PATHWAYS TO CARBON NEUTRALITY IN CALIFORNIA

Decarbonizing the Residential Sector

Stanford
Center for Carbon Storage
Carbon Removal Initiative

This brief discusses key findings from the following report: Joshua Neutel, Adam Brandt, Sally M. Benson and Sarah D. Saltzer "Pathways to Carbon Neutrality in California: Decarbonizing the Residential Sector", Stanford Center for Carbon Storage and Stanford Carbon Removal Initiative, May 2022.

Direct emissions from the Residential sector accounted for roughly 8% of California emissions in 2019. The objective of this study is to better understand residential emission sources, as well as the economic / engineering feasibility of decarbonization solutions. To achieve this objective, a bottom-up, stock-and-flow model was developed for the Residential sector. The model, called ResLEAP, was created in the Low Emissions Analysis Platform (LEAP)*.

ResLEAP was used to answer a variety of questions, including:

- What are the technologies that contribute most to energy consumption and onsite emissions?
- How do energy consumption and emissions vary geographically across the state?
- How do various electric technologies contribute to the residential load shape?
- What are the most economically and environmentally efficacious solutions?

KEY FINDINGS

1. Electrifying water and space heating will be key to decarbonizing the Residential sector.

2. Policies aimed at new homes will make marginal improvements (at best) to residential emissions. Achieving emissions goals will require improvements to the existing housing stock.

3. Lags due to equipment turnover are important. Models developed for this study show that to reach near net-zero emissions by 2045, 100% of space heater sales will need to be electric by about 2025. Water heater electrification can be delayed slightly. The overall pace of technology investment required -- mainly in space heaters, water heaters, and electric panels -- is quite staggering.

4. Water heat pumps are an important opportunity. Water heat pumps have the lowest cost of carbon abatement ($56/t) of all electric technologies evaluated in this study. Water heat pumps are closer in retail price to natural gas (NG) water heaters than space heat pumps are to NG furnaces. In addition, water heat pumps achieve efficiency gains required to return fuel benefits. Water heating is also less peak driven than space heating, and thus the grid can tolerate higher levels of water heating electrification.

5. NG furnaces can be swapped with electric resistance furnaces or space heat pumps as near like-for-like replacements. These technologies have distinct pros and cons. Electric resistance furnaces are inexpensive on a capital cost (CAPEX) basis, however significant deployment of electric resistance furnaces would require considerable grid capacity expansion. This is particularly true because space heating is a peak driven service. Space heat pumps have less effect on the grid because they are more efficient. That being said, space heat pumps are more expensive on a CAPEX basis, and they pose substantial risk to increasing fluorinated gas (F-Gas) emissions.

6. The state should consider prioritizing space heat pumps in homes that already have air conditioners (ACs) to (partially) offset high capital costs and risk of F-Gas leaks. Due to the dual functionality (provides both heating and cooling services) of heat pumps, future AC and furnace replacement costs can be converted into only one heat pump replacement cost. Furthermore, future AC F-gas leaks can be converted to heat pump F-Gas leaks, as opposed to adding additional refrigerant leaking into the system.

7. Investment in heat pumps should ideally be coupled with policies that reduce risk posed by F-Gases. Almost half of the risk can be mitigated by introducing effective programs for responsible end-of-life (EOL) management. In addition, low global warming potential (GWP) refrigerants, such as CO2, ammonia, and propane, will be needed to reach near net-zero. The state is already investigating low-GWP refrigerators and ACs, and should consider expanding this investigation to space and water heat pumps (which are available overseas).

* More information on LEAP can be found here: https://www.sei.org/

Stanford EARTH

Stanford WOODS Institute for the Environment

Stanford | ENERGY
Precourt Institute for Energy

Download full report | https://sccs.stanford.edu/california-projects/pathways-carbon-neutrality-california