low-carbon industrial heating, decarbonization of concrete manufacturing, and energy-efficient separation processes.
- Creating a load flexibility hub for the industrial, agriculture, and water sectors.

Federal Government Research and Development Programs

The U.S. DOE funds research, development, and deployment programs through the Advanced Manufacturing Office. This office is "dedicated to improving the energy and material efficiency, productivity, and competitiveness of manufacturers across the industrial sector."[368] The Advanced Manufacturing Office has three subprograms that include Applied Research and Development Projects, Pre-commercial Research and Development Consortia, and Technical Partnerships. The U.S. DOE's Office of Fossil Energy supports research in CCUS technologies that support industrial decarbonization.

The U.S. DOE's Better Plants program works with leading manufacturers to boost their efficiency, resilience, and economic competitiveness through improvements in energy efficiency. Driving energy savings can have a broad impact across the industrial sector, which leads to cost savings, greater resilience, a strengthened workforce, and increased global competitiveness. Manufacturing companies and wastewater treatment organizations partner with Better Plants to set specific energy, water, and waste reduction goals, and commit to reducing energy intensity by 25 percent over a 10-year period across all their U.S. operations.

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367 Energy Efficiency and Demand Response in Industrial, Agricultural, and Commercial Cold Storage research initiative. EPIC Interim Investment Plan and Appendices — Approved July 15, 2021. https://www.energy.ca.gov/proceedings/energy-commission-proceedings/electric-program-investment-charge-2021-2025-investment.

Research initiative #21 Enabling Grid Resilience with Load Flexibility in the Industrial, Agricultural, and Water (IAW) Sectors. Electric Program Investment Charge 4 Investment Plan: California Energy Commission Staff's Proposed Draft Initiatives. https://www.energy.ca.gov/event/workshop/2021-08/electric-program-investment-charge-2021-2025-investment-plan-scoping-draft.

368 U.S. Department of Energy Advanced Manufacturing webpage, https://www.energy.gov/eere/amo/about-us.

Better Plants provides support in the form of technical assistance, tools, resources, and national recognition to help partners achieve their goals.

Discussion at the IEPR workshop on industrial decarbonization covered local programs similar to the Better Plants program. Patrick O'Shei with the New York State Energy Research & Development Agency mentioned that they use a similar approach in their incentive programs. Derek Okada with SCE provided some results of the utility's SEM program that forms industrial cohorts of noncompetitors to promote open dialogue. The first year of implementation has shown 8.1 million kilowatt-hours (kWh) savings and 17.5 million kWh more are anticipated as a result of the third year. This approach to decarbonization begins with the commitment from top management down to the line staff to employ operational and business improvement practices to reduce energy use while achieving operational savings. SEM helps customers increase their productivity, operational efficiency, and thus their profitability, which makes this a win-win for customers, IOUs, and ratepayers.[369]

Food Production Investment Program (FPIP) (part of California Climate Investments Initiative)

Administered by CARB, the California Climate Investments is a statewide initiative that invests billions of Cap-and-Trade dollars into reducing GHG emissions, strengthening the economy, and improving public health and the environment — particularly in disadvantaged communities.[370] The program is focused on reducing GHGs as opposed to measuring kWh or therms reductions. The Cap-and-Trade Program is aimed at combating climate change by targeting GHG-intensive sectors of California's economy, including the industrial and agricultural sectors.[371] The Cap-and-Trade Program covers roughly 80 percent of the state's GHG emissions, establishes a declining limit on major GHG emissions sources in California, and creates an economic incentive for investment in greener and more efficiency technologies.[372] More information on projects funded through the California Climate Investments Initiative is in Chapter 4.

Established in 2018, FPIP is managed by the CEC and is part of the California Climate Investments Initiative. FPIP funds energy efficiency and renewable energy technologies at

369 August 3, 2021, IEPR Commissioner Workshop to Accelerate Industrial Decarbonization, Session 1: Programs and Policies transcript. https://efiling.energy.ca.gov/getdocument.aspx?tn=240047.

370 More information on FPIP and other CCI programs is available at http://www.caclimateinvestments.ca.gov/.

371 CARB. Mandatory Greenhouse Gas Emissions Reporting webpage, https://ww2.arb.ca.gov/our-work/programs/mandatory-greenhouse-gas-emissions-reporting.

372 CARB. Cap-and-Trade program webpage. https://ww2.arb.ca.gov/our-work/programs/cap-and-trade-program/about.

California food production plants. Eligibility is determined using the North American Industrial Classification System codes, specifically codes beginning in 311 for food processing and 3121 for beverage processing. In general, facilities must transform raw materials into food products to be eligible. The program aims to accelerate the adoption of advanced energy technologies that can substantially reduce energy use, operating costs, and GHG emissions. To date, $124 million has been allocated to the program, of which $117.8 million is available as grants for food production plants.

FPIP projects result in energy, GHG savings through refrigeration system conversions to low-GWP refrigerant technologies and other measures, and criteria pollutant emission reductions. Savings are validated through a measurement and verification process that compares energy use and emissions before and after new equipment is installed. These benefits persist throughout the project lifetime, which ranges from 15 to 40 years. To date, FPIP has awarded $116 million to 51 projects and will result in an estimated reduction of 164,000 metric tons of CO_2 equivalent per year (MT CO_2e/yr). This translates to a lifetime reduction of 3.3 million MT CO_2e/yr and a cost per metric ton of $33/ton.[373]

May Revise of 2021–2022 Budget — Clean Energy Investments

Included in the May Revision of the fiscal year 2021–2022 state budget were four proposed Clean Energy Investment programs to be administered by the CEC. Two of those programs apply to the industrial sector and focus on industrial decarbonization and additional funding for FPIP. The decision on these programs has been deferred to 2022.

Senate Bill 596

The bill (Becker, Chapter 246), which has been approved by the California's Legislature and signed by the Governor on September 23, 2021, requires CARB to develop and implement a comprehensive strategy for the state's cement sector to achieve net-zero GHG emissions for cement used in California as soon as possible, but not later than December 31, 2045.[374] In developing the strategy, this bill requires CARB to:

> 1) Define a metric for GHG intensity and evaluate data submitted by cement manufacturing plants to establish a baseline with which to measure GHG intensity reductions.

373 CARB. 2021. *California Climate Investments 2021 Annual Report to the Legislature*. http://www.caclimateinvestments.ca.gov/annual-report.

374 Senate Bill 596 (Becker, Chapter 246, Statutes of 2021), https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=202120220SB596.

2) Assess the effectiveness of existing measures, identifying modifications to those measures, and evaluate new measures to overcome market, statutory, and regulatory barriers inhibiting achievement of the objectives.

3) Identify actions to reduce adverse air quality impacts and support economic and workforce development in cement neighboring communities.

4) Include provisions to minimize and mitigate potential leakage and account for embedded emissions of GHGs in imported cement similar to those for cement produced in-state, such as through a border carbon adjustment mechanism.

5) Coordinate and consult with state agencies and other stakeholders (industrial facilities, utilities, manufacturers, communities located close to industrial facilities).

6) Prioritize actions that leverage state and federal incentives to decrease costs of reducing GHG emissions of concrete.

7) Evaluate measures to support market demand and incentives to encourage the production and use of low-GHG cement.

Also, this bill requires CARB to establish interim targets for reductions in the GHG intensity of cement used within the state, with the goal of reducing the GHG intensity of cement used within the state to 40 percent below the 2019 average levels by December 31, 2035.

Highlights from the IEPR Industrial Decarbonization Workshop

On August 3, 2021, the CEC hosted an IEPR Commissioner workshop on identifying programs, resources, and policies needed to help industries accelerate decarbonization and meet statutory energy and environmental goals. Speakers represented various industries, government (federal and state) agencies, academia, utilities, and other institution experts on four panels.[375] The first panel consisted of representatives from CARB, the U.S. EPA, and CEC to set the stage discussing challenges and opportunities

The second panel discussed programs to increase industrial energy efficiency and decarbonization and included representatives from the U.S. DOE, New York State Energy Research and Development, SCE, San Francisco State University, and San Diego State

375 August 3, 2021, IEPR workshop to Accelerate Industrial Decarbonization, Session 1: Programs and Policies webpage, https://www.energy.ca.gov/event/workshop/2021-08/session-1-iepr-commissioner-workshop-accelerate-industrial-decarbonization.

August 3, 2021, IEPR workshop to Accelerate Industrial Decarbonization, Session 2: Industrial Outlook webpage, https://www.energy.ca.gov/event/workshop/2021-08/session-2-iepr-commissioner-workshop-accelerate-industrial-decarbonization.

University. The panel provided insights on the U.S. DOE's current Research, Design, and Development programs that include combined heat and powered by biomass for local energy needs, Better Plants, and Technical Assistance Partnerships and New York's current programs including Emission Reduction Grants, Carbontech Development Initiatives, and Utility Collaboration and Incentive Programs. Panelists recommended the industrial decarbonization roadmap to include multiple approaches such as low-capital investments with several benefits, early investments in low-carbon technologies to ensure future market viability, and development of workforces across industries. Panelists also recommended offering more incentives to implement the technologies.

The third panel consisted of industry representatives who provided insights on adopting, exploring, and evaluating technologies such as process controls, recuperative burners, insulation, waste heat recovery, burner technologies (reheat furnace, line furnaces, and boiler sources), on-site renewable energy, alternative fuels, raw materials, renewable diesel, and biodiesel. Panelists included representatives from the Applied Medical, California Steel Industries, CalPortland, Kern Oil, and Frito Lay. The panel encouraged participation in the "Roadmap to Net Zero by 2050," "Carbon Neutrality Plan 2035," and U.S. EPA's "ENERGY STAR" programs. They also recommended the importance of more incentives, funding, clear process, interconnection process, regulatory support for energy projects, follow up on incentives, more programs like FPIP across other industries, as well as funding for smaller-scale projects.

The fourth panel provided insights on developing new approaches that create incentives for industry to be part of the solution. The panel consisted of representatives from the California Manufacturers & Technology Association, California Large Energy Consumers Association, South Coast Air Quality Management District, Western States Petroleum Association, and University of California, Davis. Panelists discussed challenges such as those related to the diversity of industries and industrial processes, the need for designs to operate for a long duration, costly major equipment replacements or process changes, and uncertainties about best practices for cost-effective decarbonization strategies. Participants recommended energy efficiency strategies to include industrial cohorts, strategic energy management programs, research development and advanced technology demonstrations, and utility or state financing.

Decarbonization in the Agricultural Sector

California is first in the nation in agricultural output, bringing in roughly $50 billion annually (including $21.7 billion in exports) for a wide variety of products.[376] Agriculture includes growing and harvesting of crops and animals but does not include food production, which is included in the industrial sector. In 2020, the agricultural sector included 24.3 million acres, nearly 69,900 farms, and more than 411,000 employees.[377] California agriculture is led primarily by the dairy, nut, and grape subsectors. California's agricultural industry is one of the state's largest users of energy and water.

Agriculture is the fifth-largest contributor of GHG emissions in California, accounting for 7.6 percent of emissions.[378] Of this amount, more than 70 percent of the emissions are emitted by livestock and about 21 percent are from irrigation crop production. In 2019, California's agricultural sector accounted for 31.8 million metric tons CO_2 equivalent annual emissions, of which, 22.6 MMT (about 71 percent) were from cattle and livestock, 6.6 MMT (about 20 percent) were from crop growing and harvesting, and the rest were from fuel combustion associated with agricultural activities (water pumping, cooling or heating buildings, processing commodities, and tractors).[379]

According to the California Water Stewardship Initiative, 8 million agricultural acres in California consume 80 percent of the total water pumped in the state and nearly 8 percent of the state's total energy, with 70 percent for water pumping. Electricity for irrigation purposes alone is more than 10 terawatt-hours in California.[380] Because most of the electricity used for water pumping comes from power plants burning fossil fuels, water use in agricultural operations contributes significantly to the state's overall carbon footprint and GHG emissions. Agricultural energy-water linkages are amplified during drought due to increased ground water pumping and lowered water tables, which require more power to pump. Further, a combination of rising energy rates, new agricultural peak load hours from 4:00 p.m. to 9:00 p.m., increasing regulation and reporting of water consumption, unpredictable and prolonged

376 California Department of Food and Agriculture. *California Agricultural Statistics Review, 2019–2020*, https://www.cdfa.ca.gov/Statistics/PDFs/2020_Ag_Stats_Review.pdf.

377 California Department of Food and Agriculture. California Agricultural Statistics Review, 2019–2020, https://www.cdfa.ca.gov/Statistics/PDFs/2020_Ag_Stats_Review.pdf.

378 CARB. Current California GHG Emission Inventory Data webpage, https://ww2.arb.ca.gov/ghg-inventory-data.

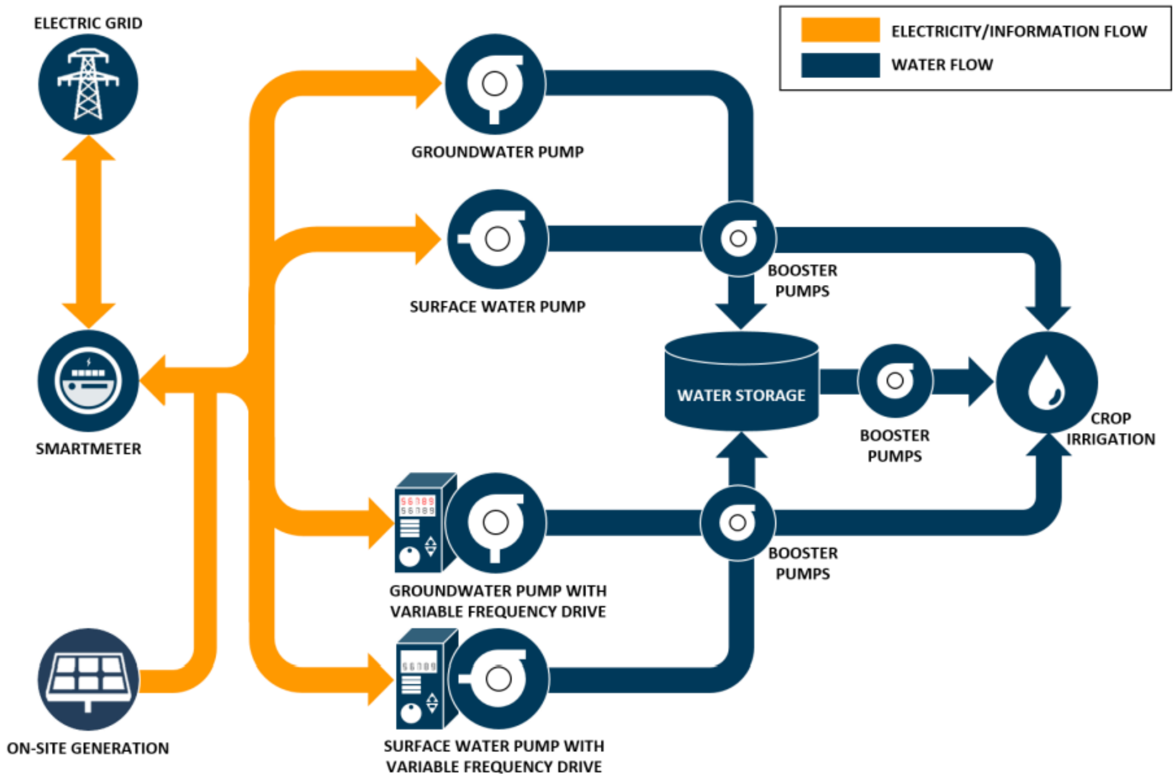
379 CARB. 2019 GHG emissions data, https://ww2.arb.ca.gov/ghg-inventory-data.

380 Jerphagnon, Olivier; Stanley Knutson; Roland Geyer; Kate Scow. (PowWow Energy). 2019. Decision Support Tool to Reduce Water and Energy Consumption in Agriculture. California Energy Commission. Publication number: CEC-500-2019-022.

droughts with changing weather patterns, and severe labor shortages are driving demand for new agricultural energy and water efficiency solutions.

Figure 26 illustrates possible water and energy flows on a typical farm in California. The predominant energy loads are from groundwater pumps, surface water pumps, and booster pumps (pumps that deliver water to and from the local water storage).[381]

Figure 26: Water Energy Flows in a Typical California Farm



Source: Lawrence Berkeley National Laboratory[382]

381 Aghajanzadeh, Arian; Michael D. Sohn; Michael A. Berger. 2019. Water-Energy Considerations in California's Agricultural Sector and Opportunities to Provide Flexibility to California's Grid. Lawrence Berkeley National Laboratory, June 2019. Contract No. DE-AC02-05CH11231.

382 Ibid.

Indoor Agriculture Subsector

Indoor agriculture or *controlled environment agriculture* represents a small segment of the agricultural market, but it is growing, especially in urban areas where consumers prefer local food production. This subsector reduces the need for transportation (and associated costs, emissions, and other impacts) and benefits communities striving to increase food security. Allied Market Research projects that the global market for vertical indoor farms will grow nearly 25 percent annually between 2019 and 2026, based on 2018 data.[383]

Indoor farming has the potential to reduce water use by more than 70 percent, providing a potential for substantial electricity reduction for water pumping. However, this reduction is partially offset by the energy requirements for lighting and environmental control.

Despite the benefits, the energy consumption of indoor farms is high relative to outdoor farming. The growth in indoor farms could result in new industrial-scale loads that are large enough to impact grid operations and planning.[384] Lighting (65 percent), air conditioning (20 percent), and dehumidifiers (10 percent) account for 95 percent of electricity usage.[385] The energy load varies greatly depending on the size and type of operations, but it could be between 500 kW and 15 megawatts (MW) — more than a retail box store but less than a data center.[386] Another report estimates that the typical indoor container farm annually consumes about 45 megawatt-hours (MWh) and that more intensive vertical farms consume 8,700 to 70,000 MWh annually.[387]

Also, California has permitted commercial cannabis cultivation, which generally occurs outdoors but is increasingly being farmed indoors. Indoor cannabis is grown primarily within retrofitted commercial spaces and warehouses. Like indoor agriculture, cannabis cultivation is energy-intensive, requiring significant space conditioning, lighting, and mechanical ventilation.

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383 Electric Power Research Institute. "Can Indoor Agriculture Help Feed a Growing World?" February 2021. https://publicdownload.epri.com/PublicAttachmentDownload.svc/AttachmentId=70746?utm_campaign=Efficient%20Electrification&utm_medium=email&_hsmi=109174283&_hsenc=p2ANqtz-_f7CMfUqGBeWlnAdTKtITGQ7ijnLNMdTkhsoMgKjnLSasxi4xIaBficGEEqFdDpbzfvtRiIjRcNxrxSoboK_Qkf9jugZKhZIuQj8ohUImBj0a8TX0&utm_content=109174283&utm_source=hs_email#page=9.

384 Ibid.

385 iFarm. 2020. "How Much Electricity Does a Vertical Farm Use?". https://ifarm.fi/blog/2020/12/how-much-electricity-does-a-vertical-farm-consume.

386 Golden, Sarah. March 2020. "Microgrids, Indoor Agriculture Go Together Like Peas and Carrots." https://www.greenbiz.com/article/microgrids-indoor-agriculture-go-together-peas-and-carrots.

387 American Council for an Energy Efficient Economy. "Controlled Environment Agriculture." https://www.aceee.org/sites/default/files/pdfs/eo-indoor-ag.pdf.

The CEC's draft forecast for the *2021 IEPR* (see Volume IV) estimates that electricity consumption for indoor cannabis production will be about 12,000 gigawatt-hours annually by 2025.[388] A report prepared to inform California's 2022 Energy Code estimates that there are more than 1,300 indoor cannabis facilities based on 2019 CalCannabis licensing information.[389] Energy intensity for a California indoor cannabis facility averages 241 kWh per square foot.[390]

Challenges and Barriers to Agricultural Decarbonization

Similar to the industrial sector, realizing the potential to decarbonize the agricultural sector is hindered by technical and economic challenges, risk aversion, and lack of real-world data on emerging technologies.

Capital Costs

Economics are a key driver for decision-making in agriculture. Installing irrigation efficiency equipment such as soil moisture monitoring, drip systems, switching to low-pressure irrigation systems, pump retrofits, variable-frequency drives, automated load management controls, and installation of renewable energy systems to reduce on-farm energy and water use can be capital-intensive. The seasonal operations and low-profit margins typical of agriculture may make such investments hard to justify. For indoor agriculture, replacing existing equipment with more energy-efficient equipment, switching fuels, or incorporating other decarbonization methods also requires upfront costs. Further, costs effectively increase if a changeout occurs before the end of the useful life of the existing process equipment.

Risk Aversity and Awareness

The agricultural sector is typically risk-averse and slow to change. Growers do not want to risk a lost crop or yield reductions because of an operational change or lack of energy reliability. There remains uncertainty about what the best and most cost-effective decarbonization strategies are, and few agricultural facilities want to risk adopting novel decarbonization strategies if they have not been fully proven as cost-effective. Also, some agricultural operators may not be aware of opportunities for efficiency gains and energy savings.

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388 California Energy Demand 2019 Revised Forecast Presentation, 2020–2030 (Page 15 of 47). https://efiling.energy.ca.gov/GetDocument.aspx?tn=230923&DocumentContentId=62562.

389 Energy Solutions and Cultivate Energy and Optimization. Controlled Environment Horticulture. California Statewide Codes and Standards Enhancement (CASE) Program. March 2021. 2022-NR-COV-PROC4-F. https://title24stakeholders.com/wp-content/uploads/2021/03/2022-T24-NR-CEH-Final-CASE-Report_w-Addendum.pdf.

390 Ibid.

Opportunities to Decarbonize Agriculture

Similar to the industrial sector, decarbonization strategies needed for the agricultural sector include a range of options specific to the unique characteristics of each subsector. These options include those listed in the "Capital Costs" section (see above).[391] The CEC's EPIC has funded research focused on advanced controls and software to increase efficiency and load flexibility of irrigation pumping to help reduce grid impacts and achieve SB 100 goals. These projects defer irrigation pumping to nonpeak periods (such as 4:00 p.m. to 9:00 p.m.) in the summer, as discussed in more detail below.

Also, the EPIC 4 Plan includes a proposal that could help decarbonize agricultural practices. The plan is to explore the use of plug-in electric vehicles to provide electric services to the grid without compromising vehicle performance. This initiative is scoped broadly and can include off-road equipment such as agricultural tractors or other zero-emission farm equipment in the early stages of commercialization.

Although outside the scope of this report, non-energy related approaches are also available to reduce GHG emissions from the agricultural sector. These approaches include adjusting livestock feed to reduce methane released from enteric fermentation (cow burps), managing manure to reduce methane release, and adopting practices to increase carbon sequestration in soil.

Distributed Energy Resources

Similar to the industrial sector, further integration of renewable energy into the agricultural sector could reduce GHG emissions and enhance energy reliability, security, and resilience. The agricultural sector can incorporate renewable energy for irrigation pumping and, when combined with energy storage and load flexibility, could help support the electric distribution and transmission system. Also, electrification of farm equipment such as tractors and flexibly managing equipment charging and discharging can act as a distributed energy resource that provides electric services while reducing fossil fuel use from agricultural operations.

Water and Energy Management Systems

Water and energy loads can be reduced with precision irrigation and water management tools that combine up-to-date information on soil moisture, weather forecasts, and other crop-specific data with utility rates and pumping load data to automate irrigation pumping. These systems can allow growers to participate in load control and demand response programs and reduce water waste and energy costs without impacting crop yields. By watering crops only

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391 California Department of Food and Agriculture. January 2021. "CDFA State Water Efficiency and Enhancement Program." https://www.cdfa.ca.gov/oefi/sweep/docs/SWEEP_flyer_2021.pdf.

when needed and not on a set time interval, it is possible to improve the quality and yield of the crop. This is especially important during drought.

Reduce Fertilizer Application

Modern farming productivity would not be possible without the use of fertilizers as part of overall crop management strategy. Ammonia and nitrogenous fertilizer production rely on gas as a feedstock and fuel source, and represent a source of embedded carbon for the agricultural sector.[392] Reducing fertilizer application to the amount necessary for crop growth, health, and vigor is another possible decarbonization pathway for the agricultural sector. Precision irrigation can include fertilizer application management to reduce overapplication, runoff, and source of embedded carbon in California's agricultural sector.

Demand Response Participation

Collectively there are between 160,000 and 170,000 irrigation pumps in the Central Valley. The potential for irrigation pumps to be managed for more frequent/regular response to dynamic demand response programs appears high, but challenges remain that require additional research and demonstration. Technology development is needed to provide growers across a wider range of crops with access to automation systems that enable time-of-use rates and other dynamic rate structures. Access to automation systems will help maximize crop yields while minimizing energy and water costs. Further, the effect of rate and incentive structures on customer use patterns needs to be evaluated and incentives may need to be modified over time. Adjustments may be necessary to maximize benefits to growers, for GHG reductions, and for grid operations.

Energy Efficiency and Load Shifting at Indoor Agricultural Operations

Indoor farms producing high-value crops typically are heated, cooled, and lit 24 hours a day, seven days a week. Through the optimization of indoor-farm operations, development and deployment of advanced, energy-efficient technologies and optimization of crop yield by energy usage, there is opportunity for electricity savings, especially in lighting technologies, space conditioning, and smart controls. Light-emitting diode (LED) lighting has been shown to reduce indoor farming energy use by more than 60 percent,[393] but further reductions are

392 U.S. Environmental Protection Agency. "Energy Efficiency and Cost Saving Opportunities for Ammonia and Nitrogenous Fertilizer Production: An ENERGY STAR® Guide for Energy and Plant Managers." March 2017. https://www.energystar.gov/sites/default/files/tools/Fertilizer_guide_170418_508.pdf?4759-51fa.

393 USDA National Institute of Food and Agriculture. 2017. LED Lighting Improves Sustainability for Specialty-Crop Producers. https://www.usda.gov/media/blog/2013/09/24/led-lighting-improves-sustainability-specialty-crop-producers.

possible. In an indoor farm, satisfactory plant growth does not depend upon lights coming on at a specific time of day or night, and this provides an opportunity for shifting electric load to times when renewable energy is available and away from when demand on the grid peaks. Also, indoor farmers have the ability to vary inputs and manipulate crop growth patterns and yields as well as product quality. Typical strategies include periods of underwatering and light *deprivation*. There is substantial undeveloped potential to align sophisticated indoor agriculture practices with grid needs. There is also value for both individual farmers, in the form of reduced energy costs, and ratepayers in improving system load patterns and reducing GHG emissions by dynamically managing those loads.

California's 2022 Energy Code establishes new efficiency standards for commercial greenhouses (referred to in the regulations as *controlled environment horticulture*). These new standards include mandatory requirements for dehumidification equipment, lighting, electrical power distribution systems, space conditioning, and the building envelope.[394] These new standards take effect January 1, 2023; however, no intermediary standards are in place until then, and energy efficiency requirements are left to the counties to manage and require.[395]

Reduced Transportation Burden with Indoor Agriculture

Indoor farming has the potential to reduce transportation and energy use associated with distribution if indoor farms are located near the point of processing or consumption. In the United States, most of the fresh produce is shipped extensive distances (in some cases between 1,500 and 2,500 miles) from the field to the consumer. Billions of dollars are spent annually delivering and distributing crops from where they are grown to where they are sold, consumed, or processed. Studies have shown that long-distance transport can result in vegetables and fruits losing a portion of the nutrition and freshness. Unless preservatives are used, long-distance shipment reduces the shelf life of the produce once it reaches the warehouse or store. Reduced shelf life leads to additional spoilage and waste. It was reported in 2008 that roughly $47 billion worth of food in the United States (which includes meat, dairy, produce, and other products) did not make it into consumers' shopping carts because of waste.[396]

394 CEC. July 14, 2021. Revised Express Term, 2022 Energy Code, Title 24 Parts 1 and 6. pp. 199-200. https://efiling.energy.ca.gov/GetDocument.aspx?tn=238848.

395 Southern California Edison. April 2021. *Market Characterization of Indoor Agriculture (Non Cannabis)*. Project Number ET20SCE7050. https://www.etcc-ca.com/reports/market-characterization-indoor-agriculture-non-cannabis?dl=1634371754.

396 Buzby, Jean C. and Jeffrey Hyman. "Total and Per Capita Value of Food Loss in the United States." *Food Policy*, 37(2012):561–570. https://www.sciencedirect.com/science/article/abs/pii/S0306919212000693.

Programs Supporting Decarbonization in Agriculture

California is supporting decarbonization in the agricultural sector with a variety of incentive, grant, and research and development programs supported at the state level, as described below.

Renewable Energy for Agriculture Program

The Renewable Energy for Agriculture Program (REAP), funded under Assembly Bill 109 (Ting, Chapter 249, Statutes of 2017), provided up to $9.5 million in grants for the installation of onsite renewable energy technologies and related equipment to serve agricultural operations in California. Funding was awarded to more than 40 projects (approved at the June 2019 CEC business meeting) demonstrating quantifiable reduction of GHG emissions through the installation of solar PV, with many projects including electric vehicle charging infrastructure.

State Water Efficiency and Enhancement Program

The California Department of Food and Agriculture (CDFA) State Water Efficiency and Enhancement Program (SWEEP) was created to provide grants to implement irrigation systems that reduce GHGs and save water on California agricultural operations. Eligible system components included (among others) soil moisture monitoring, drip systems, switching to low-pressure irrigation systems, pump retrofits, variable frequency drives, and installation of renewable energy to reduce on-farm water use and energy. SWEEP made grant awards to 828 projects covering more than 134,000 acres. As of October 2021, $81.1 million has been awarded, with more than $52.8 million in matching funds. Projects from the most recent round of funding started in June 2020 and are expected to be completed by December 2021. CDFA estimates that more than 81,000 metric tons of CO_2e will be reduced annually, the equivalent of removing 17,500 cars from the road for one year (based on emissions reductions equivalent). Moreover, SWEEP projects will help save more than 117,000 acre-feet of water annually, enough to fill roughly 70,500 Olympic-sized swimming pools.

May Revise of 2021-2022 Budget

Included in the May Revision of the fiscal year 2021–2022 state budget was proposed funding of $60 million for CDFA's SWEEP program[397] and a $50 million one-time general fund allocation for Climate Smart Agriculture for Sustainability and Resiliency (for example, methane reduction

397 Governor Gavin Newsom. May 2021. California State Budget Summary: Climate Change. http://www.ebudget.ca.gov/2021-22/pdf/Revised/BudgetSummary/ClimateChange.pdf.

projects, equipment replacement, water efficiency, healthy soils, and energy efficiency for food processing).[398]

CEC Research and Development Programs

The CEC's EPIC[399] and the Natural Gas Research and Development program[400] support agricultural research. The research programs are described in Chapter 2*.*

Since 2012, EPIC has funded several agricultural-related projects focused on development and demonstration of software tools linked to mobile devices to optimize irrigation practices. Projects include precision irrigation and water management efforts with different approaches to reduce water and energy usage using sensors, data, and analysis tools to determine the best time to water and to water only when needed.[401] Results from completed projects showed that use of the developed software tools and irrigation strategies reduced energy and water use and enabled farmers to shift consumption to periods when electricity costs are low

EPIC invested in research to develop a smart irrigation control system that improves and expands on current remote irrigation pump switching technology to make it easier for growers to participate in demand response.[402] The technologies developed provide the ability for growers to automate their preferred load control strategies in response to new time-of-use electricity rates. Beyond that basic capability, the systems facilitate automated response to utility and system operator demand response signals, enabling participation in current and future demand response and reliability programs.

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398 Governor Gavin Newsom. May 2021. California State Budget 2021–2022. http://www.ebudget.ca.gov/2021-22/pdf/Revised/BudgetSummary/FullBudgetSummary.pdf.

399 CEC. Electric Program Investment Charge Program webpage, https://www.energy.ca.gov/programs-and-topics/programs/electric-program-investment-charge-epic-program.

400 CEC. Natural Gas Program webpage, https://www.energy.ca.gov/programs-and-topics/programs/natural-gas-program.

401 Jerphagnon, Olivier, Stanley Knutson, Roland Geyer, and Kate Scow. (PowWow Energy). 2019. Decision Support Tool to Reduce Water and Energy Consumption in Agriculture. California Energy Commission. Publication number: CEC-500-2019-022. https://www.energy.ca.gov/publications/2019/decision-support-tool-reduce-energy-and-water-consumption-agriculture.

402 April 14, 2021, CEC Business Meeting. Polaris Energy Services, Inc. "Accelerated Deployment of Irrigation Pumping Demand Flexibility." EPC-20-019. https://www.energy.ca.gov/event/meeting/2021-04/energy-commission-business-meeting.

In July 2021, the CPUC approved a proposed research initiative to develop and demonstrate technological advancements for energy efficiency and load-shifting operations in existing indoor farms and retrofits of existing buildings into indoor farms.[403]

403 Energy Efficiency and Load Shifting in Indoor Farms research initiative. EPIC Interim Investment Plan and Appendices - Approved July 15, 2021. https://www.energy.ca.gov/proceedings/energy-commission-proceedings/electric-program-investment-charge-2021-2025-investment.

CHAPTER 7: Recommendations

Focus on Existing Buildings

- California has 13.7 million homes and more than 7,392 million square feet of commercial buildings. Investing at scale is necessary to reduce greenhouse gas (GHG) emissions from buildings and allow consumers to address climate change impacts from extreme heat and wildfires.
- The California Energy Commission (CEC) and other relevant agencies should work to quantify the non-energy benefits of reducing building emissions, for example improved public health, where possible encouraging monetization of these energy-related externalities such that their mitigation can increase access to capital for decarbonization projects.
- Federal, state, and local agencies should coordinate incentives and various funding sources to enable diverse financing options for building decarbonization.
- The CEC, California Public Utilities Commission (CPUC), and the California Air Resources Board (CARB) should prioritize and fund decarbonization retrofits and supporting resources in low-income and disadvantaged communities. These efforts include active engagement starting with identifying opportunities and best methods of communication, seeking input to identify best practices, researching and collaborating to reduce energy burden, developing programs that meet the needs of low-income and disadvantaged communities, conducting targeted outreach and engagement to educate these communities on available programs, and streamlining and simplifying decarbonization program applications.
- Any federal or state funds allocated for energy efficiency or decarbonization should be focused primarily on existing buildings, especially in low-income and disadvantaged communities. This allocation should include the infrastructure upgrades and remediation needed to electrify existing homes, equipment costs, and workforce training. Any regulatory or policy barriers that prevent this should be addressed.
- The CEC should assess the potential remediation needs and costs associated with building retrofits. These include the typical added upfront costs due to mold, asbestos, lead pipes, and water damage, where it is an obstacle to the installation of electric equipment.
- Consider statutory changes to enable the CEC to leverage the statewide benchmarking program to develop and establish building performance standards for existing commercial and multifamily buildings. Such standards should consider energy usage, GHG emissions, and indoor air quality.
- The state should provide a statewide information campaign to familiarize consumers with, and promote, high-efficiency electric appliances.

- The CEC and CPUC should support strategic design of building decarbonization projects and programs to maximize health co-benefits and affordability in low-income and disadvantaged communities.

Agency Coordination

- To achieve California's clean energy and carbon-neutral climate goals, the building sector should contribute its pro rata share of GHG emission reductions. The 2021 *California Building Decarbonization Assessment* found that achieving a 40 percent reduction in GHG emissions from buildings by 2030 would put buildings on such a trajectory.
- To achieve building decarbonization, agencies must work in a coordinated fashion as they deploy their primary regulatory tools, for example the CEC (such as the Building Energy Efficiency Standards and CALGreen, among others), CARB (Climate Change Scoping Plan and State Implementation Plan) and the regional air districts (Air Quality Management Plans), primarily, as well as an array of state affordable housing finance programs.
- The California Department of Housing and Community Development (HCD), California Housing Finance Agency (CalHFA), Strategic Growth Council, CARB, and the CEC should work to align California's affordable housing support programs with GHG reduction goals. The interagency Housing and Decarbonization Working Group should continue to provide a platform for coordination and develop specific guidance to the agencies.
- The CEC, CPUC, and CARB should continue to align energy efficiency and decarbonization goals and activities through interagency coordination. This coordination will improve outcomes, provide common definitions and accounting practices, and leverage data analysis and expertise.
- The CEC, CPUC, and CARB should align transportation and building electrification initiatives.
- The CEC should support other agencies — federal, state, local, and tribal — in pursuing public health and safety-oriented regulatory updates to reduce GHG emissions statewide (local ordinances, Title 24 Part 11).

Efficient-Electric New Buildings

- The CEC should shift further toward efficient electric end uses in the 2025 Energy Code, including through CALGreen, consistent with state and federal law.
- The CEC, CPUC, and CARB should work closely and deliberatively to decarbonize remaining end uses in new buildings using their own complementary authorities through the lenses of health and safety, air quality, GHG emissions, utility connection, and gas infrastructure.
- CARB and air quality management districts in non-attainment areas of the state should explore their authorities to reduce emissions from buildings under the 2022 State Implementation Plan.

- Mirroring the recommendation in the *2021 Integrated Energy Policy Report, Volume III*, the CPUC should investigate eliminating line extension allowances for new gas hookups.

Enable and Promote Load Management and Flexible Demand

- The CEC, CPUC, and California Independent System Operator (California ISO) should use load management and demand flexibility as tools to decarbonize buildings, support grid reliability, expand equitable access to electric vehicle charging infrastructure, and reduce energy costs.
- The CPUC and CEC should support the installation and use of load-shifting technologies (such as connected smart thermostats or load flexible heat pump water heaters) in existing homes, with a focus on low-income and disadvantaged communities to ensure they have equitable opportunities to benefit from new load flexibility programs.
- The CEC and California ISO should collaborate to measure the impact and appropriately expand the use of flexible demand as a grid management tool and reliability resource.

Recycle Refrigerants and Reduce High-GWP Refrigerants

- CARB's successful implementation of Senate Bill 1383 (Lara, Chapter 395, Statutes of 2016) is of central importance for decarbonizing California's buildings, both new and existing.
- The CEC and CARB, in coordination with other agencies, should explore regulatory and programmatic approaches to increase the adoption of low-GWP refrigerant technologies and minimize refrigerant leakage.
- The CEC, CARB, and the United States Environmental Protection Agency should identify strategies and tools to ensure refrigerants are properly recaptured and recycled upon equipment replacement.
- The state and utilities should support research into heat pump technologies optimized for California climate zones. The research should apply to both newly constructed and existing buildings.

Data and Analyses

- The CEC, in coordination with CPUC, should gather data on equipment sales, building retrofits, permitting trends, and decarbonization programs to provide further insight into adoption rates, GHG impacts, barriers to equitable access and deployment, and potential for program targeting and layering.
- The CEC, CPUC, CARB, and the California ISO should coordinate to standardize energy accounting methods for building decarbonization and load flexibility.

Compliance and Enforcement

- The CEC should lead alignment efforts across state and local agencies and use technology to improve and streamline the permitting process and to ensure quality installation of heating, ventilation, and air-conditioning (HVAC) systems.

- As part of the 2022 and 2025 Building Code Updates, the CEC should support increased compliance by implementing strategies that simplify, automate, digitize, and otherwise make the permitting, compliance, and documentation process easier and less expensive for the user.
- Consider expanding the statutory authority, responsibility, and resources of the Contractors State License Board to identify and take disciplinary action with higher consequences for (1) licensed contractors who fail to pull permits and fail to meet state quality installation standards for HVAC projects and (2) other persons who complete such projects without a license to do so.
- The state should require distributors sell HVAC equipment to only licensed contractors and report to the CEC the number of equipment units that are sold to each purchaser.
- The CEC should work with manufacturers and distributors to ensure that warranty registrations include the permit number for the installation of the equipment and that warranty claims require permits to have been pulled for the installation.
- The CEC should work with local agencies to require that all permits record the license number of the installing contractor.
- The CEC should consider alternative means to demonstrate compliance with the CEC's quality installation standards, including participation in utility programs that verify quality installation, use of remote quality control monitoring systems, and installation of fault detection and notification equipment.
- Building departments should continue to simplify permitting and inspection for heating and air-conditioning system replacement installations, including online permitting and remote inspections.
- Encourage training for contractors and technicians so they can properly meet quality installation standards and refrigerant recapture and recycling procedures.
- Encourage that consumer protection information be provided to persons for whom an HVAC system is installed, regarding the benefits of quality installation.

Support Local Leadership and Workforce

- The CEC, CPUC, and CARB should work through community-based organizations to identify needs and mechanisms to advance decarbonization at the local level.
- The CEC and other state agencies should continue to collaborate with, and provide funding to, local and tribal governments to support and advance GHG reduction planning and implementation.
- The CEC and other state agencies should engage early and actively with stakeholders representing worker interests. These efforts should include actively engaging with workforce development entities on decarbonization priorities, seeking input to identify best practices, developing programs that meet the needs of workforce development entities, and simplifying program access.

- Workforce training and education supported by the state and rate-payer funding should focus on just transition and community-focused clean energy jobs that benefit local communities and historically disadvantaged residents.

Embodied Carbon

- The relevant state agencies, including CARB, the Department of General Services (DGS), the California Building Standards Commission (CBSC), CEC, and HCD, should collaborate to:
  - Identify and characterize the full range of roles, authorities, responsibilities, and needs related to reducing embodied carbon in the production, use, and disposal of building materials.
  - Draft and establish an agreed-upon framework to assess embodied carbon in buildings, analyze the potential for reducing embodied carbon, determine the applicability of environmental product declarations, and establish standards, as appropriate.
  - Investigate the authority needed to require that carbon intensity metrics for building products be communicated too building designers, specifiers, and consumers. California-made products and manufacturers should not be put at an economic disadvantage to imports that have higher carbon intensity and negative environmental impact.
- Consider statutory changes to expand Buy Clean California Program to include global warming potential (GWP) impacts and limits for more building materials.
- The state should provide grant funding for California-based manufacturers or producers to develop and test technologies to decarbonize cement, steel, and other high-GWP products.
- CARB, DGS, HCD, CBSC, CEC, and other partners should coordinate to develop regulatory proposals focused on low-embodied-carbon construction goals based on existing authority.

Industrial and Agricultural Process Decarbonization

- Relevant state agencies should support a range of commercial and emerging decarbonization technologies and strategies for the industrial and agricultural sectors, including demonstrations and deployments of technologies and documentation of the potential benefits to end users and California.
- The Food Production Investment Program should serve as a model for future funding programs for industry, manufacturing, and agriculture. These programs should invest in both drop-in technologies that are known to work and emerging technologies with potential for high energy and GHG benefits.
- The CEC in coordination with other agencies should partner with the United States Department of Energy industrial assessment centers by sharing successful strategies,

and through collaborations with other states and nations whose experiences align with California's decarbonization efforts.

- The state and utilities should continue to support research and development through the CEC's Electric Program Investment Charge and the Natural Gas Research and Development program.
- Relevant state agencies should investigate the feasibility and opportunity for carbon capture, utilization, and storage (CCUS) hubs in California with centralized utilization or sequestration or both to increase the value of CCUS for industries.

Acronyms

AB	Assembly Bill
ARRA	American Recovery and Reinvestment Act
AHRI	Air-Conditioning, Heating, and Refrigeration Institute
AWHI	Advanced Water Heating Institute
BTM	behind-the-meter
BTM PV	behind-the-meter photovoltaic
BUILD	Building Initiative for Low-Emissions Development
C	Celsius
CAEATFA	California Alternative Energy and Advanced Transportation Authority
CalRecycle	California Department of Resources Recycling and Recovery
California ISO	California Independent System Operator
CARB	California Air Resources Board
CARE	California Alternate Rates for Energy
CCA	community choice aggregator
CCUS	carbon capture, utilization, and storage
CDFI	Community Development Financial Institution
CDPH	California Department of Public Health
CEC	California Energy Commission
CEQA	California Environmental Quality Act
CHEEF	California Hub for Energy Efficiency Financing
CLF	Carbon Leadership Forum
CMC	California Building Mechanical Code
CO_2	carbon dioxide
CPUC	California Public Utilities Commission
CSD	California Department of Community Services and Development
CSLB	Contractors State Licensing Board
CWDB	California Workforce Development Board
DER	distributed energy resources

DGS	Department of General Services
EC3	embodied carbon in construction calculator
EE	energy efficiency
EPD	environmental product declaration
EPIC	Electric Program Investment Charge program
ESA	energy services agreement
EUI	energy use intensity
EV	electric vehicle
FERA	Family Electric Rate Assistance
FPIP	Food Production Investment Program
GDP	gross domestic product
GEB	grid-interactive efficient building
GFO	Grant Funding Opportunity
GGRF	Greenhouse Gas Reduction Fund
GHG	greenhouse gas
GSA	General Services Administration
GWh	gigawatt-hour
GWP	global warming potential
HCD	California Department of Housing and Community Development
HFC	hydrofluorocarbon
HPWH	heat pump water heater
HSE	hourly source energy
HVAC	heating, ventilation, and air conditioning
IAC	industrial assessment center
iBank	California Infrastructure and Economic Development Bank
IEPR	Integrated Energy Policy Report
IOU	investor-owned utility
kW	kilowatt
kWh	kilowatt-hour
LADWP	Los Angeles Department of Water and Power

LED	light-emitting diode
LEED	Leadership in Energy and Environmental Design
LIFT	Low-Income Families and Tenants Program
LIHEAP	Low Income Home Energy Assistance Program
LIWP	Low-Income Weatherization Project
LSE	load-serving entity
MCE	Marin Clean Energy
MIDAS	Market Informed Demand Automation Server
MMmt	million metric tons
MW	megawatt
MWh	megawatt-hour
NBI	New Buildings Institute
NO_2	nitrogen dioxide
NO_x	oxides of nitrogen
NZE	net-zero energy
OIR	Order Instituting Rulemaking
PG&E	Pacific Gas and Electric Company
PM	particulate matter
POU	publicly owned utility
PPP	public purpose program
PV	photovoltaic
R&D	research and development
R4	Refrigerant Recovery, Recycle, and Reuse
RASS	Residential Appliance Saturation Study
RPS	Renewables Portfolio Standard
SB	Senate Bill
SCE	Southern California Edison
SCM	supplementary cementitious materials
SDG&E	San Diego Gas & Electric
SEI	Structural Engineers Institute

SEM	strategic energy management
SGIP	Self-Generation Incentive Program
SMUD	Sacramento Municipal Utility District
SoCalGas	Southern California Gas Company
SWEEP	State Water Efficiency and Enhancement Program
TDV	time-dependent valuation
TECH	Technology and Equipment for Clean Heating
UC	University of California
UEC	unit energy consumption
U.S. DOE	United States Department of Energy
U.S. EIA	United States Energy Information Administration
WAP	Weatherization Assistance Program
WBCSD	World Business Council for Sustainable Development

Glossary

Abandoning service is the technical term for taking a line out of service and out of the rate base. Most abandonments must be approved by a regulator.

Aldyl-A is a type of plastic used for gas distribution pipelines that can become brittle and fail, long before its intended end of service life. Dupont, a manufacturer of this plastic, issued its first warning about potential failures in 1982, followed by federal investigations and advisories to replace pipelines starting in 1998.

A ***balancing authority*** is responsible for operating a transmission control area. It matches generation with load and maintains consistent electric frequency of the grid, even during extreme weather conditions or natural disasters. In California there are eight balancing authorities, the largest of which are the California Independent System Operator, the Balancing Authority of Northern California, and Los Angeles Department of Water and Power.

Battery storage refers to rechargeable energy storage systems consisting of electrochemical storage batteries, battery chargers, controls, and associated electrical equipment designed to provide electrical power to a building. Such systems are typically used to provide standby or emergency power, uninterruptable power supply, load shedding, load sharing, or similar capabilities.

For a power plant to provide power via the combustion turbine to the grid, the plant takes power from the grid to start up the turbines. However, if grid power is unavailable due to a blackout or the grid being down, the power is provided by either diesel generators or batteries onsite. This is referred to as a ***black start****.* So, if the grid is down, the power plant can start itself up without the grid.

A ***British thermal unit*** is the quantity of heat required to raise the temperature of one pound of water 1 degree Fahrenheit at a specified temperature (such as 39 degrees Fahrenheit).

Cathodic disbondment in a pipeline is the breakdown of adhesion between a coating and the coated substrate to which it is applied, caused by cathodic reaction products being formed at defects in the coating film as the cathodic protection current passes into the substrate at the defective area.

Citygates are where gas moves from transmission to distribution.

Climate zones are the 16 geographic areas of California for which the Commission has established typical weather data, prescriptive packages, and energy budgets. Climate zones are defined by ZIP code and listed in California Code of Regulations, Title 24, Part 6, Reference Joint Appendix JA2.

A ***community choice aggregator*** is a local, not-for-profit, public entity that determines energy sources for local electricity needs.

Compressed natural gas is produced by compression, cooling, and dehydration of natural gas (down to less than 1 percent of its volume) that is stored in pressurized tanks and can be used in place of gasoline or diesel in vehicles.

Drought can reduce hydropower generation when water levels in the state's dams and reservoirs reach a point called ***deadpool***, where there is not sufficient water pressure to run the turbines.

Deep decarbonization is defined by the Deep Decarbonization Pathways Project as reducing United States greenhouse gas emissions by at least 80 percent from 1990 levels by 2050 via technical and policy pathways that require systemic changes to the energy economy.

A ***dekatherm*** is the quantity of heat energy that is equivalent to one million British thermal units.

A ***delivered*** price is the sum of the price paid for commodity gas supply plus the transportation service rate charged by the utility to deliver that gas to the end user. That transportation service rate also typically includes some allocation of balancing service cost and any cost for the use of storage that the California Public Utilities Commission might assign to that particular customer class.

Demand flexibility, or ***demand response***, is the practice of managing customer electricity usage in response to economic incentives.

The term ***demand scenarios*** has been coined to reflect that any one specific projection is just one of several scenarios that result from assessing a set of assumptions with numerous uncertain values.

Differentiated gas involves documenting efforts by the upstream oil and gas industry to reduce emissions through verification of emissions reductions and allowing the industry to monetize such efforts. A similar concept verifying winterization could be pursued.

Dry gas refers to gas containing low levels of liquids.

The ***duck curve*** is characterized by more drastic increases in net demand in the evening hours as solar decreases, and a net peak that occurs later in the evening when solar generation is substantially diminished or nonexistent.

The ***Electric Power Research Institute*** conducts research, development, and demonstration projects for the benefit of the public in the United States and internationally. It is an independent, nonprofit organization for public interest energy and environmental research, focused on electricity generation, delivery, and use in collaboration with the electricity sector, its stakeholders, and others.

Embodied carbon refers to the greenhouse gas emissions resulting from the extraction, manufacturing, transportation, installation, maintenance, and disposal of building materials.

Energy burden refers to the percentage of household income spent on energy costs.

Federal Energy Regulatory Commission regulates natural gas transportation in interstate commerce and construction of gas pipeline, storage, and liquefied natural gas facilities.

A ***force majeure*** is an unforeseeable circumstance that prevents someone from fulfilling a contract and includes both acts of nature (such as hurricanes or earthquakes) and extraordinary circumstances due to human intervention (for example, riots or worker strikes). A force majeure provision becomes applicable when performance becomes impossible and not when it simply becomes burdensome.

Fracking, or hydraulic fracturing, refers to the process creating fractures in rocks and rock formations by injecting specialized fluid into cracks to force them to open further to increase the rate at which petroleum or gas can be recovered from subterranean wells. Fracking is often done in combination with horizontal well drilling that allows more of the wellbore to remain in contact with the producing formation.

A ***fuel group*** is a set of regional power plants identified in the PLEXOS model that is assigned a specific burner tip location price.

Gasification is the conversion of biomass feedstocks to a gaseous fuel, while pyrolysis is the thermal decomposition of biomass in the absence of oxygen (that prevents combustion) to produce liquid fuels. These gas and liquid fuels can be used in conventional equipment (for example, boilers, engines, and turbines) or advanced equipment (such as fuel cells) for the generation of heat and electricity.

A ***gigaton*** is equal to one billion tons.

Global warming potential is a metric that allows comparisons of the global warming impacts of different gases. It is a measure of how much energy the emissions of 1 ton of a gas will absorb over a given period of time, relative to the emissions of 1 ton of carbon dioxide. The larger the global warming potential, the more that a given gas warms the Earth compared to carbon dioxide over that time period.

Grid harmonization refers to strategies and measures that harmonize customer owned distributed energy resources with the grid to maximize self-utilization of PV array output, and limit grid exports to periods beneficial to the grid and the ratepayer.

A ***high consequence area*** is a buffer area on either side of a pipeline segment that passes through developed areas where people live (for example, city or suburbs) or gather (such as a school). Pipelines in high consequence areas are required to have safety features or meet extra safety measures or both.

Hydrogen produced by splitting water using renewable electricity has significantly lower carbon emissions. Hydrogen produced in this way is known as renewable or ***green hydrogen***. (Grey hydrogen is produced from fossil fuels, emitting significant carbon dioxide in the process. Blue hydrogen is the same as grey hydrogen, except that the carbon emitted during the production process is captured and sequestered.)

LED lighting refers to lighting systems which utilize specialized semiconductors called light emitting diodes to convert electrical energy directly into light, delivering efficient light generation with little-wasted electricity.

A ***load factor*** is a measure of utilization rate in which the average load or demand is divided by the peak load or demand.

Load management standards are cost-effective programs which result in improved utility system efficiency, reduced or delayed need for new electrical capacity, reduced [fossil] fuel consumption, and lower long-term economic and environmental costs to meet the State's electricity needs.

Low-income households are defined as households at the twentieth percentile of the regional income distribution. The twentieth percentile was selected for analysis in this report because it represents households that are low-income, but do not qualify for assistance programs like the California Alternate Rates for Energy program.

Marginal abatement costs include the annualized incremental technology costs over the life of the equipment and the operational fuel costs (or savings) of using the equipment.

A ***metric ton*** is a unit of weight equal to 1,000 kilograms or approximately 2,205 pounds.

Minimum generation is generally the required minimum generation level of a utility systems thermal units needed to prevent electricity outages.

Net demand is the total electricity demand minus utility-scale solar and wind generation at a given time. The net peak typically occurs later in the afternoon and evening than the total demand peak.

Net energy metering is a billing arrangement that provides credits to behind-the-meter solar photovoltaic customers who export excess electricity to the utility. The credits can be used to pay for electricity drawn from the utility.

North American Electric Reliability Corporation ensures the reliability of the bulk power system by developing reliability standards.

The ***North American Energy Standards Board*** serves as an industry forum for the development and promotion of standards that will lead to a seamless marketplace for wholesale and retail gas and electricity, as recognized by its customers, business community, participants, and regulatory entities.

Once-through cooling technologies intake ocean water to cool the steam that is used to spin turbines for electricity generation. The ocean water that was used for cooling becomes warmer and is then discharged back into the ocean. The intake and discharge have negative impacts on marine and estuarine environments.

An ***Operational Flow Order*** is a mechanism to protect the operational integrity of the pipeline. Gas utilities may issue and implement systemwide or customer-specific Operational Flow Orders in the event of high or low pipeline inventory. Operational Flow Orders require shippers to take action to balance their supply with their customers' usage on a daily basis within a specified tolerance band.

A ***piggable pipeline*** is designed to allow a standard inspection tool, also referred to as a "pig," to negotiate it, which requires basically a more or less constant bore that has sufficiently long radius bends and traps to launch and receive the pigs.

A ***pilot light*** is a small flame that is kept lit in certain gas-fired appliances such as furnaces, water heaters, and gas fireplaces. When you turn these on, gas is released to the main burner and the pilot light ignites that gas to turn on your appliance and provide heat.

Postage stamp rates refer to the concept employed by the United States Postal Service where one price is charged for mailing a letter regardless of the distance between the sender and receiver of the mail. On the gas system, gas customers pay the same rate regardless of where they are located in relation to the distribution system rather than paying a rate that varies by distance.

Power-to-gas refers to a process where electric power is used in technologies to produce gas such as hydrogen.

Power-to-X is a process in which electrolysis-produced hydrogen fuels residential, commercial and industrial end uses, in addition to electric grid support.

Renewable gas refers to gas produced from waste and a variety of renewable and sustainable biomass sources.

Retrocommissioning refers to tuning the energy consuming systems in an existing building to operate more efficiently.

Specified minimum yield strength denotes the stress level at which a pipe will deform. It is an input to calculating maximum allowable operating pressure.

Spinning reserves in a power system are generation capacity that is on-line but unloaded (not generating) and that can respond within 10 minutes to compensate for generation or transmission outages.

Supplementary cementitious materials are materials that, when used in conjunction with portland cement, portland limestone cement, or blended cements, contribute to the properties of hardened concrete through hydraulic or pozzolanic activity or both. This reduces the amount of cement and therefore carbon that results from concrete production.

A ***terawatt*** is a unit of power equal to one trillion watts.

Transportation electrification is the process by which vehicles are switched to rely on electricity for power instead of fossil fuels.

The ***Western Electricity Coordinating Council*** promotes bulk power system reliability and security in the Western Interconnection that extends from Canada to Mexico and includes the provinces of Alberta and British Columbia, the northern portion of Baja California, Mexico, and all or portions of the 14 western states between. The Western Electricity Coordinating Council is responsible for compliance monitoring and enforcement and oversees reliability planning and assessments.

Winterization involves the installation or use of equipment, or addition of chemicals into the gas stream, by well, gathering, and processing operators to prevent infrastructure freeze-offs. Gas fired power plants can also be winterized.