Decarbonization of Heating Energy Use in California Buildings

Technology, Markets, Impacts, and Policy Solutions

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(Authors: Hopkins, Takahashi, Glick, and Whited)

EXECUTIVE SUMMARY

California has some of the most comprehensive and ambitious clean energy policies in the world, with a recently passed law requiring 100-percent carbon-free electricity by 2045,[1] and an executive order aiming for economy-wide carbon neutrality by the same date. Using strong policies to encourage energy efficiency, renewable energy and clean transportation, the state is making rapid progress toward its goals. But to hit the mark, California will need to turn its attention to an overlooked corner of the emissions picture: the fossil fuels widely used to heat the buildings where Californians live and work.

California's buildings are responsible for 25 percent of the state's climate emissions,[2] and more than half of those emissions come from burning gas or propane in furnaces and water heaters.[3] In fact, nearly 90 percent of California homes use gas for heat or hot water or both. And as the electric grid gets cleaner over time, the share of building emissions from onsite fossil fuel use will only increase, making heating and hot water the lion's share of emissions from energy use in buildings.

Shifting toward clean electric heat in California's homes and businesses will be key to the state's efforts to reduce carbon and air pollution. Today's highly efficient electric heating technologies can provide a cost-effective way to reduce pollution from California's buildings sector, especially as the electric grid continues to become cleaner, buildings become more efficient, and utilities align their pricing with carbon-cutting goals.

Today's Clean, Efficient Electric Heating Technology

Electric heat pumps move heat instead of burning fuel to create heat, making them vastly more efficient than gas-powered furnaces, boilers, hot water heaters, and dryers. Air-source heat pumps for space heating are available today for all of California's climates and building needs, and are already broadly adopted in commercial buildings, particularly in Southern California. Heat pump water heaters can meet the hot water needs for most homes and businesses. Ground-source heat pumps have higher upfront costs, but can also be cost-effective particularly in large buildings and cold climates. Solar hot water with electric backup offers another clean energy solution and can be particularly cost-effective for larger buildings that use a lot of hot water, such as

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[1] SB 100 (De Leon), signed by Governor Jerry Brown in September 2018

[2] Brook, M. California Energy Commission. "Building Decarbonization." June 14, 2018 IEPR Workshop on Achieving Zero Emission Buildings.

[3] https://www.nrdc.org/experts/joe-vukovich/real-climate-impact-californias-buildings

hotels and hospitals. Heat pump dryers provide a low- carbon option for replacing gas or conventional electric dryers, and induction cooktops offer a faster, safer, cleaner alternative to gas cookstoves. However, these technologies today represent a small share of California's market, due to regulatory barriers and higher upfront costs in older homes.

Switching to electric heat and hot water will have a significant impact on reducing gas use in California buildings. If a third of California's buildings switched to clean electric heating technology by 2030, emissions from these end uses would fall by 7 million metric tons per year. That's the equivalent of zeroing out emissions from 1.5 million cars annually or avoiding the climate pollution from nearly four 500-megawatt gas power plants running around the clock. As California's electric grid continues to shift toward clean, renewable energy sources, emissions from electric heat will continue to drop.

Electric heat and hot water will also save consumers in energy costs over the life of the equipment, particularly if the new systems are used alongside improvements in energy efficiency and utility policies that help customers take advantage of off-peak pricing.

Financial, Comfort, and Health Benefits for Consumers

In new homes equipped with cost-effective solar panels, in line with California's new building code, highly efficient electric heat will cut energy bills by several hundred dollars annually. In older homes without solar, electric heating would be cost-competitive with gas when combined with simple energy efficiency improvements, such as attic insulation and air sealing. Savings vary depending on climate, building type, and especially utility rates. Electric rates with a significant difference in peak and off-peak pricing offer opportunities for customers to set their heat pumps to operate when electricity is cheapest and cleanest.

Upfront costs of clean electric heating are generally lower than conventional gas alternatives in new construction, by $1,500 or more in our model, as higher heat pump equipment costs are more than offset by avoiding the cost of plumbing the building for gas and connecting it to the gas main in the street, as well as by using a single heat pump for heating and cooling instead of a separate furnace and air conditioner. Operational energy costs vary by rate design, climate zone, and by how much solar is on the building. By sizing the solar array to generate enough electricity to power clean electric heating in addition to conventional electric loads like cooling, lighting, and plug-in equipment, home owners can save between $200 and $500 annually on their utility bills. From a lifecycle cost perspective, clean heating in new buildings can range between savings of more than $8,400 to a small net cost of under $400. Across climate zones, higher cost savings are achieved by using more dynamic electric rates and by maximizing cost-effective solar PV to supply the larger electric load.

In existing buildings, upfront costs of clean heating retrofits are generally higher and they vary more from home to home. For example, from $1,500 in lower costs when

replacing both the furnace and air conditioner with a heat pump along with minimal electric upgrades, to $900 in higher costs when replacing only the furnace. Electrical wiring, panel and/or service upgrade may be required in some homes, whether for heat pumps, electrical vehicle chargers, or just safety upgrades. When required, electrical upgrades could range from another few hundred dollars for wiring only to several thousand for a panel and/or service upgrade.

Operational energy costs in existing buildings also vary, depending on rates and location, but customers can reduce energy bills by up to $500 to $800 in the Bay Area and Sacramento where heating demand is higher than in the Los Angeles region, when using electrification-friendly rates, some basic air sealing and attic insulation energy efficiency upgrades, and on-site solar. The lifecycle cost of clean heating retrofits in existing buildings varies between savings of $7,300 and an extra cost of $9,700, showing the need for market development to bring down the cost of the technology and make it accessible to all. Life cycle cost-effectiveness is increased when pairing electrification with energy efficiency and more dynamic rate designs and by maximizing cost-effective solar PV to supply the larger electric load.

Using clean electricity instead of gas heat will reduce greenhouse gas emissions by between 31 percent and 73 percent depending on the size of the solar array and climate zone. These reductions come from the much higher energy efficiency of heat pump technology compared to gas alternatives, combined with powering them with cleaner electricity.

Clean heating can also improve health, safety, and comfort. Electric heating technologies improve indoor air quality by avoiding indoor combustion emissions that can cause headaches, fatigue, queasiness, eye, nose, and throat irritation, and serious lung disease, including cancer and other health impacts.[4] Heat pumps can also increase home comfort by operating virtually silently and providing more stable temperatures.

Electric Grid Benefits

Without additional energy efficiency measures, we find that the widespread use of electric heat could increase California's overall electricity use by approximately 19 percent, while decreasing gas use by a third. But done right, with energy efficiency and if much of the additional load is shifted to off-peak hours when renewable energy is plentiful, electrification can reduce electric system costs. The smart use of electric heat would spread fixed grid infrastructure costs over higher electricity sales and would help absorb surplus renewable energy during periods of low demand, helping achieve California's goal of a 100-percent carbon-free grid in an affordable manner.

[4] California Air Resources Board, https://www.arb.ca.gov/research/indoor/combustion.htm

Electric water heaters and, to some extent, reasonably well-insulated and airtight buildings can act like thermal batteries, storing heat for later use. By pre-heating hot water tanks and buildings during times when demand is low or when renewable energy is abundant, homes and businesses can shift more of their electricity use to off-peak hours. This would reduce peak strain on the grid and also help integrate more renewable energy into the system.

Buildings that can use electric heat to store clean, renewable energy instead of burning gas on site would be assets on a renewable grid. Efficient heat pumps, paired with building efficiency measures such as insulation and smart thermostats, will be key to cost-effective emissions cuts.

Policy Recommendations

Most buildings are around for 50 to 100 years or more, and the space and water heating equipment within them lasts 10 to 20 years. To take advantage of natural equipment replacement cycles, high- efficiency electric heat pumps need to become mainstream by 2030.

This gives California a dozen years to develop the market and make this heating technology affordable and accessible to all. The technology exists, it needs policy support to jump start its sales, reduce its costs, and make it more broadly available. Specific policy changes can help make this happen:

- Raise awareness and educate customers, policy makers, product distributors, and the building trades on the technology's availability, and its financial, health, safety, and comfort benefits. Lack of awareness is one of the key barriers to adoption of this emerging clean energy technology.

- Set targets and develop plans to create market certainty, encourage investment, and provide a clear framework to guide the development of new policies and programs (and secure stable funding for those programs).

- Remove regulatory and market barriers that are hindering market development, by updating policies such as incentive programs, limitations on fuel-switching programs, and rate design, to reflect California's clean energy resources and policy objectives. Also remove accessibility barriers through financial incentives and financing to overcome capital cost and product availability issues.

- Transform the market by accelerating and scaling adoption through mechanisms such as building codes, integrating electrification with other policies such as energy efficiency retrofits, and continued product research, development, and deployment programs.

Done right, building decarbonization will also provide major affordability, quality of life, and public health benefits to Californians. But reaping these benefits requires massive market transformation, on the scale of the renewable electricity and electric vehicle

revolutions. The decarbonization of California's buildings will take decades, but it must start now to avoid unnecessary stranded costs and set in motion the virtuous cycle of declining equipment, installation, and operating costs that will make clean and affordable buildings accessible to all.

Californiacan also have an outsized influence on the rest of the world, which is looking at the Golden State for clean energy leadership. Addressing California's building decarbonization challenge in a way that benefits customers, the grid, and the environment is critical to achieving our climate and clean energy goals globally.