

15 What will it take to get to net-zero emissions in California?

California has long been a leader in climate policy, which has inspired climate policies globally and across the U.S. The California Global Warming Solutions Act of 2006, also known as Assembly Bill (AB) 32, was the first program in the country to require a reduction of greenhouse gas (GHG) emissions and take a comprehensive, long-term approach to doing so [1]. Since the passing of AB 32, several other policies have been put in place to support California's ambition for climate action, most notably, Executive Order B-55-18, which calls for the state to achieve carbon neutrality economy-wide by 2045 [2].

Additionally, AB 32 requires the California Air Resources Board (CARB) to develop a Scoping Plan that describes a pathway to reduce GHGs. The first Scoping Plan was approved by CARB in 2008 and the plan is now updated every five years. The latest update was completed in 2022 [3]. The plan lays out a sector-by-sector roadmap for the state based on a technologically feasible, cost-effective, and equity-focused path.

Given California's ambitious climate goals, many energy systems models have been used to assess California's decarbonization policies. The goal of this study was to provide an independent assessment of decarbonization options and alternatives and build a detailed bottom-up quantitative assessment of the magnitudes and costs of decarbonization of many of the elements of the California energy system.

KEY FINDINGS

- 1.** Greenhouse gas emissions estimated with our system-wide model for California agree well with the estimates of the CARB Reference Case and Proposed Scenario with similar assumptions.
- 2.** There is no single technology or resource that would allow California to reach net-zero emissions by 2045. A combination of efficiency improvements, renewable electricity generation, carbon capture & storage (CCS), electrification of energy services including transportation and heating, biofuels, hydrogen, low global warming potential (GWP) refrigerants and carbon dioxide removal (CDR) will be needed to meet the goal.
- 3.** This study finds that about 80% of emissions reductions envisioned in the CARB Proposed Scenario can be realized via eight proposed measures: direct air capture (DAC), decarbonizing light-duty vehicles (LDV), decarbonizing heavy-duty vehicles (HDV), clean electricity generation, industrial fuel switching, decarbonizing residential buildings, industrial CCS, and F-gas mitigation.

KEY FINDINGS (CONT.)

- 4.** This study suggests that 250 – 450 GW of capacity additions will be required to power California’s decarbonized future. The scale of this buildout cannot be understated, equating to 3 – 6 times California’s current grid capacity and 8 – 15 times the amount of capacity California has added since 2000.
- 5.** Without an expandable, 100% carbon free, dispatchable power source, reaching 100% emission-free electricity generation will be quite difficult, requiring large amounts of solar and battery storage to maintain reliability during periods of limited renewables. Use of a small amount of natural gas with CCS (NGCCS) combined with a clean generation constraint of 99% would produce emission reductions comparable to a 100% carbon-free grid at lower cost.
- 6.** Demand response can reduce battery storage buildout, but even in the most aggressive load shifting scenarios, battery storage is still needed in a significant way.
- 7.** Battery electric vehicles (BEVs) are a relatively affordable and effective mitigation option for the transportation sector. Deploying ZEVs as rapidly as possible will be required if 2045 goals are to be met. Gradual deployment towards those goals can reduce emissions substantially even if the timing goals are not met. The speed with which ZEVs are deployed is one of the single largest drivers in cumulative emissions impacts and has a direct influence on the amount of CDR that will be needed in 2045 to meet California’s goal of net-zero emissions.
- 8.** CCS is an effective and relatively affordable option for the industrial sector. Incentives like 45Q and the Low Carbon Fuel Standard have a large impact on CCS technoeconomic competitiveness, and a case can be made to extend the expiry date of 45Q, especially for the manufacturing subsector.
- 9.** High GWP refrigerant leaks are one of California’s larger emissions sources and are projected to grow due to heat pump installations. Responsible end-of-life management can help, but innovative low GWP refrigerants will be needed for deep reductions.
- 10.** The buildings sector is and will remain the largest user of electricity. Setting aggressive electric appliance (electric resistance, heat pumps) emissions reduction targets is an important element to reducing building emissions for existing buildings.
- 11.** Hydrogen is currently a comparatively expensive fuel switching option but is presently most cost-effective for HDVs. Hydrogen generation costs are relatively small compared to the cost of distribution and storage (D&S). Research and development will be needed to reduce these costs.
- 12.** Renewable natural gas (RNG) and renewable diesel (RD) are like-for-like replacements with their fossil counterparts (natural gas and diesel), making them attractive decarbonization options. However, supply of these fuels is limited, demand for them is global, and thus their uses should be prioritized carefully, perhaps in difficult to decarbonize applications
- 13.** Reaching net-zero will be difficult to impossible without significant DAC or the development of new technologies that can replace the need for DAC. Research and development is needed to reduce the cost of DAC.
- 14.** Meeting California’s emission goals will require a massive amount of infrastructure buildout (electricity generators, transmission & distribution [T&D], BEV charging, CDR, CCS, building upgrades, and more) in a short amount of time. It is critical that the state find ways to eliminate red tape, streamline permitting activities and foster cooperation

Proposed Action Items

The findings of this study have been consolidated into a tangible list of action items, both in terms of research and development (R&D) and policy opportunities.

RESEARCH AND DEVELOPMENT

CDR: R&D is needed to reduce the cost and parasitic load for DAC technologies. CDR is the largest contributor to 2045 abated emissions in the CARB Proposed Scenario despite being amongst the highest cost. DAC also becomes one of the larger users of electricity by 2045.

F-Gases: Low GWP refrigerants will be needed at scale to achieve deep reductions.

Biofuel feedstocks: Identifying new RNG and renewable diesel feedstocks could help these fuels play a larger role, easing the burden on electrification.

Hydrogen Costs: Hydrogen fuel switching is expensive, driven by high end-use (fuel cell vehicles) and D&S costs. R&D to reduce these costs could allow hydrogen to play a larger role in decarbonization.

Li Ion battery costs: All of the scenarios evaluated in this study necessitated a significant amount of grid-scale Li Ion storage, and thus reducing the cost of grid-scale electricity will be crucial.

POLICY OPPORTUNITIES

Electric home appliances: Most homes that will exist by 2045 already exist today; as such, existing policies aimed at new homes are not sufficient – more rapid deployment of electric appliances are needed for existing homes as well.

Grid emissions targets: Current regulations require a 100% carbon-free grid by 2045. This study shows that a CGC of 99% reduces overbuilding while having a negligible impact on emissions. Clean baseload power sources such as NGCCS (90% capture) and hydropower also reduce cost. An evaluation of this regulation is suggested.

Permitting: Climate change is an infrastructure problem. Given the speed and scale with which new infrastructure (electric generators, T&D, BEV charging, CDR, CCS, building appliances, and more) will be required, it is critical that the state find ways to eliminate red tape and streamline permitting activities.

45Q incentive: While some subsectors may be able to install CCS retrofits in the nearer term (e.g., power plants, steam methane reformers) other manufacturing subsectors (e.g., petrochemicals, food) may only be able to after 2032, when 45Q expires. This expiry date has been extended twice so far, and a case can be made that it should be extended even longer.

References

- [1] California Air Resources Board, “AB 32 Global Warming Solutions Act of 2006,” [Online]. Available: <https://ww2.arb.ca.gov/resources/fact-sheets/ab-32-global-warming-solutions-act-2006>.
- [2] E. G. Brown, “Executive Order B-55-18 to Achieve Carbon Neutrality,” Executive Department of the State of California, 2018. [Online]. Available: <https://www.ca.gov/archive/gov39/wp-content/uploads/2018/09/9.10.18-Executive-Order.pdf>.
- [3] California Air Resources Board, “2022 Scoping Plan Documents,” 2022. [Online]. Available: <https://ww2.arb.ca.gov/our-work/programs/ab-32-climate-change-scoping-plan/2022-scoping-plan-documents>.