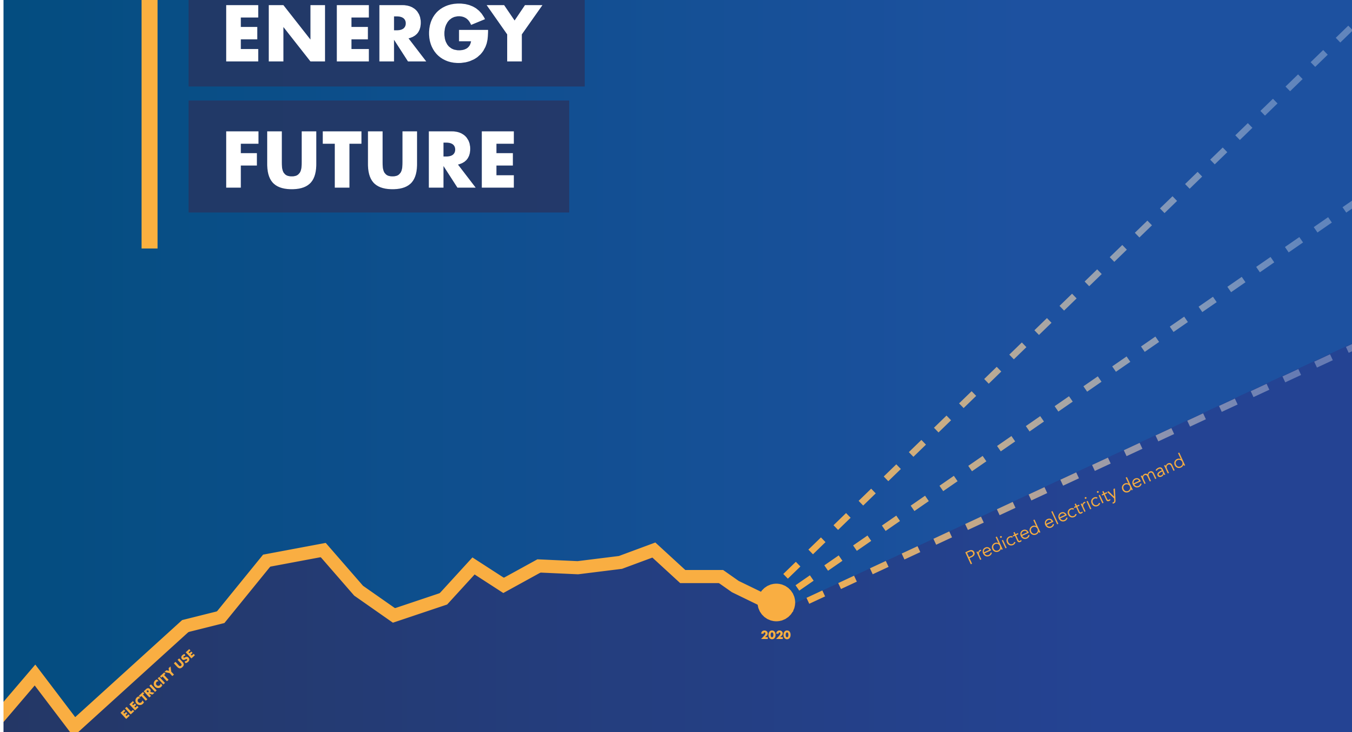
KEY CHALLENGES for

CALIFORNIA'S ENERGY FUTURE



8 CHALLENGES ON THE ROAD TO NET-ZERO

OVERVIEW • POLICIES • EQUITY

1. ELECTRIFICATION & GRID DEVELOPMENT
2. UTILITY SCALE SOLAR & WIND
3. RELIABILITY & THE NEED FOR CLEAN, FIRM POWER
4. DECENTRALIZING THE GRID
5. CARBON CAPTURE & STORAGE
6. THE FUTURE OF THE NATURAL GAS SYSTEM
7. DECARBONIZING TRANSPORTATION
8. CAP-AND-TRADE

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Key Challenges for CALIFORNIA'S ENERGY FUTURE

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About CCST
The California Council on Science and Technology is a nonpartisan, nonprofit organization established via the California State Legislature in 1988. CCST responds to the Governor, the Legislature, and other State entities who request independent assessment of public policy issues affecting the State of California relating to science and technology. CCST engages leading experts in science and technology to advise state policymakers—ensuring that California policy is strengthened and informed by scientific knowledge, research, and innovation.

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A Message from CCST

In early 2022, CCST consulted with more than 30 experts across California's preeminent academic and research institutions as well as policy makers to identify which energy issues needed additional attention given existing policy conversations and importance to California's clean energy future. This document provides **high-level summaries of eight key challenges** identified during these conversations.

Several of these challenges are intensely debated. In such cases, we seek not to recommend any particular path but instead to summarize the character of the debate and the central arguments put forth.

This document is not meant to provide a comprehensive technical assessment of these topics but rather preliminary introductions to key energy challenges for the state of California. It has been researched and written by select CCST staff and principal researchers under the guidance of a steering committee having an appropriate range of expertise, a balance of perspectives, and no conflicts of interest. Our hope is to inspire readers to take a deeper dive using other resources, including those highlighted at the end of each section. Where available resources are insufficient to address disagreement, CCST stands ready to work with its academic and research partners to bring additional clarity and relevant information to policymakers.

Key Challenges for California's Energy Future

Overview of California's Energy Transition

by the Key Challenges for California's Energy Future
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The system of energy sources and applications we enjoy today has evolved over hundreds of years and has gone through multiple transformations over that period. Our complex energy system has many interacting technical and governance components. The current energy system emits greenhouse gases and causes other environmental impacts including air, water, and soil pollution. Low-income and communities of color disproportionately experience the negative impacts of our current energy system. Motivated by the dire and mounting risks of climate change and opportunities for a more prosperous, just, and healthy California, we are in the midst of a rapid transition of our energy system and other aspects of our economy that contribute to greenhouse gas emissions. Strong, rapid action guided by careful, evidence-based, and inclusive planning can help minimize the impact of climate change while securing a safe, prosperous, and equitable future for all Californians.

At a high level, decarbonizing energy has **three fundamental elements:**

1. Maximize efficiency and electrify energy use across sectors to the greatest extent possible.
2. Provide affordable, accessible, and reliable carbon-free electricity for a highly electrified economy.
3. Decarbonize activities that cannot be electrified by using clean fuels, efficiency, conservation, and better land use planning and infrastructure.

We are now entering an era of fundamental, large-scale structural changes to the energy system, during which the choices we make must ensure that the future energy system has adequate capacity and is both reliable and cost effective.

Beyond the cost and performance of individual elements in the energy system, decision makers will also need to consider the full system implications and tradeoffs of technology investment choices for reliability, affordability, the environment, and equity.

During this period of transformational change over the next 2-3 decades, we must ensure that the up-front costs of this transition do not create barriers that prevent communities from accessing clean energy technologies.

Since the negative impacts of current fossil-fueled energy and transportation systems disproportionately fall on disadvantaged communities, there is a tremendous opportunity for this transition to help reduce historical inequity and injustice as well.

California has led the nation in innovative climate policy implementation. Over the past two decades, the state has developed and implemented a multipronged strategy that has achieved substantial progress toward reducing California's greenhouse gas emissions, utilizing both sectoral policies and a Cap-and-Trade Program that operates across multiple sectors.[i] Through executive orders by the state's Governors and extensive action by the Legislature, California has set bold and legally binding goals to achieve deep reductions in greenhouse gas emissions by 2030 and carbon neutrality by 2045.

In 2022, CCST staff consulted with policymakers and more than 30 experts across California's preeminent academic and research institutions to identify energy issues that needed additional attention given policy conversations and their importance to California's clean energy future. This process identified eight high-level key challenges, which are explored across the eight sections of this document. These sections highlight major challenges and opportunities, environmental justice and equity considerations, and resources for more information. In the future, other topics could be added to this list of eight as needs and relevance arise. Neither the set of topics chosen for sections nor the sections themselves are comprehensive, but are aimed at succinctly summarizing the status, challenges, and potential solutions.

This Overview describes a framework for California's energy transition and highlights key issues that require attention. Of course, the complexities of this transition cannot be fully represented in a short Overview, nor can this document provide an exhaustive discussion of all relevant information. But it is intended to provide context for the subsequent sections that together can help inform policy making for sustainable, carbon-free, equitable energy for all Californians.

i *See section **8. Cap-and-Trade**.*

1. Maximize efficiency and electrify energy use across sectors to the greatest extent possible.

For many activities that currently rely on fossil fuel use, electrification provides the best strategy for developing a carbon-free energy system and is a fundamental strategy for meeting California's climate goals.

Transportation and buildings have been the major focus of electrification to date. There are also electrification opportunities in other sectors including industry. This strategy is effective because it is possible to produce electricity from zero and near-zero greenhouse gas emission sources, and electrification solutions often offer efficiency gains compared to conventional fossil-fueled combustion.

In many cases, notably in transportation, more advanced and efficient technologies will replace emission-intensive ones. Investments in these technologies will pay dividends in the form of energy cost savings over the long run. In addition, the value provided by improved health from cleaner air and reduced climate change impacts will almost always outweigh the up-front costs. Attention must be paid to those who bear the costs to ensure equitable access and affordability.[ii]

2. Provide affordable, accessible, and reliable carbon-free electricity for a highly electrified economy.

Economic growth, population growth, and electrification are expected to increase demand for electricity. This demand can be tempered by continued attention to improving energy efficiency. California has abundant renewable resources. Rapid buildout of renewable energy, particularly utility-scale solar and wind generation, is a central strategy for California's electricity decarbonization. In siting utility-scale solar and wind, the state must meet clean energy needs while also supporting other land use priorities such as agriculture, wildlife conservation, and recreation. Given this, siting and permitting can take far longer than is consistent with the envisioned buildout rate. These projects also often require concurrent development of transmission to interconnect with the electricity grid.

California has a good understanding of the magnitude of the state's potential renewable energy resources, but it needs a realistic assessment of the magnitude of renewable energy that can be practically developed in the next decades given other environmental and social goals as well as legal, geographic, and transmission constraints. The next SB 100 Joint Agency Report, planned for release in 2025, will address the potential land-use impacts of its scenarios and is a step in that direction.[iii]

Solar and wind power are central to California's carbon-free electricity strategy but present intermittency challenges from day to night and on a seasonal basis that can impact grid reliability if not effectively managed. California is deploying

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ii *See section **7. Decarbonizing Transportation** for electrification of the transportation sector. See **6. The Future of the Natural Gas System** for building electrification. See **1. Electrification and Grid Development** for the impact of electrification on California's aging grid and the needs for grid upgrades to accommodate decarbonization.*

iii *See sections **2. Utility-Scale Solar and Wind Development**, **3. Reliability and the Need for Clean, Firm Power**, and **1. Electrification and Grid Development**.*

energy storage, demand response, and other strategies to manage the shorter-term intermittency of these resources. Additionally, California will need clean, firm power to manage the longer-term intermittency of renewable energy, for example, in winter periods when renewable energy supply is at a minimum. Clean, firm power—such as geothermal power, power from clean fuels, nuclear power, or gas with carbon capture and storage—can be available whenever needed and for as long as needed.

> **Ultimately, a diverse electricity generation portfolio that also includes clean, firm power would be more resilient to seasonal fluctuations and extreme weather events. As important as clean, firm power is, all the primary technologies have environmental impacts, drawbacks, and obstacles—like any power. California will need to make some difficult but critical decisions in deciding how to incorporate clean, firm power into its electricity sector planning.**[iv]

As more vehicles and homes are powered by electricity, there will be increasing demand placed on California's electricity grid. These new and increasing demands require upgrades and expansion of a grid that is already challenged by wildfires, extreme heat, and weather events. Both transmission and distribution infrastructure will need to be upgraded to accommodate additional demand and new energy resources. Microgrids have also been identified as one way to increase energy reliability and energy resilience, particularly for communities that are disproportionately burdened by grid disruptions. If effectively leveraged, distributed energy resources can enhance energy resilience for consumers and the grid at large.[v]

> **California needs careful thought about how to pay for the energy transition including necessary generation, energy storage, and upgrades to the grid. If many of these costs go into utility rates, load growth may not be adequate to keep costs affordable for consumers. Consequently, other funding mechanisms should be considered as well.**

3. Decarbonize activities that cannot be electrified by using clean fuels, efficiency, conservation, and better land use planning and infrastructure.

Electrification is almost always the best option for decarbonization, but some activities that currently use fossil fuels cannot easily be electrified. These include some forms of heavy-duty transport, aviation, and some industrial applications that either require high quality heat or fossil fuels as feedstocks for producing other materials (like plastics and chemicals). For most of these applications, the most straightforward decarbonization path would be to replace fossil fuels with clean fuels. These clean fuels all require energy for production and tend to be quite expensive, but they provide a high degree of flexibility. While few clean fuels are truly carbon neutral, many offer the opportunity to significantly reduce greenhouse gas emissions.[vi]

Hydrogen represents California's primary option for clean fuel, including either "green" hydrogen produced using renewable energy to split water molecules, or "blue" hydrogen formed from

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iv *See sections* ***3. Reliability and the Need for Clean, Firm Power***, ***5. Carbon Capture and Storage***, *and* ***6. The Future of the Natural Gas System***.

v *See sections* ***1. Electrification and Grid Development*** *and* ***4. Decentralizing the Grid***.

vi *See sections* ***6. The Future of the Natural Gas System***, ***5. Carbon Capture and Storage***, ***3. Reliability and the Need for Clean, Firm Power*** *and* ***7. Decarbonizing Transportation***.

methane and requiring sequestration of co-produced carbon dioxide (CO_2).[vii]

> **Hydrogen is an indirect greenhouse gas. In evaluating hydrogen as a clean fuel, care should be taken to ensure that the excess warming due to hydrogen leakage in various applications does not offset the benefit of using hydrogen as a clean fuel.**

Limited alternatives for clean fuel might include a) synthetic hydrocarbons formed in a process that captures carbon from biomass or the atmosphere; b) biofuels, including advanced processes that do not use edible crops as feedstock; c) renewable hydrogen produced by electrolysis or steam methane reformation with carbon capture; or d) ammonia. The costs and consequences of these or other options require evaluation. Typically, clean fuels are more expensive and limited in supply compared to their fossil alternatives.

> **Choices for clean fuel require a full evaluation of unintended consequences and tradeoffs. Each proposed fuel choice will need life-cycle analysis that includes assessment of indirect impacts. Clean fuels will be limited, so California needs a highest and best use plan for whatever clean fuel can be brought to market.**

Carbon capture and storage may be an option for decarbonizing some industries such as cement manufacturing. The cement industry is a major contributor of greenhouse gas emissions resulting equally from the use of fossil fuels to heat limestone and the CO_2 released from the heated limestone itself. [viii]

While greenhouse gas emissions have declined in most sectors, transportation emissions have remained relatively static due to continued growth in vehicle miles traveled (VMT). Reducing VMT—which can be accomplished by implementing more compact development patterns, supporting public transportation, and placing housing, jobs, and services in closer proximity to one another—is necessary to meet state greenhouse gas reduction targets. SB 375 (Steinberg, 2008) requires regional planning organizations to develop Sustainable Community Strategies that lower emissions by facilitating walkability, biking, public transportation, transit-oriented development, and other land use strategies. However, funding constraints, housing shortages, and the inability to enforce Sustainable Community Strategies—among other factors—hamper the State's ability to reduce VMT.

> **Reducing VMT will require increased collaboration between state, local, and regional agencies to implement compact development patterns; funding for housing near jobs and services; investment in public transit, walking, and biking infrastructure; and robust public engagement.**[ix]

California has the legal and regulatory framework in place to decarbonize energy in the state by midcentury. Electrification and innovation can vastly reduce the use of fossil fuels and increase energy efficiency across many sectors. A combination of renewable energy, energy storage, and clean, firm power can decarbonize electricity production. For any applications that present challenges for electrification, clean fuels, efficiency, conservation, and land-use planning become critical and primary strategies to help California achieve its climate goals.

> **California needs strong, rapid implementation coupled with careful and inclusive planning for a more prosperous, just, and healthy future.**

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vii *See sections* ***5. Carbon Capture and Storage*** *and* ***6. The Future of the Natural Gas System****.*

viii See section ***5. Carbon Capture and Storage***.

ix *See section* ***7. Decarbonizing Transportation****.*

Electrification & Grid Development

Grappling with an aging power grid and a rapidly expanding demand for electricity.

Overview

California's decarbonization strategy calls for vehicle and building **electrification***, but as more vehicles and homes are powered by electricity, there will be increasing demand placed on California's grid. The California Air Resources Board (CARB) estimates that electricity demand could increase in the state by 76% by 2045 (relative to demand in 2022).[1]

The challenge of meeting these new demands comes alongside California's concurrent transition to 100% renewable and zero-carbon resources as mandated by SB 100 (de León, 2018) and the integration of **distributed energy resources** like rooftop solar. These new and increasing demands require upgrades and expansion of a grid that is already challenged by wildfires, extreme heat, and weather events.[2,3]

Transmission infrastructure carries high-voltage electricity over long distances to distribution substations. These substations reduce the voltage and then transfer the power to distribution networks that deliver the lower voltage electricity over short distances to consumers. Both transmission and distribution infrastructure will need to be upgraded to accommodate additional demand and new energy resources. The California Independent System Operator (CAISO)—which oversees the operation of approximately 80% of California's bulk electric power system, transmission lines, and electricity market—estimates that adding and upgrading transmission lines to meet predicted demand will cost $30.5 billion over the next 20 years.[4]

1 California Air Resources Board. (2022). 2022 Scoping Plan for Achieving Carbon Neutrality. Available at: https://ww2.arb.ca.gov/sites/default/files/2022-11/2022-sp.pdf.

2 California ISO. (2022). California ISO extends Flex Alert to Thursday, Sept. 1. Available at: http://www.caiso.com/Documents/california-iso-extends-flex-alert-to-thursday-sept-1.pdf.

3 California ISO, California Public Utilities Commission, and California Energy Commission. (2021). Root Cause Analysis: Mid-August 2020 Extreme Heat Wave. Available at: http://www.caiso.com/Documents/Final-Root-Cause-Analysis-Mid-August-2020-Extreme-Heat-Wave.pdf.

4 California ISO. (2022). 20-Year Transmission Outlook. Available at: http://www.caiso.com/InitiativeDocuments/Draft20-YearTransmissionOutlook.pdf.

***** Find **bold** words in the Glossary (Appendix A).

Increasing demand for electricity

Improved energy efficiencies will mitigate some growth in demand but will be insufficient to offset the predicted increase in demand from population growth, economic growth, and electrification efforts (see **Figure 1.1**).

A number of key policies are driving the adoption of electric vehicles in California. For example, Executive Order N-79-20 (2020) mandates that 100% of new vehicle sales be zero-emission vehicles (ZEVs) by 2035. CARB's Advanced Clean Cars II Regulation sets interim targets on the path to 100% passenger ZEVs by 2035,[5] while the Advanced Clean Fleet Regulation establishes targets for medium- and heavy duty vehicles.[6] Vehicle electrification will increase needs for grid upgrades to accommodate vehicle charging.[7] For example, modeling suggests that the addition of 5 million ZEVs by 2030 would increase electricity demands by 10%[8] if not managed with **demand response** technologies.

To support building decarbonization, the California Energy Commission (CEC) updated the Energy Code to encourage electric heat pumps and electric ovens over natural gas-powered appliances. Increasing numbers of California communities are discouraging or instituting bans on natural gas in new home construction (see **Section 6**).

As of 2020, 72% of households in California had air conditioning.[9] As natural gas heaters are swapped for electric heat pumps—which also provide air conditioning in addition to space heating—this percentage is likely to increase. Increasing temperatures and heat waves caused by climate change will increase reliance on air conditioning.[10]

Carbon capture and storage (CCS), direct air capture of carbon, and the production of hydrogen via electrolysis are all energy intensive processes. Current forecasts, such as *CAISO's 20-year Transmission Outlook*, assume these technologies—should they come to play a prominent role in California's energy future—will use power generated onsite rather than drawn from the grid.[11] However, if they require grid power, these technologies will place an even greater demand on the power system.

Some newly electrified end uses (like electric vehicles and water heating) could be configured to draw energy from the grid only when energy costs are low and the grid is not stressed (because demand is low or because there is excess renewable energy being generated). This is known as **load shifting** and is a form of demand response that could help reduce the need for costly transmission and distribution upgrades. Demand response is covered in more detail in **Section 3**.

Changing energy supplies

These additional demands on the grid coincide with a requirement for increasingly higher percentages of electricity generation to come from renewable resources which are predominantly

5 California Air Resources Board. (2022). Advanced Clean Cars II. Available at: https://ww2.arb.ca.gov/our-work/programs/advanced-clean-cars-program/advanced-clean-cars-ii.

6 California Air Resources Board. (2023). Advanced Clean Fleets. Available at: https://ww2.arb.ca.gov/our-work/programs/advanced-clean-fleets.

7 Jenn, A., and Highleyman, J. (2022). Distribution Grid Impacts of Electric Vehicles: A California Case Study. *Iscience*, 25(1), pp. 103686.

8 Jenn, A., and Highleyman, J. (2022). Distribution Grid Impacts of Electric Vehicles: A California Case Study. *Iscience*, 25(1), pp. 103686.

9 U.S. Energy Information Administration. (2023). Highlights for Air Conditioning in U.S. Homes by State, 2020. Available at: https://www.dropbox.com/s/r5hm39dgris15vl/08%20-%20Cap%20and%20Trade.docx?dl=0.

10 Aufhammer, M. (2018). Climate Adaptive Response Estimate: Short and Long Run Impacts of Climate Change on Residential Electricity and Natural Gas Consumption. Available at: https://www.energy.ca.gov/sites/default/files/2019-11/Energy_CCCA4-EXT-2018-005_ADA.pdf.

11 California ISO. (2022). 20-Year Transmission Outlook. Available at: http://www.caiso.com/InitiativeDocuments/Draft20-YearTransmissionOutlook.pdf.

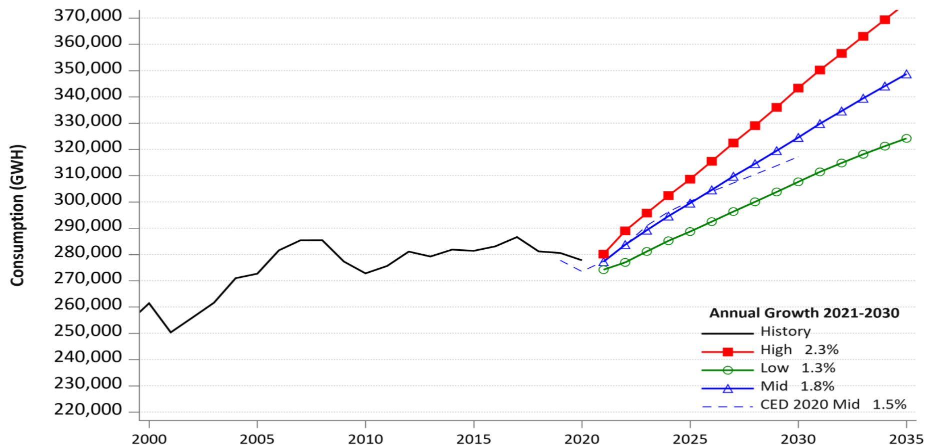

Figure 1.1. Predicted growth in electricity demand by 2035 compared to historical electricity consumption trends. Model includes low, medium, and high demand scenarios that reflect differing assumptions about key variables such as electric vehicle adoption and economic growth rates.

Source: California Energy Commission. (2022). Final 2021 Integrated Energy Policy Report Volume IV Energy Demand Forecast.

intermittent (as per SB 1078, Sher, 2022; SB 350, de León 2015; SB 100, de León, 2018; and SB 1020, Laird, 2022) and as current sources of **firm power** go offline. For example, SB 100, de León, 2018 and AB 1279 (Muratsuchi, 2022), effectively require the elimination of any natural gas plants without CCS from the electricity sector.

Diablo Canyon Power Plant (DCPP)—California's last operational nuclear facility which currently provides roughly 6% of California's power[12]—is scheduled to close no later than 2030 (as per SB 846, Dodd, 2022).[13]

Fossil fuels and DCPP will need to be replaced by a combination of renewable resources like solar, wind, geothermal, **biomethane**, and hydroelectric power and complemented by additional energy storage.[14] Modeling for CARB's 2022 Scoping Plan suggests that renewable and zero-carbon power capacity will need to increase by 180 **gigawatts (GW)** by 2045. Annual build rates for solar power and battery storage will have to increase 60% and 700%, respectively (compared to historic maximums) to meet California's 2045 decarbonization targets.[15] Some natural gas capacity will need to be replaced with other

12 Nyberg, M. (2021). 2021 Total System Electric Generation. *California Energy Commission*. Available at: https://www.energy.ca.gov/data-reports/energy-almanac/california-electricity-data/2021-total-system-electric-generation.

13 Dodd, B. (2022). SB 846. Diablo Canyon Powerplant: Extension of Operations. California State Legislature.

14 California Air Resources Board. (2022). 2022 Scoping Plan for Achieving Carbon Neutrality. Available at: https://ww2.arb.ca.gov/sites/default/files/2022-11/2022-sp.pdf.

15 California Air Resources Board. (2022). 2022 Scoping Plan for Achieving Carbon Neutrality. Available at: https://ww2.arb.ca.gov/sites/default/files/2022-11/2022-sp.pdf.

sources of clean, firm power (see **Section 3**).[16] As these new energy resources come online, new and upgraded transmission infrastructure will be required to move the electricity from generation sites to consumers.

As of July 2022, 12 GW of rooftop solar had been installed in California.[17] Rooftop solar generation has reduced demand on the electric grid by about 25% during periods of solar power production, i.e., when the sun is shining.[18] While distributed energy resources may improve grid resilience if dispatched appropriately,[19] they introduce new challenges related to grid interconnection and energy economics (see Section 4 for more details). For example, distribution networks can only accommodate a certain number of distributed energy resources before they require upgrading—this is known as the **hosting capacity**.

Reliability challenges

California's utilities have faced constraints on their ability to provide reliable power to consumers. For example, in August 2020, CAISO was forced to institute rotating outages for the first time in nearly 20 years during an extreme heat wave when a combination of factors—including increased demand for air conditioning, decreased generation efficiency at natural gas power plants, and limited energy imports—created an energy shortfall.[20] These blackouts affected hundreds of thousands of residents.[21]

Climate change is predicted to increase the frequency of these extreme heat events. California came close to a repeat of this experience in early September 2022, when CAISO issued Flex Alerts for 10 straight days, urging consumers to conserve electricity between 4:00 p.m. to 9:00 p.m. during a record-breaking heat wave.[22]

In early 2022, the CEC had predicted that the combination of extreme heat, drought, wildfires, and project delays could result in an energy shortfall of up to 7 GW that summer, growing to 10 GW by 2025.[23] To help address this, SB 846 (Dodd, 2022) provided a pathway to extend DCPP operations through 2030 (DCPP was initially slated to close in 2025). AB 205 (Committee on Budget, 2022) created a Strategic Reliability Reserve Fund to support the procurement of 5 GW of generation that can be called upon when the state is faced with a potential energy shortfall. The California Public Utilities Commission (CPUC) ordered utilities to procure an additional 4 GW of capacity by 2026 on top of the historic 11.5 GW procurement order for renewable and zero-carbon resources it had issued in 2021.[24]

16 Gill, L., Gutierrez, A., and Weeks, T. (2021). 2021 SB 100 Joint Agency Report, Achieving 100 Percent Clean Electricity in California: An Initial Assessment. *California Energy Commission, California Public Utilities Commission and California Air Resources Board*. Publication number: CEC-200-2021-00. Available at: https://www.energy.ca.gov/publications/2021/2021-sb-100-joint-agency-report-achieving-100-percent-clean-electricity.

17 California Solar Initiative. (2023). California Distributed Generation Statistics. Accessed on 11/03/2022 at: https://www.californiadgstats.ca.gov/.

18 California Public Utilities Commission. (ND). Modernizing California's Net Energy Metering Program to Meet Our Clean Energy Goals. Available at: https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/demand-side-management/net-energy-metering/nem-revisit/net-billing-tariff-fact-sheet.

19 Rickerson, W. et al. (2019). The Value of Resilience for Distributed Energy Resources: An Overview of Current Analytical Practices. National Association of Regulatory Utility Commissioners. Available at: https://pubs.naruc.org/pub/531AD059-9CC0-BAF6-127B-99BCB5F02198.

20 California ISO, California Public Utilities Commission, and California Energy Commission. (2021). Root Cause Analysis: Mid-Augst 2020 Extreme Heat Wave. Available at: http://www.caiso.com/Documents/Final-Root-Cause-Analysis-Mid-August-2020-Extreme-Heat-Wave.pdf.

21 California ISO, California Public Utilities Commission, and California Energy Commission. (2021). Root Cause Analysis: Mid-Augst 2020 Extreme Heat Wave. Available at: http://www.caiso.com/Documents/Final-Root-Cause-Analysis-Mid-August-2020-Extreme-Heat-Wave.pdf.

22 California ISO. (2022). Flex Alert Extended to Sunday, Sept. 4 Due to High Heat. Available at: http://www.caiso.com/Documents/flex-alert-extended-to-sunday-sept-4-due-to-high-heat.pdf.

23 California Energy Commission. (2022). Draft 2022 Integrated Energy Policy Report Update. Available at: https://www.energy.ca.gov/data-reports/reports/integrated-energy-policy-report/2022-integrated-energy-policy-report-update.

24 California Public Utilities Commission. (2023). CPUC Augments Historic Clean Energy Procurement Goals to Ensure Electric Reliability. Accessed on 5/25/2023 at: https://www.cpuc.ca.gov/news-and-updates/all-news/cpuc-augments-historic-clean-energy-

Congestion on the transmission grid can create pockets of imbalances where it is difficult to either export excess renewable generation out of an area or to import renewable energy into an area to meet demand. The reliable delivery of renewable energy resources requires the resolution of both types of constraints.

An increasing reliance on solar power introduces challenges of maintaining grid reliability and meeting demand after the sun has gone down—something currently largely accomplished with natural gas power plants. Energy storage can help by capturing excess renewable energy produced during the day and discharging it back to the grid in the evening. CAISO now has more than 3.5 GW of battery storage, which helped prevent rotating outages during the September 2022 heat wave.[25] See **Section 3** for more on energy storage and other solutions for improving grid reliability.

Relevant State Institutions

- California Air Resources Board (CARB)
- California Department of Water Resources (DWR)
- California Energy Commission (CEC)
- California Independent System Operator (CAISO)
- California Public Utilities Commission (CPUC)
- Assembly Budget Subcommittee 3 on Climate Crisis, Resources, Energy, and Transportation
- Assembly Utilities and Energy Committee
- Assembly Natural Resources Committee
- Senate Budget Subcommittee 2 on Resources, Environmental Protection and Energy
- Senate Energy, Utilities, and Communications Subcommittee on Clean Energy Future
- Senate Natural Resources and Water Committee
- Joint Leg. Committee on Climate Change Policies

Scale, impacts, and challenges of necessary grid infrastructure development

CAISO estimates that the high-voltage bulk infrastructure necessary to transition to clean energy by 2040 will require a $30.5 billion investment.[26]

The construction of new generation and transmission infrastructure impacts both land use and biodiversity.[27]

Potential transmission line sites are constrained by the size of site; the number of landowners (creating complications including reaching right-of-way agreements); public opposition to projects; environmental sensitivities or other land-use restrictions; and the need for upgrades to sites that make construction prohibitively expensive.[28]

Developing and upgrading transmission infrastructure requires complex coordination among agencies including CAISO, CARB, CEC, CPUC, and the Governor's Office, as well as counties, utilities, labor, project developers, communities, and more. State agencies already coordinate their various grid planning efforts to ensure needed transmission infrastructure is built.

More work is being done to incorporate other interested parties, such as the recently created Energy Unit at the Governor's Office of Business and Economic Development (AB 137, Committee on Budget, 2021).

Transmission infrastructure projects require long lead times (CAISO estimates eight to 10 years for some projects) primarily due to right-of-way acquisition and environmental permitting require-

procurement-goals-to-ensure-electric-reliability-2023.

25 California ISO. (2022). Summer Market Performance Report. Available at: http://www.caiso.com/Documents/SummerMarketPerformanceReportforSeptember2022.pdf.

26 California ISO. (2022). 20-Year Transmission Outlook. Available at: http://www.caiso.com/InitiativeDocuments/Draft20-YearTransmissionOutlook.pdf.

27 Biasotto, L.D., and Kindel, A. (2018). Power Lines and Impacts on Biodiversity: A Systematic Review. *Environmental Impact Assessment Review*, 71, pp. 110-119.

28 Colvin, M., and Prochnik, J.S. (2021). Building a Zero Carbon California Grid: Moving from Models to an Implementable Plan. *California Air Resources Board*. Available at: https://ww2.arb.ca.gov/sites/default/files/2021-11/EDF-sp22-electricity-ws-11-02-21.pdf.

ments.[29] These planning horizons are in tension with the necessary build out pace. AB 205 (Committee on Budget, 2022) grants the CEC authority to certify renewable facilities and associated transmission lines, providing developers an alternative pathway to going through local permitting processes.

Though they have received less attention to date, many distribution networks will also require upgrades in a high-electrification future. One model suggests that by 2030, ZEV charging will necessitate upgrades to roughly 20% of **feeder circuits** across the Pacific Gas & Electric service territory; only one-fifth of those are currently scheduled for upgrades.[30] These upgrades may create bottlenecks that slow the pace of electrification if not proactively addressed.[31]

Both distribution and transmission lines may pose wildfire risks. Undergrounding high-risk power lines is one of the most effective mitigation methods.[32] However, constructing underground lines costs significantly more than aboveground lines ($3 to $5 million per mile versus $800,000 for distribution lines).[33]

Environmental Justice and Equity Considerations

Grid failure disproportionately impacts low-income individuals and communities. For example, replacing spoiled food is more economically burdensome for low-income households than it is for wealthier households.

Grid failure and rotating outages are life-threatening for medically vulnerable individuals who live at home and rely on medical equipment for life support.

California, and the U.S. more broadly, has a history of redlining—a practice in which public and private institutions denied or severely restricted financial services to Black and other people of color.[34] Race, as well as environmental factors, were criteria used to assess creditworthiness of neighborhoods. The legacies of this practice continue in California whereby underinvestment in low-income neighborhoods and communities of color has resulted in less access to clean energy technologies.[35]

CPUC's proposed net billing tariff would create an Equity Fund to support clean energy and storage for low-income Californians. The Equity Fund could further expand existing low-income storage and community solar programs like the Self Generation Incentive Program.[36]

29 California ISO. (2022). 20-Year Transmission Outlook. Available at: http://www.caiso.com/InitiativeDocuments/Draft20-YearTransmissionOutlook.pdf.

30 Jenn, A., and Highleyman, J. (2022). Distribution Grid Impacts of Electric Vehicles: A California Case Study. *Iscience*, 25(1), pp. 103686.

31 Brockway, A. et al. (2022). Can Distribution Grid Infrastructure Accommodate Residential Electrification and Electric Vehicle Adoption in Northern California? Energy Institute at Haas Working Paper 327. Available at: https://haas.berkeley.edu/wp-content/uploads/WP327.pdf.

32 California Public Utilities Commission. (2021). CPUC Undergrounding Programs Description. Accessed on 11/29/2022 at: https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/infrastructure/electric-reliability/undergrounding-program-description.

33 Pacific Gas & Electric. (ND). Facts about Undergrounding Electric Lines. Accessed on 11/15/2022 at: https://www.pgecurrents.com/2017/10/31/facts-about-undergrounding-electric-lines/.

34 California Environmental Protection Agency. (2021). Pollution and Prejudice Redlining and Environmental Injustice in California. Available at: https://storymaps.arcgis.com/stories/f167b251809c43778a2f9f040f43d2f5.

35 California Environmental Protection Agency. (2021). Pollution and Prejudice Redlining and Environmental Injustice in California. Available at: https://storymaps.arcgis.com/stories/f167b251809c43778a2f9f040f43d2f5.

36 California Public Utilities Commission. (2021). Modernizing California's Net Energy Metering Program to Meet Our Clean Energy Goals. Available at: https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/demand-side-management/net-energy-

Regulatory processes that address infrastructure decommissioning and rate structure modifications may help to provide an orderly transition away from fossil fuels and lessen negative impacts on disadvantaged communities.[37] AB 205 (Committee on Budget, 2022) instructs the CPUC to establish an income-based rate structure for fixed charges (i.e., charges not based on power consumption).

Relevant Policies
(Laws/Regulations)

Renewables Portfolio Standard (RPS) Program
SB 1078 (Sher, 2002)

The RPS Program mandated an initial 20% of electricity retail sales to come from renewable resources by 2017. SB 1078 defined eligible renewables to include small hydropower, solar, wind, and geothermal, among others. SB 350 (de León, 2015) introduced interim annual RPS targets with three-year compliance periods and requires 65% of RPS procurement to be derived from long-term contracts of 10 or more years. SB 100 (de León, 2018) increased the RPS target to 60% by 2030 and requires all the state's electricity to come from carbon-free resources by 2045.

Clean Energy and Pollution Reduction Act
SB 350 (de León, 2015)

SB 350 increases California's renewable electricity procurement goal from 33% by 2020 to 50% by 2030, thus supporting greater use of resources eligible for the Renewables Portfolio Standard.

SB 350 mandates doubling statewide energy efficiency savings for electricity and natural gas end uses by 2030.

SB 350 requires large utilities to submit integrated resource plans (IRPs) on how they will meet consumers' needs, reduce greenhouse gas emissions, and increase use of clean energy resources.

The 100 Percent Clean Energy Act of 2018
SB 100 (de León, 2018)

SB 100 establishes a goal that by 2045 all retail electricity sold in California and state agency electricity needs will be powered by renewable and zero-carbon resources.

SB 100 updates the Renewables Portfolio Standard to ensure that by 2030 at least 60% of state's electricity is renewable.

SB 100 requires the California Energy Commission, California Public Utilities Commission and California Air Resources Board to use existing laws to achieve 100% clean electricity and issue joint policy on SB 100 by 2021 and every four years after that.

Clean Energy, Jobs, and Affordability Act of 2022
SB 1020 (Laird, 2022)

SB 1020 added interim targets for renewable energy and zero-carbon electricity retail sales as legislated in SB 100 (de León, 2018): 90% by 2035 and 95% by 2040. SB 1020 requires state agencies to use 100% renewable energy and zero-carbon resources by 2030 and establishes a Climate and Equity Trust fund to manage rising electricity rates that threaten affordability.

Energy Storage Systems
AB 2514 (Skinner, 2010)

AB 2514 encourages the incorporation of storage systems within the electric grid. The benefits to adding storage include integrating greater quantities of renewable energy into the grid, reducing need for fossil-fueled power plants and transmission, and reducing fossil fuel generation during peak load periods.

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metering/nem-revisit/net-billing-tariff-fact-sheet.

37 Southern California Edison. (2019). Pathway 2045 Update to the Clean Power and Electrification Pathway. Available at: https://download.newsroom.edison.com/create_memory_file/?f_id=5dc0be0b2cfac24b300fe4ca&content_verified=True.

Energy
AB 205 (Committee on Budget, 2022)
AB 205 provides funding for the California Energy Commission to establish distributed energy resource investments and demand response programs.

AB 205 also established the Strategic Reliability Reserve Fund to be overseen by the California Department of Water Resources. The 2022 Budget allocated $2.2 billion to the Reliability Reserve Fund to support the procurement of up to 5 GW of generation that can be called upon when the state is faced with a potential energy shortfall.

Read More

2022 Scoping plan for achieving carbon neutrality
California Air Resources Board (2022).

California smart grid annual report 2019
California Public Utilities Commission (2020).

Distribution grid impacts of electric vehicles: A California case study.
Jenn, A., and Highleyman, J. (2022). iScience, 25(1).

Clean firm power is the key to California's carbon-free energy future.
Long, J.C.S. et al. (2021). Issues in Science and Technology.

20-Year Transmission Outlook
California ISO (2022).

2

Utility-Scale Solar and Wind Development

Dramatically scaling California's capacity to produce renewable energy without compromising the State's natural and working lands.

Overview

Approximately 26% of California's energy is currently provided by utility-scale wind and solar facilities (as of 2021).[38] SB 100 (de León, 2018) requires that by 2045, 100% of retail electricity will be provided by zero-carbon and renewable resources.

Many alternatives exist (e.g., geothermal, natural gas with **carbon capture and storage***, nuclear, hydro-, solar, and wind power). Due to low costs and high resource availability, solar and wind power will likely comprise the majority of California's energy portfolio in a zero-carbon, renewable future.[39]

Distributed solar resources (e.g., rooftop solar) are and will continue to be important. Expanding this resource could avoid some of the impacts of utility-scale solar. However, these distributed resources will likely not meet all demand for renewable electricity. Further, utility-scale facilities are much more cost-effective than these small-scale applications.[40] To meet predicted demand, unprecedented construction of utility-scale solar and wind facilities will be required.[41]

For example, California currently has 16 **gigawatts (GW)** of utility-scale solar;[42] the SB 100 Joint Agency Report projects that an additional 70 GW of utility-scale solar will be required by 2045. Each GW of solar currently requires between 2,900 and 4,200 acres of land on average.[43] The state is also committed to protecting and managing **natural and working lands** as a

38 California Energy Commission. (2021). 2021 Total System Electric Generation. *California Energy Commission*. Available at: https://www.energy.ca.gov/data-reports/energy-almanac/california-electricity-data/2021-total-system-electric-generation.

39 Gill, L., Gutierrez, A., and Weeks, T. (2021). 2021 SB 100 Joint Agency Report, Achieving 100 Percent Clean Electricity in California: An Initial Assessment. *California Energy Commission, California Public Utilities Commission and California Air Resources Board.* Publication number: CEC-200-2021-00. Available at: https://www.energy.ca.gov/publications/2021/2021-sb-100-joint-agency-report-achieving-100-percent-clean-electricity.

40 Ramasamy, V. et al. (2022). U.S. Solar Photovoltaic System and Energy Storage Cost Benchmarks, with Minimum Sustainable Price Analysis: Q1 2022 (No. NREL/TP-7A40-83586). *National Renewable Energy Lab.*

41 Gill, L., Gutierrez, A., and Weeks, T. (2021). 2021 SB 100 Joint Agency Report, Achieving 100 Percent Clean Electricity in California: An Initial Assessment. *California Energy Commission, California Public Utilities Commission and California Air Resources Board.* Publication number: CEC-200-2021-00. Available at: https://www.energy.ca.gov/publications/2021/2021-sb-100-joint-agency-report-achieving-100-percent-clean-electricity.

42 Nyberg, M. (2023). Electric Generation Capacity and Energy. Available at: https://www.energy.ca.gov/data-reports/energy-almanac/california-electricity-data/electric-generation-capacity-and-energy.

43 Bolinger, M., and Bolinger, G. (2022). Land Requirements for Utility-Scale PV: An Empirical Update on Power and Energy Density. *IEEE Journal of Photovoltaics*, 12(2), pp. 589-594.

***** Find **bold** words in the Glossary (Appendix A).

strategy for meeting the state's goals for reducing greenhouse gas emissions (as per SB 1386, Wolk, 2016).

In siting utility-scale solar and wind, the state must consider clean energy needs, while also supporting other land use priorities such as agriculture, wildlife conservation, and recreation. New utility-scale solar often requires new transmission to deliver power to customers; this infrastructure presents its own siting challenges.

Wind and solar production

The attractiveness of wind and solar generation has increased with increasing energy efficiency. Improvements in technology have made them a cost-competitive part of California's plan for decarbonization.

Most of California's utility-scale solar farms are concentrated in the Central Valley.[44] Wind facilities tend to be co-located with cropland and rangeland.[45]

In California, an average of 1 GW of utility-scale solar and 300 **megawatt (MW)** of wind have been built each year over the last 10 years. Modeling conducted for the SB 100 Joint Agency Report suggests that the average annual build rates will need to be nearly tripled (2.8 GW and 900 MW per year for solar and wind, respectively) and sustained for the next 25 years.[46] Note that this model assumes roughly 28 GW of natural gas capacity is maintained as a source of **firm power**. More work is needed to estimate the maximum amount of solar and wind power possible by mid-century given all the factors that affect development.[47]

Sites for utility-scale facilities must first have adequate wind or solar resources. Land use regulations, site topology, and community acceptance further constrain options. These constraints often lead to new facility construction being situated away from communities in remote locations with adequate land.[48] The delivery of energy produced at these new remote facilities to distant consumers requires expanding and upgrading California's transmission infrastructure.[49] California's transmission capacity may need to be expanded by as much as 20% to 60%, depending on the final energy resource portfolio.[50]

Solar and wind facilities require large amounts of land. For example, the Solar Star project occupies 3,200 acres north of Los Angeles. On average and with current technology, between 2,900 to 4,200 acres are needed for every 1 GW of solar power.[51] Approximately 30,000 to 44,700 acres are needed per 1 GW of wind power,[52] though much of the area occupied by wind farms

44 California Energy Commission. (2022). Utility-Scale Solar Capacity and Electrical Generation by County. California State Geoportal. Accessed on 11/28/2022 at: https://gis.data.ca.gov/documents/CAEnergy::utility-scale-solar-capacity-and-electrical-generation-by-county/explore.

45 Harrison-Atlas, D., Lopez, A., and Lantz, E. (2022). Dynamic Land Use Implications of Rapidly Expanding and Evolving Wind Power Deployment. *Environmental Research Letters*, 17(4), pp. 044064.

46 Gill, L., Gutierrez, A., and Weeks, T. (2021). 2021 SB 100 Joint Agency Report, Achieving 100 Percent Clean Electricity in California: An Initial Assessment. *California Energy Commission, California Public Utilities Commission and California Air Resources Board.* Publication number: CEC-200-2021-00. Available at: https://www.energy.ca.gov/publications/2021/2021-sb-100-joint-agency-report-achieving-100-percent-clean-electricity.

47 The Nature Conservancy. (2022). Power of Place – West: Executive Summary. Accessed 5/15/2023 at: https://www.nature.org/content/dam/tnc/nature/en/documents/TNC_Power-of-Place-WEST-Executive_Summary_WEB-9.2.22.pdf.

48 O'Shaughnessy, E. et al. (2022). Drivers and Energy Justice Implications of Renewable Energy Project Siting in the United States. *Lawrence Berkeley National Laboratory*, *Energy Analysis & Environmental Impacts Division.* Available at: https://escholarship.org/content/qt68c4g1xr/qt68c4g1xr.pdf.

49 California ISO. (2022). ISO 2021-2022 Transmission Plan. Available at: http://www.caiso.com/InitiativeDocuments/ISOBoardApproved-2021-2022TransmissionPlan.pdf.

50 Long, J.C.S. et al. (2021). California Needs Clean Firm Power, and So Does the Rest of the World: Three Detailed Models of the Future of California's Power System all show that California needs Carbon-Free Electricity Sources that don't Depend on the Weather. *Clean Air Task Force.*

51 Bolinger, M., and Bolinger, G. (2022). Land Requirements for Utility-Scale PV: An Empirical Update on Power and Energy Density. *IEEE Journal of Photovoltaics*, 12(2), pp. 589-594.

52 National Renewable Energy Laboratory. (ND). Energy Analysis. Land Use by System Technology. *National Renewable Energy*

Photo: American Public Power Association

Modeling conducted for the SB 100 Joint Agency Report suggests that the average annual build rates [of utility-scale solar and wind] will need to be nearly tripled and sustained for the next 25 years.[57]

can still be used for other purposes.[53] The next SB 100 Joint Agency Report, planned for release in 2025, will evaluate the potential land-use impacts of its scenarios.[54]

California's coast also has up to 112 GW of offshore wind potential.[55] The CEC set a planning goal of 25 GW of offshore wind by 2045.[56] The first auction for leases to construct offshore wind facilities off the coast of California was held in early December 2022; final bids totaled $757.1 million.[57]

Because offshore wind speeds tend to peak in the late afternoon and early evening when solar resources are declining, offshore wind complements land-based wind and solar generation and could help address some of the daily intermittency challenges of solar power (see **Section 3**).[58]

Lab. Accessed on 11/01/2022 at: https://www.nrel.gov/analysis/tech-size.html.

53 Harrison-Atlas, D., Lopez, A., and Lantz, E. (2022). Dynamic Land Use Implications of Rapidly Expanding and Evolving Wind Power Deployment. *Environmental Research Letters*, 17(4), pp. 044064.

54 California Energy Commission. (2022). 2025 SB 100 Report: Scoping Phase: Tribal Listening Session. Accessed 5/16/2023 at: https://www.energy.ca.gov/sites/default/files/2023-03/2025_SB100_Report_Scoping_Tribal_Listening_Session_ADA.pdf

55 Sathe, A. et al. (2020). Research and Development Opportunities for Offshore Wind Energy in California. *California Energy Commission*. Publication Number: CEC-500-2020-053. Available at: https://www.energy.ca.gov/sites/default/files/2021-05/CEC-500-2020-053.pdf.

56 California Energy Commission. (2022). CEC Adopts Historic California Offshore Wind Goals, Enough to Power Upwards of 25 Million Homes. Available at: https://www.energy.ca.gov/news/2022-08/cec-adopts-historic-california-offshore-wind-goals-enough-power-upwards-25.

57 Lopez, N. (2022). First-ever California Offshore Wind Auction Nets $757 Million. CalMatters. Available at: https://calmatters.org/environment/2022/12/california-offshore-wind/.

58 Speer, B., Keyser, D., and Tegen, S. (2016). Floating Offshore Wind in California: Gross Potential for Jobs and Economic

Challenges to siting renewable facilities

Potential sites for utility-scale renewable energy include privately owned land, state and federal lands and waters, or a mix with multiple jurisdictions and oversight agencies, requiring the coordination of planning and management of land parcels. In California, county governments typically have planning control over related siting decisions.

To encourage private investment in solar facilities, the construction of qualifying solar facilities has been excluded from "ad valorem" property taxation in California since 1980, meaning that the construction of such facilities results in no new tax to the local government (which would otherwise receive a tax benefit with any new development). However, this exclusion—recently extended through 2026 by SB 1340 (Hertzberg, 2022)—disincentivizes counties to prioritize solar development when other development alternatives are available. Kern County—home to more than 60,000 acres of solar panels—has been vocal about their opposition to the solar tax exclusion, claiming that it has cost the county $110 million in lost tax revenue over the last 10 years.[59]

Some communities oppose utility-scale renewable power generation, citing concerns over changes to their communities' characteristics and quality of life, that the energy produced would serve consumers outside the areas of planned developments rather than benefiting those who bear the burden, and that communities had not been sufficiently consulted during planning.[60,61]

Relevant State Institutions

- California Energy Commission (CEC)
- California Department of Fish and Wildlife
- California Natural Resources Agency (CNRA)
- California State Lands Commission
- California Public Utilities Commission (CPUC)
- The Governor's Office of Tribal Affairs
- Assembly Utilities & Energy Committee
- Assembly Natural Resources Committee
- Assembly Subcommittee No. 3 Climate Crisis, Resources, Energy, and Transportation
- Senate Energy, Utilities and Communications Committee
- Senate Governance and Finance
- Senate Natural Resources and Water Committee
- Senate Subcommittee No. 2 on Resources, Environmental Protection and Energy
- Senate Subcommittee on Clean Energy Future
- Joint Leg. Committee on Climate Change Policies

For example, in 2019, San Bernardino County—the largest county in California—banned construction of large solar and wind farms on 1 million acres of private land, citing opposition from local residents, despite claims from developers that the projects would bring jobs and tax revenue.[62]

Other counties have banned wind turbine development within their borders due to complaints about aesthetics and noise.[63] Conflicts about renewable facilities may be caused by insufficient community engagement in advance of renewable facility development; poor coordination among

Impacts from Two Future Scenarios (No. NREL/TP-5000-65352). *National Renewable Energy Laboratory*. Available at: https://www.nrel.gov/docs/fy16osti/65352.pdf.

59 Grinnell, C. (2022). Senate Governance and Finance Committee. Senate Floor Analysis on SB-1340 (Hertzberg, 2022): Property Taxation: Active Solar Energy Systems: Extension. California State Legislature. Available at: https://leginfo.legislature.ca.gov/faces/billAnalysisClient.xhtml?bill_id=202120220SB1340#.

60 Cart, J. (2022). Wrangling Over Renewables: Counties Push Back on Newsom Administration Usurping Local Control. *CalMatters*. Accessed on 11/01/2022 at: https://calmatters.org/environment/2022/08/renewable-energy-california-counties/.

61 Wainwright, O. (2023). How Solar Farms took over the California Desert: 'An Oasis has become a Dead Sea.' *The Guardian*. Available at: https://www.theguardian.com/us-news/2023/may/21/solar-farms-energy-power-california-mojave-desert.

62 Cart, J. (2022). Wrangling Over Renewables: Counties Push Back on Newsom Administration Usurping Local Control. *CalMatters*. Accessed on 11/01/2022 at: https://calmatters.org/environment/2022/08/renewable-energy-california-counties/.

63 California Energy Commission. (2021). Electricity from Wind Energy Statistics and Data. *California Energy Commission: Data on Renewable Energy Markets and Resources: Energy Almanac.* Accessed on 11/01/2022 at: https://ww2.energy.ca.gov/almanac/renewables_data/wind/index_cms.php.

utilities, regulators, and planners; limited data; and/or incommensurable values.[64]

These challenges have impeded the construction of new renewable facilities. In response, in June 2022, California legislators passed AB 205 (Committee on Budget, 2022), which grants the California Energy Commission (CEC) authority to certify renewable facilities and associated transmission lines (that meet given criteria), providing developers an alternative pathway to local permitting processes.

Possible synergies among land uses

Though more expensive on a per watt basis, distributed solar has the advantage of requiring no new land conversion. California's rooftops—already supporting 12 GW of solar power as of November 2022[65]—could potentially support an estimated 128.9 GW of solar power, with a generation potential equivalent to 71% of all energy needed in California in 2021.[66] In 2019, the CEC mandated that starting in 2020 all newly constructed low-rise residential, high-rise multifamily, and commercial buildings be equipped with solar panels.[67,68] Parking lots also represent opportunities for solar panel installation.[69] See **Section 4** for more on **distributed energy resources**.

California has 4,000 miles of canals that convey water across the state. Modeling suggests that if these canals were covered by solar panels, the shading would prevent the evaporation of around 65 billion gallons of water a year and provide 13 GW of renewable power, enough to power 9.75 million homes.[70] In February 2022, California's Department of Water Resources awarded the Turlock Irrigation District $20 million in funding for a pilot project, "Project Nexus," to be constructed in the Central Valley as a proof of concept.[71]

Solar farms could be optimized for compatibility with certain crops that do well in shade or partial shade,[72] such as lettuce, alfalfa, sweet potatoes, and kale (this is known as "agrovoltaics"). By shading the soil, solar panels can significantly reduce water evaporation[73] and enhance resilience of dryland farms.[74]

The Multibenefit Land Repurposing Program from the California Department of Conservation provides grants for the transition of agricultural lands to land uses that reduce reliance on groundwater and provide other benefits (including renewable energy) in drought-stricken areas.[75]

64 Susskind, L. et al. (2022). Sources of Opposition to Renewable Energy Projects in the United States. *Energy Policy,* 165, pp. 112922.

65 California Solar Initiative. (2023). California Distributed Generation Statistics. Accessed on 11/03/2022 at: https://www.californiadgstats.ca.gov/.

66 Gagnon, P. et al. (2016). Rooftop Solar Photovoltaic Technical Potential in the United States. A detailed assessment (No. NREL/TP-6A20-65298). *National Renewable Energy Lab.*

67 California Energy Commission. (2018). Energy Commission Adopts Standards Requiring Solar Systems for New Homes, First in Nation. Available at: https://www.energy.ca.gov/news/2018-05/energy-commission-adopts-standards-requiring-solar-systems-new-homes-first.

68 California Energy Commission. (2021). 2022 Building Energy Efficiency Standards Summary. Available at: https://www.energy.ca.gov/sites/default/files/2021-08/CEC_2022_EnergyCodeUpdateSummary_ADA.pdf.

69 Hernandez-Jason, S. (2021). Solar Parking Canopy Goes Online, Providing UCSC with 2 Megawatts of Renewable Energy. *UC Santa Cruz Newscenter.* Accessed on 11/28/2022 at: https://news.ucsc.edu/2021/09/solar-array-parking.html.

70 McKuin, B. et al. (2021). Energy and Water Co-Benefits from Covering Canals with Solar Panels. *Nature Sustainability*, 4(7), pp. 609-617.

71 California Department of Water Resources. (2022). Innovative Solar Project Awarded State Funds: DWR Funds Turlock Irrigation District to Install Solar Panels Over Canals. Available at: https://water.ca.gov/News/News-Releases/2022/Feb-22/DWR-Funds-Turlock-Irrigation-District-to-Install-Solar-Panels-Over-Canals.

72 Miskin, C. et al. (2019). Sustainable Co-Production of Food and Solar Power to Relax Land-Use Constraints. *Nature Sustainability*, 2(10), pp. 972-980.

73 Omer, A.A.A. et al. (2022). Water Evaporation Reduction by the Agrivoltaic Systems Development. *Solar Energy*, 247, pp. 13-23.

74 Barron-Gafford, G.A. et al. (2019). Agrivoltaics Provide Mutual Benefits Across the Food–Energy–Water Nexus in Drylands. *Nature Sustainability*, 2(9), pp. 848-855.

75 California Department of Conservation. (2022). Solicitation Notice and Application for: Multibenefit Land Repurposing

Environmental impacts of renewable energy installation

While less harmful than oil and gas developments, utility-scale wind and solar facilities still have negative environmental impacts.

Wind and solar facilities are known to impact wildlife where they are located, particularly birds and bats.[76] For example, every year in Southern California, an estimated 19,000 to 38,000 birds are killed by wind turbines and an estimated 16,000 to 60,000 birds are killed at utility-scale solar facilities.[77] If these impacts are not mitigated, additional renewable development will likely lead to population declines for some species.[78]

Other impacts on wildlife include habitat loss and impeded migration corridors. Careful siting to avoid sensitive habitats can help mitigate these impacts. Sensors, acoustic deterrents, and adjustments to operation times can reduce wildlife deaths at wind farms.[79] Offshore wind facilities may negatively impact marine life, including fisheries, encouraging careful siting.[80]

Solar farms sited in deserts are detrimental to native plant species (many of which are of cultural value to Native American tribes) and facilitate the spread of invasive grasses.[81] As with other forms of development, land disturbance due to utility-scale wind, solar, and transmission installations can release greenhouse gases from soil and damage grasslands and rangelands that naturally sequester carbon and control erosion.[82]

Environmental Justice and Equity Considerations

While scaling California's production of renewable energy has the potential to benefit disadvantaged communities—by providing cleaner and safer energy, as well as jobs and other economic benefits—these benefits are not always realized, and net impacts at the local level may be negative.[83] For example, some residents near large solar developments in the Mojave Desert "feel like [they've] been sacrificed."[84] Communities may be under-represented in decision-making or lack full information on impacts and risks.[85] Early and ongoing community engagement can

Program. *Division of Land Resource Protection.* Accessed on 11/28/2022 at: https://www.conservation.ca.gov/dlrp/grant-programs/Documents/grant/00_Land%20Repurposing%20Program%20Guidelines_FINAL.pdf.

76 California Energy Commission and California Department of Fish and Game. (2007). California Guidelines for Reducing Impacts to Birds and Bats from Wind Energy Development. Commission Final Report. *California Energy Commission, Renewables Committee, and Energy Facilities Siting Division, and California Department of Fish and Game, Resources Management and Policy Division.* Publication number: CEC-700-2007-008-CMF. Available at: https://nrm.dfg.ca.gov/FileHandler.ashx?DocumentID=9832.

77 Walston Jr., L.J. et al. (2016). A Preliminary Assessment of Avian Mortality at Utility-Scale Solar Energy Facilities in the United States. *Renewable Energy*, 92, pp. 405-414.

78 Conkling, T.J. et al. (2022). Vulnerability of Avian Populations to Renewable Energy Production. *Royal Society Open Science*, 9(3), pp. 211558.

79 Agha, M. et al. (2020). Wind, Sun, and Wildlife: Do Wind and Solar Energy Development 'Short-Circuit' Conservation in the Western United States? *Environmental Research Letters,* 15(7), pp. 075004.

80 Gill, A.B. et al. (2020). Setting the Context for Offshore Wind Development Effects on Fish and Fisheries. *Oceanography*, 33(4), pp. 118-127.

81 Grodsky, S.M., and Hernandez, R.R. (2020). Reduced Ecosystem Services of Desert Plants from Ground-Mounted Solar Energy Development. *Nature Sustainability*, 3(12), pp. 1036-1043.

82 Van de Ven, D.J. et al. (2021). The Potential Land Requirements and Related Land Use Change Emissions of Solar Energy. *Scientific Reports*, 11(1), pp. 1-12.

83 O'Shaughnessy, E. et al. (2022). Drivers and Energy Justice Implications of Renewable Energy Project Siting in the United States. *Lawrence Berkeley National Laboratory*, *Energy Analysis & Environmental Impacts Division.* Available at: https://escholarship.org/content/qt68c4g1xr/qt68c4g1xr.pdf.

84 Wainwright, O. (2023). How Solar Farms took over the California Desert: 'An Oasis has become a Dead Sea.' *The Guardian.* Available at: https://www.theguardian.com/us-news/2023/may/21/solar-farms-energy-power-california-mojave-desert.

85 Ross, E. et al. (2022). Intersections of Disadvantaged Communities and Renewable Energy Potential: Data Set and Analysis to Inform Equitable Investment Prioritization in the United States. *Renewable Energy Focus*, 41, pp. 1-14.

help alleviate concerns[86] and ensure projects maximize local benefits.[87] The process should be as transparent as possible to cultivate trust.[88]

The development of distributed energy resources such as microgrids by and with communities can also enhance energy resilience during energy disruptions while also providing cost savings and grid services during normal operations (see **Section 4**).

Rural communities and Tribes may not have their preferences and input adequately addressed. For example, in 2015, the Colorado River Indian Tribes filed a lawsuit against Riverside County for approving a 3,660-acre solar project that impacted Tribal resources.[89] In addition to state laws and policies related to land use with impacts on Tribal lands and sovereignty, national environmental laws with impact on renewable energy development include the National Environmental Protection Act (NEPA), the National Historic Preservation Act (NHPA), and the Federal Land Policy and Management Act (FLPMA), with each stipulating participation requirements for the general public and consultation with Tribal nations.[90]

Relevant Policies

(Laws/Regulations)

Desert Renewable Energy Conservation Plan (DRECP)

The plan focuses on 10.8 million acres of public lands in desert areas within seven California counties. The plan identifies potential sites for renewable energy development and access to transmission networks on public lands while also protecting desert habitat, species, cultural heritage, and current recreational use in the Mojave, Colorado, and Sonoran Deserts. The California Energy Commission, U.S. Bureau of Land Management, California Department of Fish and Wildlife, and the U.S. Fish and Wildlife Service collaborated to develop the DRECP across jurisdictional boundaries.[91]

California Environmental Quality Act (CEQA)

SB 275 (1970)

CEQA requires that environmental impacts of development projects or major land use decisions be conducted.

California Endangered Species Act (CESA)

The act aims to protect endangered native species and their habitats from threats including those related to land use change or developments, including renewable energy projects, with potential to "jeopardize the continued existence of any endangered species

86 Susskind, L. et al. (2022). Sources of Opposition to Renewable Energy Projects in the United States. *Energy Policy*, 165, pp. 112922.

87 O'Shaughnessy, E. et al. (2022). Drivers and Energy Justice Implications of Renewable Energy Project Siting in the United States. *Lawrence Berkeley National Laboratory*, *Energy Analysis & Environmental Impacts Division*. Available at: https://escholarship.org/content/qt68c4g1xr/qt68c4g1xr.pdf.

88 O'Shaughnessy, E. et al. (2022). Drivers and Energy Justice Implications of Renewable Energy Project Siting in the United States. *Lawrence Berkeley National Laboratory*, *Energy Analysis & Environmental Impacts Division*. Available at: https://escholarship.org/content/qt68c4g1xr/qt68c4g1xr.pdf.

89 Wright, J. (2015). CRIT Sues Riverside County Over Solar Project. *ParkerLive*. Accessed 11/28/2022 at: https://parkerliveonline.com/2015/06/24/crit-sues-riverside-county-over-solar-project/.

90 Susskind, L. et al. (2022). Sources of Opposition to Renewable Energy Projects in the United States. *Energy Policy*, 165, pp. 112922.

91 U.S. Department of the Interior: Bureau of Land Management. Desert Renewable Energy Conservation Plan. Accessed on 11/03/22 at: https://www.blm.gov/programs/planning-and-nepa/plans-in-development/california/desert-renewable-energy-conservation-plan.

or threatened species or result in the destruction or adverse modification of habitat essential to the continued existence of those species."

Natural Community Conservation Planning Act (NCCP)

The act aims to protect plants, animals, and habitats at the regional level while allowing for compatible economic development. The NCCP encourages coordination among landowners, state agencies, and developers in the identification of potential environmental and other impacts. Plans are cooperative, voluntary, and provide a framework to identify potential impacts to wildlife or habitat early in the process of siting a project within a community.

Energy: Land Exchange for Renewable Energy-related Projects
AB 982 (Skinner, 2011)

This law requires the State Lands Commission to enter into an agreement with the U.S. Secretary of the Interior to facilitate land exchanges that consolidate school land parcels into contiguous holdings suitable for renewable energy-related projects.

Native Americans: California Environmental Quality Act
AB 52 (Gatto, 2014)

This law requires consultation with Native American Tribes that are culturally or traditionally connected to the geographic area of a proposed project. The purpose is to identify and prevent or minimize impacts on Native American prehistoric, historic, archaeological, cultural, and sacred places.

Resource Conservation: Working and Natural Lands
SB 1386 (Wolk, 2016)

SB 1386 declares it the policy of the state to consider the protection and management of natural and working lands as part of its approach to meeting greenhouse gas reduction goals.

Energy
AB 205 (Committee on Budget, 2022)

Among other things, AB 205 grants the California Energy Commission the authority to certify renewable facilities and associated transmission lines (that meet given criteria), providing developers with an alternative pathway to local processes.

California Global Warming Solutions Act of 2006: Climate Goal: Natural and Working Lands
AB 1757 (Garcia, 2022)

AB 1757 requires the California Natural Resources Agency to determine an ambitious range of targets for natural carbon sequestration and nature-based climate solutions that reduce greenhouse gas emissions in support of the state's goal of carbon neutrality by 2045.

Property Taxation: Active Solar Energy Systems: Extension
SB 1340 (Hertzberg, 2022)

SB 1340 extends the exclusion of the construction of active solar energy systems from ad valorem taxation through the 2025-2026 fiscal year. Energy systems that qualify for exclusion prior to the repeal date (January 1, 2027) will continue to receive the exclusion until there is a subsequent change in ownership.

Read More

A New Solar Landscape: Improving Landscape Planning for Utility-Scale Solar Planning.
Elkind, E.N., and Lamm, T. (2018). UCLA and UC Berkeley Schools of Law.

Renewables, Land Use, and Local Opposition in the United States.
Gross, S. (2020). Brookings Institute.

Identifying Least-Conflict Solar PV Development in California's San Joaquin Valley.
Pearce, D., Strittholt, J., Watt, T., and Elkind, E.N. (2016). UC Berkeley.

Assessing the Techno-Economics and Environmental Attributes of Utility-Scale PV with Battery Energy Storage Systems (PVS) Compared to Conventional Gas Peakers for Providing Firm Capacity in California.
Roy, S., Shah, S.I., and Sinha, P. (2020).

Utility-Scale Renewable Energy Generation Roadmap.
Energies,13, pp. 488. Schwartz, H., and Brueske, S. (2020). California Energy Commission. Publication number: CEC-500-2020-062.

Sources of Opposition to Renewable Energy Projects in the United States.
Susskind, L. et al. (2022). Energy Policy, 165.

Reliability and the Need for Clean, Firm Power

Managing the intermittency of renewable resources.

Overview

Wind and solar resources are integral to California's path to decarbonization, but these weather- and season-dependent resources introduce reliability challenges. To cost-effectively resolve these challenges and still meet **net-zero*** by 2045 (as per AB 1279, Muratsuchi, 2022), the state will need clean, **firm power**—carbon-neutral power that can be delivered for as long as needed in the amount needed.

Utility-scale wind and solar currently comprise the majority (76%) of California's portfolio of renewable energy.[92] In 2021, 24.9% of the total electricity generated in-state came from these intermittent renewable resources (17.1% and 7.8% from solar and wind, respectively).[93] Moreover, demand for electricity is expected to increase 76% (relative to demand in 2022) by 2045 as a result of population growth and electrification efforts.[94]

Energy storage, **demand response**, and grid regionalization can alleviate some—but not all—of the challenges associated with **intermittent** renewable resources. A diverse portfolio that also includes clean, firm power—be it geothermal, nuclear, renewable hydrogen, natural gas with **carbon capture and storage**, or something else—would address seasonal fluctuations and extreme weather events and is predicted to result in significantly reduced system costs and therefore lower electricity rates.

92 Nyberg, M. (2021). 2021 Total System Electric Generation. *California Energy Commission*. Available at: https://www.energy.ca.gov/data-reports/energy-almanac/california-electricity-data/2021-total-system-electric-generation.

93 Nyberg, M. (2021). 2021 Total System Electric Generation. *California Energy Commission*. Available at: https://www.energy.ca.gov/data-reports/energy-almanac/california-electricity-data/2021-total-system-electric-generation.

94 California Air Resources Board. (2022). 2022 Scoping Plan for Achieving Carbon Neutrality. Available at: https://ww2.arb.ca.gov/sites/default/files/2022-11/2022-sp.pdf.

***** Find **bold** words in the Glossary (Appendix A).

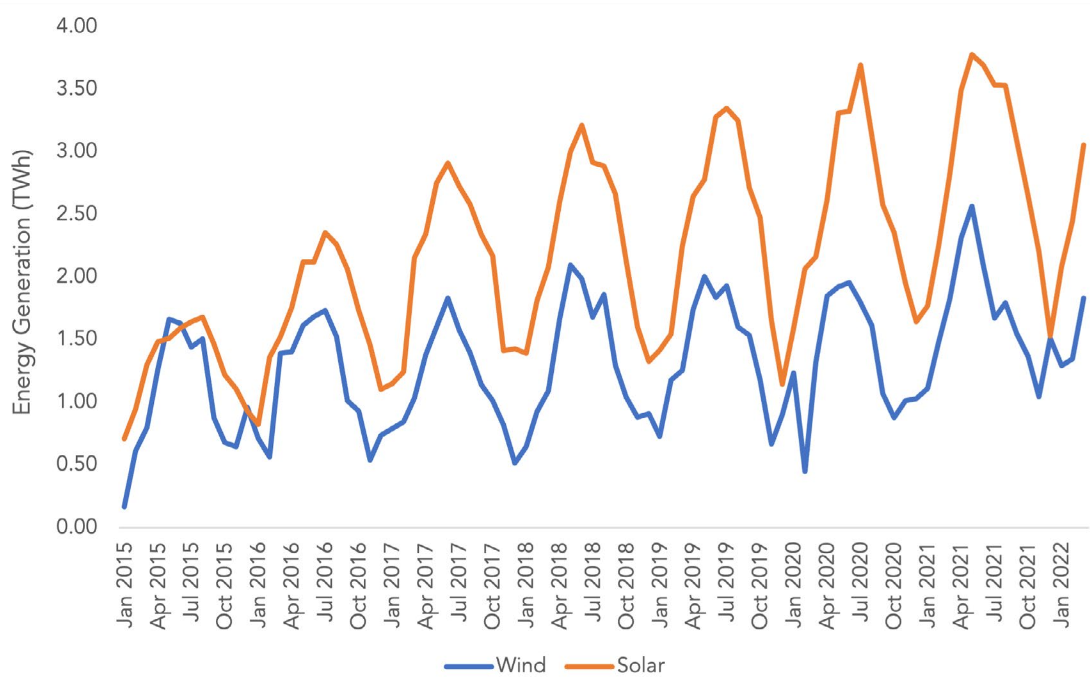

Figure 3.1. Utility-scale wind and solar generation over time in the CAISO service territory. Units are in terawatt hours (TWh).

Data from California Independent System Operator (CAISO) Monthly Metered Renewable Generation. Accessed on 11/16/2022.

The nature of renewable intermittency

Wind and solar generation are variable or "intermittent": they depend on weather conditions, season, and time of day. Seasonal mismatch between supply and demand presents the most challenging issue to resolve. Average daily output from current wind and solar developments in winter is just 30% to 40% of maximum summer output (see **Figure 3.1**).

This is significant as the electrification of space heating will increase demand in the winter.[95]

Winter—rather than summer—may become the more challenging season for California's electric grid.[96] Occasional weather patterns covering 1,000 kilometers (620 miles) or more can cause reduced solar production that can last for weeks or, in extreme cases, months.

Current battery technology is not suited for cost-effectively resolving these seasonal differences in energy generation or addressing shortfalls created by atypical weather events (see more on energy storage below).[97]

Other challenges are associated with balancing the daily supply of renewable energy with con-

95 Buonocore, J. J. et al. (2022). Inefficient Building Electrification Will Require Massive Buildout of Renewable Energy and Seasonal Energy Storage. *Scientific Reports*, 12, pp. 11931.

96 Abido, M.Y. et al. (2022). Seasonal Challenges for a California Renewable-Energy-Driven Grid. *Iscience*, 25(1), pp. 103577.

97 Long, J.C.S. et al. (2021). California Needs Clean Firm Power, and So Does the Rest of the World: Three Detailed Models of the Future of California's Power System all show that California needs Carbon-Free Electricity Sources that don't Depend on the Weather. *Clean Air Task Force*.

sumer demand. Solar production peaks midday, while demand for energy usually peaks around 4 p.m. to 6 p.m.,[98] just as solar resources are starting to go offline. This creates the need to quickly ramp other sources of energy generation to compensate. During the middle of the day, renewable generation may exceed demand and needs to be exported to other parts of the West, stored for use at other times, or **curtailed**.[99] These challenges are illustrated in a chart of **net demand** (total energy demand minus renewable energy generation) known as the "**duck curve**" (**Figure 3.2**).

The state presently relies on 39.5 **gigawatts (GW)** of in-state, unmitigated (i.e., without carbon capture and storage) natural gas to meet demand when solar and wind generation are insufficient (as of 2022).[100] However, SB 100 (de León, 2018) and AB 1279 (Muratsuchi, 2022), effectively require the elimination of unmitigated natural gas from the electricity sector.

Due to intermittency issues and fluctuations in available power, a zero-carbon system based primarily on wind and solar would require building excess capacity or generation potential and associated storage so that when solar or wind output is low, there is still sufficient electricity to meet demand.[101] This excess build-out would likely increase cost as this infrastructure would be idle for significant periods of time; further, this would require more land use conversion and transmission infrastructure, both of which generate challenges of siting and permitting.

Batteries and other energy storage

Energy storage systems could include electrochemical, mechanical, or thermal technologies. All can be leveraged to improve the reliability of the grid and reduce the need for fossil fuel generation. By absorbing excess renewable energy and discharging it back to the grid later when demand is high but renewable production is limited, energy storage systems can both alleviate the need for renewable energy curtailment during the day and soften the need for ramping other sources of generation in the evening.

Modeling conducted for the SB 100 Joint Agency Report projects that 49,000 **megawatts (MW)** (i.e., 49 GW) of short-duration battery storage will be needed to meet clean energy targets by 2045.[102] For context, California Independent System Operator (CAISO) estimated the grid contained around 3,500 MW of battery storage in September 2022 (up from 250 MW in 2020).[103] Most of this storage is in the form of lithium-ion batteries that can only discharge energy for up to four hours.

Long duration energy storage systems can address some of the challenges associated with seasonal deficiencies and extreme weather. AB 205 (Committee on Budget, 2022) created a Long-Duration Energy Storage Program at the California Energy Commission (CEC) with a $380 million budget to support innovative systems capable of continuously discharging energy for eight or more hours. In early November 2022,

98 California ISO. (2022). California ISO Peak Load History 1998 through 2022. Accessed on 11/29/2022 at: https://www.caiso.com/documents/californiaisopeakloadhistory.pdf.

99 California ISO. (2022). Managing Oversupply. Accessed on 11/29/2022 at: http://www.caiso.com/informed/Pages/ManagingOversupply.aspx.

100 Nyberg, M. (2023). Electric Generation Capacity and Energy. *California Energy Commission.* Accessed on 5/18/2023 at: https://www.energy.ca.gov/data-reports/energy-almanac/california-electricity-data/electric-generation-capacity-and-energy.

101 Gill, L., Gutierrez, A., and Weeks, T. (2021). 2021 SB 100 Joint Agency Report, Achieving 100 Percent Clean Electricity in California: An Initial Assessment. *California Energy Commission, California Public Utilities Commission and California Air Resources Board.* Publication number: CEC-200-2021-00. Available at: https://www.energy.ca.gov/publications/2021/2021-sb-100-joint-agency-report-achieving-100-percent-clean-electricity.

102 Gill, L., Gutierrez, A., and Weeks, T. (2021). 2021 SB 100 Joint Agency Report, Achieving 100 Percent Clean Electricity in California: An Initial Assessment. *California Energy Commission, California Public Utilities Commission and California Air Resources Board.* Publication number: CEC-200-2021-00. Available at: https://www.energy.ca.gov/publications/2021/2021-sb-100-joint-agency-report-achieving-100-percent-clean-electricity.

103 California ISO. (2022). Summer Market Performance Report. Available at: http://www.caiso.com/Documents/SummerMarketPerformanceReportforSeptember2022.pdf.

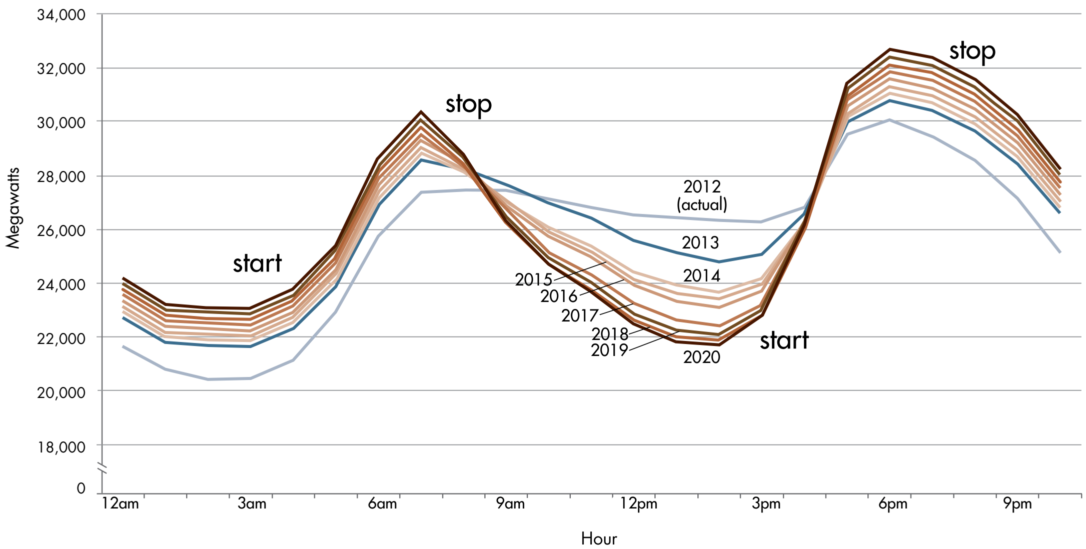

Figure 3.2. This "duck curve" shows net demand (total energy demand minus renewable energy generation) over time on a specific day, January 11. The duck curve illustrates the steep ramps necessary when other sources of energy generation must be quickly shut down or brought online to either make room or compensate for renewable energy generation. Licensed with permission from the California ISO.

the CEC announced the first award under this program: a $31 million grant was provided to the Viejas Tribe of Kumeyaay Indians to support a long-duration energy storage project using non-lithium technologies.[104]

Pumped storage hydropower (PSH) has long been the most common utility-scale energy storage system in California and the United States. PSH comprises two reservoirs at different elevations. Power is generated when water is released from the upper reservoir and passes through a turbine on its way to the lower. The system is recharged (like a battery) by pumping the water back into the upper reservoir. California currently has about 4,500 MW of PSH.

Demand response

One tool for mitigating intermittency is through demand response—a method of grid management where consumers are signaled to adjust their energy use (Decision 17-12-003).[105]
To date, most demand response tools in California are signals for consumers to reduce or "shed" demand (e.g., CAISO Flex Alerts). However, consumers could also be signaled to shift their demand from one time of day to another ("**load shifting**").

Like energy storage (above), load shifting could avert curtailment of renewable generation during the day and soften the generation ramps necessary in the evening, providing up to $700 million worth of system benefits in California annually.[106] Newly electrified technologies (like **heat**

104 California Energy Commission. (2022). California Energy Commission Approves $31 Million for Tribal Long-Duration Energy Storage Project. Accessed on 11/29/2022 at: https://www.energy.ca.gov/news/2022-11/california-energy-commission-approves-31-million-tribal-long-duration-energy.

105 California Public Utilities Commission. (2021). Demand Response (DR). Accessed on 11/29/2022 at: https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/electric-costs/demand-response-dr.

106 Alstone, P. et al. (2017). 2025 California Demand Response Potential Study — Charting California's Demand Response Future: Final Report on Phase 2 Results. Lawrence Berkeley National Laboratory. Available at: https://eta-publications.lbl.gov/sites/default/files/lbnl-2001113.pdf.

pumps and electric vehicles) could automate load shifting and represent significant load shift resources.[107] In April 2022, the California Public Utilities Commission (CPUC) expanded incentives in the Self-Generation Incentive Program (SGIP) to include heat pump water heaters designed to load shift.[108] SB 846 (Dodd, 2022) directs the CEC, CPUC, and CAISO to develop and regularly update load shifting targets to reduce peak net demand.

Coordination across states

Multistate coordination could help ease some of the challenges associated with intermittent renewable energy.[109] Increasing the geographic diversity of wind and solar resources smooths variability in generation.[110] Expanding connections of California's grid to other states in the West could help increase the utilization of renewable generation when it exceeds demand. In response to ACR 188 (Holden, 2022), CAISO contracted the National Renewable Energy Laboratory to produce a report on the impacts of expanded regional energy coordination.[111]

Clean firm power options

SB 423 (Stern, 2022) requires the California Energy Commission (CEC) to consider the role of firm zero-carbon resources that can address atypical weather events and support a clean, reliable, and resilient grid. There are currently few options for clean, firm power. While this may change, the most compelling choices that would enable California to achieve a net-zero economy by 2045 are geothermal energy, nuclear power, hydropower, natural gas with carbon capture and storage (CCS), and renewable hydrogen. See below for discussions of each. There are benefits and costs to all choices, but each of these resources could help to ensure reliability of a grid primarily powered by intermittent renewable resources. Further, each of these options would help stabilize the cost of electricity.

Research suggests that a greater diversity of options will result in a more resilient grid and lower costs for consumers.[112] Although clean, firm power may be more expensive than solar and

Relevant State Institutions

- California Air Resources Board (CARB)
- California Department of Water Resources (DWR)
- California Energy Commission (CEC)
- California Independent System Operator (CAISO)
- California Public Utilities Commission (CPUC)
- The Governor's Office of Emergency Services
- The Governor's Office of Tribal Affairs
- Assembly Budget Subcommittee no 3 on Climate Crisis, Resources, Energy, and Transportation
- Asm. Environmental Safety and Toxic Materials Cmte.
- Assembly Natural Resources Committee
- Assembly Utilities and Energy Committee
- Senate Budget Subcommittee 2 on Resources, Environmental Protection and Energy

107 Gerke, B. F. et al. (2020). The California Demand Response Potential Study, Phase 3: Final Report on the Shift Resource through 2030. Lawrence Berkeley National Laboratory. Available at: https://eta-publications.lbl.gov/sites/default/files/ca_dr_potential_study_-_phase_3_-_shift_-_final_report.pdf

108 California Public Utilities Commission. (2022). CPUC Provides Additional Incentives and Framework for Electric Heat Pump Water Heater Program. Available at: https://www.cpuc.ca.gov/news-and-updates/all-news/cpuc-provides-additional-incentives-and-framework-for-electric-heat-pump-water-heater-program.

109 Gill, L., Gutierrez, A., and Weeks, T. (2021). 2021 SB 100 Joint Agency Report, Achieving 100 Percent Clean Electricity in California: An Initial Assessment. *California Energy Commission, California Public Utilities Commission and California Air Resources Board.* Publication number: CEC-200-2021-00. Available at: https://www.energy.ca.gov/publications/2021/2021-sb-100-joint-agency-report-achieving-100-percent-clean-electricity.

110 GE Energy. (2010). Western Wind and Solar Integration Study: Executive Summary. *National Renewable Energy Laboratory*. Available at: https://www.nrel.gov/docs/fy10osti/47781.pdf.

111 Hurlbut, D., Greenfogel, M., and Speetles, B. (2023). The Impacts on California of Expanded Regional Cooperation to Operate the Western Grid (Final Report). *National Renewable Energy Laboratory*. Available at: http://www.caiso.com/Documents/Expanded-Regional-Cooperation-ACR-188-Final-Report-Feb2023.pdf.

112 Long, J.C.S. et al. (2021). California Needs Clean Firm Power, and So Does the Rest of the World: Three Detailed Models of the Future of California's Power System all show that California needs Carbon-Free Electricity Sources that don't Depend on the

wind per **kilowatt (kW)**, the critical role these resources will play in addressing intermittency and reliability issues will facilitate lower overall costs to the consumer.[113,114,115] An optimal energy portfolio would be best informed by considering the impacts of each resource on cumulative system costs rather than the specific costs per kW of each technology.

Geothermal energy

California is the U.S.'s largest producer of geothermal energy, with sites including the Geysers—the world's largest complex of geothermal plants—in northern California and the Salton Sea in southern California. California's 40 geothermal plants currently produce more geothermal energy than any other state and account for about 5% of the state's total energy.[116] California currently has 2,693 MW of geothermal capacity.[117] While geothermal represents a smaller fraction of California's energy supply than wind and solar, there is potential to expand development. The geothermal resources in the Salton Sea alone represent an estimated 2,200 MW of untapped generation capacity;[118] across California, the potential could be as high as 15,000 MW.[119] Geothermal energy requires less land than solar or wind, and once established, is a source of clean, firm power. The expansion of geothermal is challenged by high costs for exploratory drilling, though research for technical innovations and to reduce costs is ongoing.[120]

Geothermal brine waters contain low concentrations of lithium—a highly valuable mineral used in most rechargeable batteries that is considered to be "essential to the economic and national security of the United States."[121] The CEC is supporting demonstration projects that seek to effectively separate lithium from geothermal brine as one avenue for improving the economics of geothermal energy.[122] The CEC estimates that the Salton Sea has the potential to produce more than 600,000 tons of lithium carbonate per year, which is equivalent to $7.2 billion per year under current market conditions.[123]

Geothermal energy can operate as a **base load** resource (i.e., operating continuously to meet baseline demand) and be ramped to meet peak demand if necessary.

Weather. *Clean Air Task Force.*

113 Gill, L., Gutierrez, A., and Weeks, T. (2021). 2021 SB 100 Joint Agency Report, Achieving 100 Percent Clean Electricity in California: An Initial Assessment. *California Energy Commission, California Public Utilities Commission and California Air Resources Board.* Publication number: CEC-200-2021-00. Available at: https://www.energy.ca.gov/publications/2021/2021-sb-100-joint-agency-report-achieving-100-percent-clean-electricity.

114 Breckel, A. et al. (2022). Growing the Grid: A Plan to Accelerate California's Clean Energy Transition. *Environmental Defense Fund, Clean Air Task Force.*

115 Long, J.C.S. et al. (2021). California Needs Clean Firm Power, and So Does the Rest of the World: Three Detailed Models of the Future of California's Power System all show that California needs Carbon-Free Electricity Sources that don't Depend on the Weather. *Clean Air Task Force.*

116 Nyberg, M. (2021). 2021 Total System Electric Generation. *California Energy Commission.* Available at: https://www.energy.ca.gov/data-reports/energy-almanac/california-electricity-data/2021-total-system-electric-generation.

117 Nyberg, M. (2023). Electric Generation Capacity and Energy. *California Energy Commission.* Accessed on 5/18/2023 at: https://www.energy.ca.gov/data-reports/energy-almanac/california-electricity-data/electric-generation-capacity-and-energy.

118 Goodman, D., Mirick, P., and Wilson, K. (2022). Salton Sea Geothermal Development: Nontechnical Barriers to Entry—Analysis and Perspectives. *Pacific Northwest National Laboratory.* Available at: https://www.pnnl.gov/main/publications/external/technical_reports/PNNL-32717.pdf.

119 U.S. Geological Survey. (2008). Assessment of Moderate- and High-Temperature Geothermal Resources of the United States. Available at: https://pubs.usgs.gov/fs/2008/3082/pdf/fs2008-3082.pdf.

120 Kolker, A. (ND). Exploration and Targeting. Geothermal Research. *National Renewable Energy Laboratory.* Accessed 11/29/2022 at: https://www.nrel.gov/geothermal/exploration-targeting.html.

121 The US Department of Commerce. (2020). A Federal Strategy to Ensure Secure and Reliable Supplies of Critical Minerals. Available at: https://www.commerce.gov/sites/default/files/2020-01/Critical_Minerals_Strategy_Final.pdf.

122 California Energy Commission. (2020). Geothermal, Lithium Recovery Projects get Boost from California Energy Commission. Available at: https://www.energy.ca.gov/news/2020-05/geothermal-lithium-recovery-projects-get-boost-california-energy-commission.

123 Ventura, S. et al. (2020). Selective Recovery of Lithium from Geothermal Brines. *California Energy Commission.* Available at: https://www.energy.ca.gov/sites/default/files/2021-05/CEC-500-2020-020.pdf.

Nuclear power

Zero-carbon nuclear energy has long played an important role in California's power generation, although the percent of the grid powered by nuclear energy has declined as plants have been decommissioned. Roughly 6% of California's energy comes from Diablo Canyon Power Plant (DCPP),[124] California's last operational nuclear facility. Another 3.3% of California's energy is from imported nuclear power.

DCPP has long been contentious as the facility is located near seismic fault lines, creating community concerns about safety in addition to radioactive waste management.[125] Furthermore, people of color—and particularly Native American communities—are disproportionately impacted by uranium mining and nuclear waste disposal in the United States.[126]

Pacific Gas & Electric (PG&E) originally petitioned for decommissioning DCPP in 2025, citing the high costs of running the plant, burdensome regulatory requirements, and a potential lack of need.[127] However, a joint study by Stanford University and Massachusetts Institute of Technology researchers concluded that keeping Diablo Canyon open past 2025 would help California meet its climate goals and reduce emissions.[128] According to another model, retaining Diablo Canyon until 2045 would reduce emissions from the electricity sector by 40 million metric tons (MMT) and generate more than $4 billion in savings.[129] To improve reliability over the short-term, SB 846 (Dodd, 2022) has provided a pathway to extend DCPP operations through 2030 (pending approval from the Nuclear Regulatory Commission, the U.S. Department of Energy, and state regulatory agencies) and provides PG&E a loan of up to $1.4 billion to do so.

The San Onofre Nuclear Generating Station (SONGS) had a similar maximum capacity as DCPP. Its unexpected closure in 2012 caused an immediate rise in electricity prices, natural gas usage, electricity imports, and greenhouse gas (GHG) emissions.[130] California is proactively developing regulations to ensure that when DCPP is decommissioned, similar effects can be avoided. For example, SB 1090 (Monning, 2018) and SB 846 (Dodd, 2022) require the CPUC's integrated resource plans to be designed to avoid any increases in greenhouse gas emissions due to the eventual closure of DCPP.

Compared to other energy resources, nuclear power tends to be relatively inflexible—meaning that it can't easily (or economically) be ramped up or down in response to demand (with some exceptions). Consequently, nuclear power runs best as a base load resource.

Next generation nuclear technologies are on the horizon. Some of these feature enhanced safety mechanisms, the potential for small-scale or modular designs, and dramatic reductions in nuclear waste.[131] Current California law prohibits the construction of any new nuclear facilities until the federal government identifies a viable option for nuclear waste disposal (Warren-Alquist

124 Nyberg, M. (2021). 2021 Total System Electric Generation. *California Energy Commission*. Available at: https://www.energy.ca.gov/data-reports/energy-almanac/california-electricity-data/2021-total-system-electric-generation.

125 Van Niekerken, B. (2016). Diablo Canyon Nuclear Plant: A Legacy of Powerful Protests. *San Francisco Chronicle*. Accessed 11/03/2022 at: https://www.sfchronicle.com/chronicle_vault/article/Diablo-Canyon-nuclear-plant-A-legacy-of-powerful-8344582.php.

126 Jantz, E. (2018). Environmental Racism with a Faint Green Glow. *Natural Resources Journal*, 58, pp. 247.

127 California Public Utilities Commission. (2018). Decision Approving Retirement of Diablo Canyon Nuclear Power Plant. Available at: https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M205/K090/205090240.PDF.

128 Aborn, J. et al. (2021). An Assessment of the Diablo Canyon Nuclear Plant for Zero Carbon Electricity, Desalination, and Hydrogen Production. *Stanford Energy*.

129 Newell, S. et al. (2022). Retaining Diablo Canyon: Economic, Carbon, and Reliability Implications. The Brattle Group. Accessed on 5/17/2023 at: https://carbonfreeca.org/wp-content/uploads/2022/06/2022-06-09_Brattle-Report-on-Impacts-of-Diablo-Extension.pdf.

130 U.S. Energy Information Administration. (2012). San Onofre Nuclear Outage Contributes To Southern California's Changing Generation Profile. Accessed on 11/03/2022 at: https://www.eia.gov/todayinenergy/detail.php?id=8770.

131 National Academy of Sciences, Engineering, and Medicine. (2023). Laying the Foundation for New and Advanced Nuclear Reactors in the United States. *The National Academies Press*. Available at: https://nap.nationalacademies.org/catalog/26630/laying-the-foundation-for-new-and-advanced-nuclear-reactors-in-the-united-states.

Act, 2022, §25524.1). The nation is currently in violation of the Nuclear Waste Policy Act and will need to revisit this issue to make a new plan for waste disposal. A licensed waste repository will not likely be in place before mid-century. Consequently, any new nuclear power in California would require reversal of this provision.

Over the long term, nuclear fusion technology—which does not produce any nuclear waste—may hold promise as a clean energy solution for California.[132] Though it is unlikely to play a large role in achieving a net-zero economy by 2045, new and promising technologies appear to be on track for power production demonstrations in the next few decades. This could be an important resource later in the century.

Hydropower

Established hydropower is a zero-carbon flexible resource that is strategically deployed to ensure grid reliability. Over the last decade, hydroelectric production has varied significantly. During "wet" years like 2017 and 2019, California's large and small hydroelectric resources provided roughly 14-15% of total energy consumed in the state. During dry years, like 2015 and 2021, they accounted for only 4-5%.[133] Reduced hydropower has historically increased California's reliance on natural gas and energy imports, leading to increased GHG emissions.[134] Hydropower can be used as a base load or peaking resource. During dry years, hydropower tends to be reserved for meeting net demand on summer evenings.[135] Reservoirs are dependent upon spring and summer snowmelt, but because of climate change, more precipitation is predicted to fall as rain rather than snow,[136] leading to uncertainty about the long-term reliability of this resource for meeting net demand in summer.[137] Further, demands for hydroelectric power compete with other objectives including a secure water supply, flood control, and supporting fish populations.

New hydropower would be difficult to site and permit, and the state does not currently plan to construct any new large (greater than 30 MW) hydropower facilities. New hydropower may be inadvisable given that flooded vegetation leads to the production of **methane**, a strong greenhouse gas.[138]

Natural gas with carbon capture and storage

As mentioned previously, California currently relies on natural gas to ensure grid reliability. The State could continue to use natural gas in this capacity and leverage much of the current natural gas infrastructure if these facilities implemented CCS, so long as sufficient capture rates can be achieved. Natural gas with CCS could be reserved to meet peak demand or provide power at night when solar resources are offline.

CCS is often dismissed or opposed in part because previous facilities have demonstrated lower-than-expected capture efficiencies. For example, the Sturgeon Refinery in Alberta, Canada

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132 Bishop, B. (2022). Lawrence Livermore National Laboratory Achieves Fusion Ignition. Accessed on 5/18/2023 at: https://www.llnl.gov/news/lawrence-livermore-national-laboratory-achieves-fusion-ignition.

133 California Energy Commission. (2022). Total System Electric Generation 2009-2021. Accessed on 11/29/2022 at: https://www.energy.ca.gov/media/7311.

134 Nyberg, M. (2022). In-State Electric Generation by Fuel Type (GWh). Accessed on 11/29/2022 at: https://www.energy.ca.gov/data-reports/energy-almanac/california-electricity-data/electric-generation-capacity-and-energy.

135 Erne, D. (2022). Final 2021 Integrated Energy Policy Report. Volume II: Ensuring Reliability in a Changing Climate. *California Energy Commission*. Publication Number: CEC-100-2021-001-V2. Available at: https://efiling.energy.ca.gov/GetDocument.aspx?tn=241583.

136 Pierce, D. W. et al. (2018). Climate, Drought, and Sea Level Rise Scenarios for California's Fourth Climate Change Assessment. California Energy Commission. Available at: https://www.energy.ca.gov/sites/default/files/2019-11/Projections_CCCA4-CEC-2018-006_ADA.pdf.

137 Tarroja, B. et al. (2019). Implications of Hydropower Variability from Climate Change for a Future, Highly Renewable Electric Grid in California. *Applied Energy*, 237(1), pp. 353-366.

138 Deemer, B. R. et al. (2016). Greenhouse Gas Emissions from Reservoir Water Surfaces: A New Global Synthesis. *Bioscience*, 66(11), pp. 949-964.

captures only 70% of its total carbon emissions.[139] However, new technologies are being developed that, if successful, could capture all or nearly all the carbon dioxide. For example, a 300 MW natural gas power plant is being constructed in Odessa, Texas which will demonstrate a new approach to carbon capture that is expected to achieve 100% capture efficiency.[140]

To date, CCS has not presented a compelling financial case for the electricity sector. Separating the carbon dioxide from the emission stream is a costly additional step that does not directly contribute to the production of electricity. The successful build out of CCS facilities in California would require support from climate policies. The expanded tax credits for CCS provided by the Inflation Reduction Act may help to address this barrier.

California has a geology well-suited to carbon sequestration, given its extensive depleted oil and gas reservoirs and deep saline reservoirs in the Central Valley. Long-term retention rates at storage facilities and the potential for leaks from pipelines and storage reservoirs would need attention. The state and federal government have been developing regulatory frameworks to conduct CCS safely.

Please see **Section 5** for a more complete discussion of CCS.

Hydrogen

Zero-carbon hydrogen can be produced by using renewable energy to split water into its constituent hydrogen and oxygen components (a process known as electrolysis).[141] Electrolytic hydrogen is often referred to as "green" hydrogen but there are disagreements about this terminology.

Alternatively, hydrogen can be produced from methane in a process called steam methane reformation. Most hydrogen (95%) produced today is produced through steam methane reformation.[142] This method of hydrogen production emits carbon dioxide, and thus would need to be accompanied by CCS to be considered a low-carbon resource. Hydrogen produced through steam methane reformation with CCS is often called "**blue hydrogen**." Hydrogen can be either combusted (burned) or used in a **fuel cell**; when burned, hydrogen produces nitrogen oxides.

Hydrogen rarely exists in a usable state in nature; pure hydrogen must be created in a process that requires energy. Thus, hydrogen is more accurately understood as an energy storage solution rather than a source of energy itself. Once created, hydrogen can be stored for long periods of time before being used as an energy resource. Electrolytic hydrogen is thus an attractive solution for converting excess solar and wind capacity for long-duration energy storage, thereby improving grid resilience.

Electrolytic hydrogen—as well as hydrogen produced by other pathways—also has potential applications in hard-to-electrify sectors including long-haul transportation (see **Section 7**), steel and cement production, industrial operations, and agriculture. SB 1075 (Skinner, 2022) requires the CPUC and CEC to consider the role of hydrogen in their respective decarbonization strategies.

Hydrogen is known to be an indirect GHG—this means that while it is not a GHG itself, hydrogen interacts with other molecules in the atmosphere in a process that ultimately causes methane and sometimes **ozone** to remain in the atmosphere longer than they would otherwise.[143] Thus, hydrogen leakage must be strictly controlled, which is challenging

139 Sturgeon Refinery. (2023). Carbon Capture and Storage. Accessed on 5/17/2023 at: https://nwrsturgeonrefinery.com/project/carbon-capture-and-storage/.

140 Patal, S. (2022). NET Power's First Allam Cycle 300-MW Gas-Fired Project will be Built in Texas. *POWER*. Accessed on 5/17/2023 at: https://www.powermag.com/net-powers-first-allam-cycle-300-mw-gas-fired-project-will-be-built-in-texas/.

141 Maiden, T.O., and Schmoll, E. (2022). California Clean Hydrogen Bill Targets Alternative Energy Sources for Expansion. *EHS Law Insights: Reed Smith.* Available at: https://www.ehslawinsights.com/2022/02/california-clean-hydrogen-bill-targets-alternative-energy-sources-for-expansion/.

142 U.S. Department of Energy. (ND). Hydrogen Production: Natural Gas Reforming. Accessed 5/30/2023 at: https://www.energy.gov/eere/fuelcells/hydrogen-production-natural-gas-reforming.

143 Warwick, N. et al. (2022). Atmospheric Implications of Increased Hydrogen Use. *Crown*. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1067144/atmospheric-implications-of-increased-

given the incredibly small size of the hydrogen molecule. This is an active area of research at several public and private research institutions.

Other clean fuels are possible but limited. For example, ammonia may be an attractive solution but has not been fully evaluated. **Biomethane** will be one critical clean fuel in the portfolio, but supplies are limited.[144] These limited clean fuel supplies should be allocated only to the most recalcitrant decarbonization challenges.

Environmental Justice and Equity Considerations

Natural gas facilities—which currently provide 75% of the flexibility the California grid requires to accommodate renewable resources[145]—are disproportionately located near disadvantaged communities.[146] Until cost-effective, clean, firm power alternatives are found, these communities will continue to be burdened by pollution generated by natural gas plants.

Each of the clean, firm power options presented here have the potential to negatively impact nearby communities. Inclusive decision-making will be essential to ensure a more equitable transition to a net-zero economy.

Relevant Policies

(Laws/Regulations)

Self-Generation Incentive Program (SGIP)

Provides incentives to support distributed energy systems including wind turbines, waste heat-to-power technologies, pressure reduction turbines, internal combustion engines, microturbines, gas turbines, fuel cells, and advanced energy storage systems.

Renewables Portfolio Standard (RPS) Program
SB 1078 (Sher, 2002)

The RPS Program mandated an initial 20% of electricity retail sales to come from renewable resources by 2017. In 2018, SB 100 (de León, 2018) was signed into law, which increases RPS to 60% by 2030 and requires all the state's electricity to come from carbon-free resources by 2045.

SB 1078 defined eligible renewables to include small hydropower, solar, wind, and geothermal among others. SB 350 introduced interim annual RPS targets with three-year compliance periods and requires 65% of RPS procurement to be derived from long-term contracts of 10 or more years.

Clean Energy Pollution Reduction Act
SB 350 (de León, 2015)

SB 350 increases California's renewable electricity procurement goal from 33% by 2020 to 50% by 2030, thus supporting greater use of resources eligible for the Renewables Portfolio Standard.

SB 350 mandates doubling statewide energy efficiency savings for electricity and natural gas end uses by 2030. SB 350 requires large utilities to submit integrated resource plans on how they

hydrogen-use.pdf.

144 Jaffe, A. M. et al. (2016). The Feasibility of Renewable Natural Gas as a Large-Scale, Low Carbon Substitute. *California Air Resources Board*. Available at: https://ww2.arb.ca.gov/sites/default/files/classic/research/apr/past/13-307.pdf.

145 California Air Resources Board. (2022). 2022 Scoping Plan for Achieving Carbon Neutrality. Available at: https://ww2.arb.ca.gov/sites/default/files/2022-11/2022-sp.pdf.

146 PSE Healthy Energy. (2017). Natural Gas Power Plants in California's Disadvantaged Communities. Available at: https://www.psehealthyenergy.org/wp-content/uploads/2017/04/CA.EJ_.Gas_.Plants.pdf.

will meet consumers' needs, reduce greenhouse gas emissions, and increase use of clean energy resources.

The 100 Percent Clean Energy Act of 2018
SB 100 (de León, 2018)

SB 100 establishes a goal that by 2045 all retail electricity sold in California and state agency electricity needs will be powered by renewable and zero-carbon resources.

SB 100 updates the Renewables Portfolio Standard to ensure that by 2030 at least 60% of state's electricity is renewable.

SB 100 requires the CEC, CPUC, and CARB to use existing laws to achieve 100% clean electricity and issue joint policy on SB 100 by 2021 and every four years after that.

Clean Energy, Jobs, and Affordability Act of 2022
SB 1020 (Laird, 2022)

SB 1020 added interim targets for renewable energy and zero-carbon electricity retail sales as legislated in SB 100 (de León, 2018): 90% by 2035 and 95% by 2040. SB 1020 requires state agencies to use 100% renewable energy and zero-carbon resources by 2030 and establishes a Climate and Equity Trust fund to manage rising electricity rates that threaten affordability.

California Global Warming Solutions Act
AB 32 (Nunez, 2006)

AB 32 required California to reduce greenhouse gas emissions to 1990 levels by 2020 and is designed to mitigate risks of climate change, improve energy efficiency, expand renewable energy, support cleaner transportation, and reduce waste. AB 32 requires CARB to develop a Scoping Plan (e.g., the 2022 Scoping Plan) that delineates strategies for achieving emission reduction goals.

AB 32 also requires convening an Environmental Justice Advisory Committee to advise on Scoping Plans and climate programs. SB 32 (Pavley, 2016) expanded emissions targets to reflect a 40% reduction from 1990 levels by 2030.

California Climate Crisis Act
AB 1279 (Muratsuchi, 2022)

AB 1279 declares the policy of the state to achieve net-zero greenhouse gas emissions as soon as possible, but no later than 2045, and to achieve and maintain net negative emissions thereafter. Further, this law mandates that emissions by 2045 are reduced by 85% below 1990 levels (this is to ensure that direct emission reductions are favored over the broad deployment of carbon removal technologies).

This law requires CARB to work with relevant agencies to 1) ensure scoping plan updates include measures to achieve these policy goals; and 2) identify and implement strategies to enable carbon dioxide removal solutions and carbon capture, utilization, and storage technologies.

Diablo Canyon Nuclear Power Plant
SB 1090 (Monning, 2018)

SSB 1090 requires the CPUC to ensure that integrated resource plans avoid increases in greenhouse gas emissions resulting from the closure of Diablo Canyon Nuclear Power Plant.

Diablo Canyon Powerplant: Extension of Operations
SB 846 (Dodd, 2022)

SB 846 invalidates the CPUC's approval of the PG&E request to decommission Diablo Canyon Powerplant (DCPP). SB 846 provides a pathway to extend the life of Diablo Canyon Powerplant through 2030 and provides PG&E a loan of up to $1.4 billion to do so. Relicensing through 2030 will first require PG&E to receive approval from the Nuclear Regulatory Commission, the U.S. Department of Energy, and several state regulatory agencies.

SB 846 directs the CEC, CPUC, and CAISO to develop load shifting targets to reduce peak net demand. These targets are to be updated for each integrated energy policy report. Further, the CEC, in consultation with the CPUC and CAISO, is to recommend policies that would increase load shifting and other forms of demand response that would not inadvertently lead to increased greenhouse gas emissions.

Green Hydrogen: Emissions of Greenhouse Gases
SB 1075 (Skinner, 2022)

SB 1075 requires the CPUC and CEC to consider the role of green hydrogen in their respective decarbonization strategies. SB 1075 affirms the intent of the Legislature to develop a leading green hydrogen industry in the state. SB 1075 supports the evaluation of other forms of hydrogen as possible decarbonization solutions.

Energy: Firm Zero-carbon Resources
SB 423 (Stern, 2022)

SB 423 requires the CEC to consider and incorporate firm zero-carbon resources into its integrated energy policy reports. By 2023, the CEC must submit to the Legislature an assessment of such resources that support a "clean, reliable, and resilient electrical grid in California" and achieve goals set by SB 100 (de León, 2018).

Read More

Seasonal Challenges for a California Renewable-Energy-Driven Grid. Abido, M.Y. et al. (2022). iScience, 25(1), 103577.

An assessment of the Diablo Canyon Nuclear Plant for zero-carbon electricity, desalination, and hydrogen production. Aborn, J. et al. (2021). Stanford Energy.

2025 Calif. Demand Response Potential Study — Charting California's Demand Response Future: Final Report on Phase 2 Results.
Alstone, P. et al. (2017). Lawrence Berkeley National Laboratory.

California's Electricity of the Future.
CARB, CEC, CAISO, CPUC, and Office of Planning and Research. (2021).

Modeling California Policy Impacts on Greenhouse Gas Emissions. Greenblat, J. B. (2015). Energy Policy, 78, 158-172.

California Needs Clean Firm Power, and so does the Rest of the World: Three Detailed Models of the Future of California's Power System all show that California Needs Carbon-Free Electricity Sources that don't Depend on the Weather.
Long, J.C.S. et al. (2021).

Clean Firm Power is the Key to California's Carbon-Free Energy Future. Long, J.C.S. et al. (2021). Issues In Sci. and Tech.

Low-Income Barriers Study, Part A: Overcoming Barriers to Energy Efficiency and Renewables for Low-Income Customers and Small Business Contracting Opportunities in Disadvantaged Communities. Scavo, J. et al. (2016). Calif. Energy Commission. Pub. Number: CEC-300-2016-009-CMF.

Decentralizing the Grid

Effectively integrating local energy generation and storage to improve energy resilience.

Overview

California's power grid—which is more than a century old in some places—is struggling to respond to the growth in energy demand, the addition of renewable resources, extreme heat, and increasingly common wildfires. Brown outs, black outs, and public safety power shutoffs will become more common if solutions for energy resilience are not realized.

California is embarking on plans to modernize the electric grid by further integrating and coordinating new types of energy generation and storage at the local level.[147]

These smaller scale energy resources are known as **distributed energy resources (DERs)*** and include things like solar panels, back-up generators, and batteries that are typically **behind-the-meter** (**demand response** and energy efficiency are also considered DERs, but this section focuses on DERs that provide local energy generation and storage, specifically).

If effectively leveraged, DERs can enhance energy resilience for consumers and the grid at large. However, transitioning from California's historically centralized grid—whereby power is generated by a small number of large power plants and then transmitted across long distances to consumers across the state—to a more decentralized grid that also draws power from innumerable DERs will take a fundamental shift in grid management and introduces numerous challenges.

147 California Public Utilities Commission. (2021). Order Institute Rulemaking to Modernize the Electric Grid for a High Distributed Energy Resources Future. Available at: https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M382/K451/382451995.PDF.

***** Find **bold** words in the Glossary (Appendix A).

Vulnerabilities of the centralized power grid

Centralized power is provided by utility-scale energy generation facilities. As the state transitions to 100% renewable and zero-carbon resources (as per SB 100, de León, 2018), the development of utility-scale wind and solar generation will be increasingly challenged by land use constraints (see **Section 2**).

Increasingly common wildfires, caused by more frequent periods of high heat and extreme drought, impact the stability of California's grid. This issue particularly concerns communities in rural regions and at the wildland-urban interface.

Power lines cause about 1% of fire ignitions in California but are responsible for half of the 20 most destructive fires ever recorded in the state.[148] To reduce this risk, California's **investor-owned utilities** initiate intentional and planned **public safety power shutoffs (PSPS)**—whereby power is cut to electrical lines that have a risk of failing—during periods of enhanced wildfire risk.

Between 2017 and 2020, these utility providers conducted 47 PSPS that lasted an average of 38 hours and impacted millions of customers.[149] PSPS disproportionately impact lower income and disadvantaged communities.[150] Utility providers are working to advance their risk forecasting and implement grid infrastructure upgrades so that they can better target and reduce the footprints of PSPS events.[151]

Studies have shown that PSPS and other outages have increased the use of back-up generators, 90% of which are powered by diesel fuel, leading to increased emissions and health-related impacts.[152]

During heat waves, demand for air conditioning persists longer into the evening and can create congestion on the transmission grid. Extreme heat can also reduce the output of some electric generation sources, including some natural gas plants, geothermal facilities, and thermal power plants.[153] These conditions create the potential for energy shortfalls, particularly during evening hours when solar generation drops while demand stays high as observed during the outages in August 2020.[154]

Distributed solar power and storage

California already has a significant DER capacity, primarily in the form of solar: 12 gigawatts (GW) of rooftop solar has been installed (as of July 2022).[155]

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148 Abatzoglou, J. T. et al. (2020). Population Exposure to Pre-emptive De-energization Aimed at Averting Wildfires in Northern California. *Environmental Research Letters*, 15(9), pp. 094046.

149 Murphy, P. (2021). Preventing Wildfires with Power Outages: The Growing Impacts of California's Public Safety Power Shutoffs. *PSE Healthy Energy*. Accessed on 11/03/2022 at: https://www.psehealthyenergy.org/news/blog/preventing-wildfires-with-power-outages-2/.

150 Abatzoglou, J. T. et al. (2020). Population Exposure to Pre-emptive De-energization Aimed at Averting Wildfires in Northern California. *Environmental Research Letters*, 15(9), pp. 094046.

151 Pacific Gas & Electric. (2022). Public Safety Power Shutoff (PSPS): California Public Utilities Commission Public Briefing. Available at: https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/safety-and-enforcement-division/meeting-documents/psps-briefings-august-2022/final_pge-cpuc-public-psps-briefing.pdf.

152 Cohn, L. (2022). California Bills Aim to Help Communities Create Resilience, Cut Emissions with Microgrids and DERs. *Microgrid Knowledge*. Available at: https://www.microgridknowledge.com/distributed-energy/article/11427504/california-bills-aim-to-help-communities-create-resilience-cut-emissions-with-microgrids-and-ders.

153 Allen-Dumas, M.R. et al. (2019). Extreme Weather and Climate Vulnerabilities of the Electric Grid: A Summary of Environmental Sensitivity Quantification Methods. *Oak Ridge National Laboratory*. Available at: https://www.energy.gov/sites/prod/files/2019/09/f67/Oak%20Ridge%20National%20Laboratory%20EIS%20Response.pdf.

154 California ISO, California Public Utilities Commission, and California Energy Commission. (2021). Root Cause Analysis: Mid-August 2020 Extreme Heat Wave. Available at: http://www.caiso.com/Documents/Final-Root-Cause-Analysis-Mid-August-2020-Extreme-Heat-Wave.pdf.

155 California Solar Initiative. (2023). California Distributed Generation Statistics. Accessed on 11/03/2022 at: https://www.

California has supported rooftop solar markets through the Net Energy Metering Program (NEM). Under the program, customers who produce excess energy can receive financial credit on their electric bills for the surplus energy fed back into the grid. NEM makes the installation of solar panels more economical, though the program is not without challenges. The California Public Utilities Commission (CPUC) recently approved changes to NEM, reducing the credits customers can receive (see more below).

When used in tandem, solar power and storage can enhance energy resilience for consumers. For example, during PSPS or other outages, these systems allow consumers continued access to solar-generated electricity.

Distributed energy storage—if effectively deployed—could ease some of the challenges associated with **intermittent** renewable resources and reduce the need for fossil fuel generation (see **Section 3**).

By absorbing excess renewable energy produced during periods of low demand and then delivering that energy back to the grid during peak **net demand**, storage could reduce stress on the grid, improve flexibility during peak net demand, and allow for greater penetration of intermittent renewable resources. This potential role for distributed storage has not yet been fully realized as current **price signals** are ineffective at encouraging this behavior.[156]

DERs—if effectively coordinated and leveraged—can improve the reliability of the grid. For example, by helping to meet local demand, DERs can alleviate transmission line congestion. All three of California's largest investor-owned utilities are piloting programs for coordinating DERs on local distribution networks.[157,158,159]

If successful, these programs could defer or substitute for further investment in generation, transmission, and distribution infrastructure,[160] alleviating some of the challenges discussed in Sections 1, 2, and 3.

Microgrids for resilience and safety

Microgrids are a group of one or more interconnected DERs that can supply energy to consumers independent from the main power grid. They typically include a local source of energy generation, a means of storing energy, electrical cables to connect end-users, and a control system to manage the distribution of energy. Microgrids can be powered by renewable resources or fossil fuel, and their scale can vary from a residence to an entire region. Modern microgrids are predominantly powered by renewable sources, especially solar power. Some microgrids are "off-the-grid" and will always operate independently, while others are "grid-connected" and can switch between operating as part of the grid and operating independently in "island mode" when the main grid is incapable of providing power.[161]

Locally managed microgrids may be able to improve energy and climate resilience within

californiadgstats.ca.gov/.

156 California Public Utilities Commission. (2022). Advanced Strategies for Demand Flexibility Management and Customer DER Compensation. Energy Division White Paper and Staff Proposal. Available at: https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/demand-response/demand-response-workshops/advanced-der---demand-flexibility-management/ed-white-paper---advanced-strategies-for-demand-flexibility-management.pdf.

157 Pacific Gas & Electric. (2022). Distributed Energy Resources Partnership Pilot. Accessed on 11/29/2022 at: https://www.pge.com/en_US/residential/save-energy-money/savings-programs/savings-programs-overview/partnership-pilot.page.

158 Southern California Edison. (2022). Integrated Distributed Energy Resources Partnership Pilot. Accessed on 11/29/2022 at: https://www.sce.com/business/savings-incentives/integrated-distributed-energy-resources-partnership-pilot.

159 San Diego Gas & Electric. (2022). Partnership Pilot. Accessed on 11/29/2022 at: https://www.sdge.com/partnership-pilot.

160 San Diego Gas & Electric. (2022). Partnership Pilot. Accessed on 11/29/2022 at: https://www.sdge.com/partnership-pilot.

161 California Council on Science and Technology. (2022). The Role of Microgrids in Providing Reliable and Equitable Access to Electricity. *California Council on Science and Technology*. Accessed on 11/29/2022 at: https://ccst.us/wp-content/uploads/2022_Microgrids_OnePager_CCST.pdf.

communities most vulnerable to power outages by ensuring access to energy during weather or heat emergencies. Microgrids can provide power to those most at risk, including elderly populations and the medically vulnerable. Additionally, a microgrid that relies on renewable energy resources can lessen the use of diesel-generated back-up energy systems, providing air quality and health benefits. For example, the microgrid at Blue Lake Rancheria in Humboldt County provides the Blue Lake Tribe with renewable energy and energy resilience during outages. The microgrid reduces greenhouse gas emissions and generates $200,000 in energy savings per year.[162]

Microgrids can improve grid reliability by supplementing grid power and supporting large end-user demands.

Relevant State Institutions

- California Energy Commission (CEC)
- California Independent System Operator (CAISO)
- California Public Utilities Commission (CPUC)
- Calif. Dept. of Forestry and Fire Protection (CalFire)
- The Governor's Office of Tribal Affairs
- Assembly Budget Subcommittee No. 3 Climate Crisis, Resources, Energy, and Transportation
- Assembly Natural Resources
- Assembly Utilities & Energy Committee
- Senate Budget Subcommittee No. 2 on Resources, Environmental Protection and Energy
- Senate Energy, Utilities and Communications Subcommittee on Clean Energy Future
- Senate Environmental Quality Committee
- Senate Natural Resources and Water Committee
- Joint Leg. Committee on Climate Change Policies
- Joint Leg. Committee on Emergency Management

Supporting distributed energy resources in California

The California Energy Commission's (CEC) Electric Program Investment Charge (EPIC) provides over $130 million in research funding annually to accelerate the transformation of the electricity sector. EPIC-funded research explores opportunities to expand renewable energy, increase affordability for and health of communities, and enable a more decentralized grid.

The Microgrid Incentive Program, authorized by the CPUC in early 2021 and launching in 2023, will fund clean energy microgrids to support the resilience of vulnerable communities, enhance the reliability of critical infrastructure, minimize the impacts of outages on low-income and medically vulnerable households, and reduce greenhouse gas emissions (by providing alternatives to back-up diesel generators).[163]

The CPUC's Self-Generation Incentive Program (SGIP) provides rebates to drive the adoption of qualifying behind-the-meter DERs that achieve reductions in greenhouse gas emissions (as per SB 700, Wiener, 2018).

The Solar on Multifamily Affordable Housing (SOMAH) Program, also administered by the CPUC, incentivizes solar panel installations for low-income tenants and property owners in disadvantaged communities.

The challenges of decentralizing

A highly decentralized grid characterized by multidirectional energy flows (with many customers both drawing energy from the grid and producing energy that feeds the grid) will require transforming transmission and distribution systems—reshaping traditional roles and responsibilities of utility providers and

162 Carter, D. et al. (2019). Demonstrating a Secure, Reliable, Low-Carbon Community Microgrid at the Blue Lake Rancheria. *California Energy Commission*. Available at: https://www.energy.ca.gov/sites/default/files/2021-05/CEC-500-2019-011.pdf.

163 California Public Utilities Commission. (2023). CPUC Charts Course for Microgrid Incentive Program to Increase Community Resilience. Available at: https://www.cpuc.ca.gov/news-and-updates/all-news/cpuc-charts-course-for-microgrid-incentive-program-to-increase-community-resilience-2023.

energy markets and requiring new engineering standards.[164,165] The CPUC is evaluating how best to address these challenges of a "high distributed energy resources future."[166]

Because they are usually behind-the-meter, DERs are often not "visible" to grid operators. This means that exported power from DERs complicates **load balancing**—the act of ensuring power supplied to the grid matches that required for energy use (or load), resulting in a consistent electric frequency of the grid.[167]

The interconnection of DERs and microgrids with the main power grid is confronted by significant challenges, including long timelines for interconnection, high costs for the grid upgrades necessary for supporting DERs, and outdated technical standards.[168] SB 1339 (Stern, 2018) requires large electrical corporations to facilitate the interconnection of microgrids with the main power grid with the hope of streamlining interconnection and reducing delays.

Net energy metering

The rates at which customers should be paid for the excess energy they feed into the grid is a contentious debate. For example, the former net energy metering rate structure in California (NEM 2.0) paid consumers **retail rates** for the excess energy they exported to the grid as opposed to paying for the value of the energy alone. Retail rates are what utilities charge consumers for every unit of power they use, and they reflect the bundled costs of energy generation, transmission, and distribution, as well as the costs of wildfire mitigation and investments in renewable energy. Retail rates are roughly two to three times greater than the value of the energy.[169]

This rate structure effectively subsidized power for consumers with rooftop solar and shifted the costs of infrastructure maintenance and other fixed costs (that are normally included in utility fees) to those without solar power.[170] This rate structure exacerbated inequalities given that low-income consumers face more barriers to installing rooftop solar.[171]

In response, the CPUC recently unanimously approved NEM 3.0 which reduces the rates paid for exported energy by about 75%; this new rate structure is applicable to any systems installed after the date NEM 3.0 took effect (April 15, 2023). These new rate structures are based on an "Avoided Cost Calculator" that estimates the relative value provided by DERs, which is dependent on time of day and stress on the grid (among other things).

Because exported energy will fetch a higher price in the evening than it would midday, NEM 3.0 is meant to help incentivize homeowners to install energy storage systems. However, the reduced rates decrease the economic incentive to install rooftop solar—something that has been criticized

164 Gridworks. (2022). Evaluating Alternative Distribution System Operator Models for California. Available at: https://gridworks.org/wp-content/uploads/2022/03/Evaluating-Alternative-DSO-Models-for-California.docx.pdf.

165 De Martini, P., Kristov, L., and Schwartz, L. (2015). Distribution Systems in a High Distributed Energy Resources Future. *Lawrence Berkeley National Lab*, No. LBNL-1003797.

166 California Public Utilities Commission. (2021). Order Institute Rulemaking to Modernize the Electric Grid for a High Distributed Energy Resources Future. Available at: https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M382/K451/382451995.PDF.

167 California ISO. (ND). The ISO Grid. Available at: http://www.caiso.com/about/Pages/OurBusiness/The-ISO-grid.aspx.

168 Valova, R., and Brown, G. (2022). Distributed Energy Resource Interconnection: An Overview of Challenges and Opportunities in the United States. *Solar Compass*, 10002.

169 Borenstein, S., Fowlie, M., and Sallee, J. (2021). Designing Electricity Rates for an Equitable Energy Transition. *Energy Institute at Haas*, 314.

170 California Public Utilities Commission. (2021). Decision Revising Net Energy Metering Tariff and Subtariffs. Available at: https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M430/K903/430903088.PDF.

171 Barbose, G. et al. (2022). Residential Solar-Adopter Income and Demographic Trends: 2022 Update. *Lawrence Berkeley National Laboratory.* Available at: https://eta-publications.lbl.gov/sites/default/files/solar-adopter_income_trends_final_0.pdf.

by solar advocates and some environmental nonprofits.[172,173]

Environmental Justice and Equity Considerations

Vulnerable populations and communities—including aging populations, children, pregnant people, those with chronic health conditions, those experiencing poverty or housing insecurity, and others—will experience more severe impacts of climate change and are more prone to heat-related illness and death.[174] Californians of color are still disproportionately exposed to environmental harm, including greater likelihood of heat islands, air pollution, exposure to contaminants, and more, due to the historical policy of redlining.[175]

These populations would benefit most from DERs, yet they often face the most challenges to accessing them.[176] As per SB 350 (de León, 2015), the CEC examined barriers to the adoption of rooftop solar. Barriers identified included a lack of capital and credit, low home-ownership rates, complexities of multifamily housing, and building age and condition.[177] The CEC's recommendations included coordinating programs for low-income customers, supporting the deployment of community solar, and innovative financing programs. Programs like the SGIP, SOMAH, and EPIC earmark some funding (or all, as with SOMAH) for low-income or disadvantaged communities to help address these barriers.

Energy storage systems and demand response technologies can alleviate the **energy burden** borne by low-income households (i.e., the proportion of household income spent on energy costs). The Self-Generation Incentive Program (SGIP) earmarks $100 million for low-income communities, stating that rebates will "lower the cost of energy storage technology to almost, if not completely, free of cost" for qualifying customers.[178]

Marginalized and lower-income households disproportionately experience energy insecurity and have fewer resources to permanently or temporarily relocate during heat emergencies. Studies show that Californian regions with a greater fire threat have lower household incomes and home values and a higher percentage of older residents and Native American populations.[179]

Solutions include community resilience centers that can provide year-round programming, as

172 California 1st District Court of Appeal. (2023). Center for Biological Diversity, Environmental Working Group, and the Protect our Communities Foundation v. Public Utilities Commission of the State of California. Available at: https://www.biologicaldiversity.org/programs/energy-justice/pdfs/CA-Public-Utilities-Commission-Petition-Rooftop-Solar-05-03-2023.pdf.

173 Lin, R. et al. (2022). Letter from 125+ Organizations Urging California's Governor to Stand up for Rooftop Solar and Equity in NEM Proceeding. *Center for Biological Diversity*. Available at: https://www.biologicaldiversity.org/programs/energy-justice/pdfs/9-14-22_Letter-from-more-than-125-organizations-to-Gov-Newsom-re-NEM-proceeding.pdf.

174 Governor's Office of Planning and Research. (2018). Defining Vulnerable Communities in the Context of Climate Adaptation. Available at: https://opr.ca.gov/docs/20180723-Vulnerable_Communities.pdf.

175 California Environmental Protection Agency. (2021). Pollution and Prejudice Redlining and Environmental Injustice in California. Available at: https://storymaps.arcgis.com/stories/f167b251809c43778a2f9f040f43d2f5.

176 Light, T. et al. (2022). Advancing Equity in Access to Distributed Energy Resources in California. *Journal of Science Policy & Governance*, 20(1). https://doi.org/10.38126/JSPG200106.

177 Scavo, J. et al. (2016). Low-Income Barriers Study, Part A: Overcoming Barriers to Energy Efficiency and Renewables for Low-Income Customers and Small Business Contracting Opportunities in Disadvantaged Communities. California Energy Commission. Accessed on 11/29/2022 at: https://assets.ctfassets.net/ntcn17ss1ow9/3SqKkJoNIvts2nYVPAOmGH/fe590149c3e39e51593231dc60eeeeff/TN214830_20161215T184655_SB_350_LowIncome_Barriers_Study_Part_A__Commission_Final_Report.pdf.

178 California Public Utilities Commission. (ND) Participating in Self-Generation Incentive Program (SGIP). Available at: https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/demand-side-management/self-generation-incentive-program/participating-in-self-generation-incentive-program-sgip.

179 Masri, S. et al. (2021). Disproportionate Impacts of Wildfires Among Elderly and Low-Income Communities in California from 2000–2020. *International Journal of Environmental Research and Public Health*. 18(8), pp. 3921.

well as services and shelter during emergencies and power outages. AB 211 (Committee on Budget, 2022) established the Community Resilience Center Program, to be administered by the Strategic Growth Council, which will award grants for the construction or retrofitting of facilities that can serve as community resilience centers.

Only so many DERs can be supported on a distribution network before upgrades to the circuit are required—this is known as the **hosting capacity**. Research shows that patterns of hosting capacity in California result in inequitable access to DERs for disadvantaged communities and Black-identifying households.[180] Centering equity as one objective in prioritizing grid upgrades could help address these inequities.

Relevant Policies

(Laws/Regulations)

Public Utilities: Energy Metering

SB 656 (Alquist, 1995)

SB 656 required electric utilities to establish compensation schemes for customers who generate electricity in excess of their own needs and export said energy to the grid. This scheme requires measuring the difference between the electricity supplied by a utility to the customer and the electricity exported by the customer to the grid—known as net energy metering. AB 327 (Perea, 2013) required large investor-owned utilities to switch over to the current standard tariff structure known as NEM 2.0. In November 2022, the CPUC issued a proposal for NEM 3.0.[181]

Budget Act of 2013: Public Resources

SB 96 (Cmte. on Budget and Fiscal Review, 2013)

SB 96 created the Electric Program Investment Charge (EPIC) Program. Overseen by the CEC, EPIC invests more than $130 million annually in research on expanding renewable energy, building safe/resilient electricity systems; advancing electric technologies; enabling a more decentralized electric grid; improving affordability, health, and comfort in communities; and supporting local economies.

Clean Energy and Pollution Reduction Act of 2015

SB 350 (de León, 2015)

SB 350 mandated that the CEC study barriers to solar energy generation and other renewable energy technologies confronted by low-income and disadvantaged communities.

Electricity: Microgrids: Tariffs

SB 1339 (Stern, 2018)

SB 1339 directs CPUC, under consultation with CEC and CAISO, to develop "standards, protocols, methods, rates, and tariffs that serve and reduce barriers to microgrid deployment statewide, while prioritizing system, public, and worker safety, and avoiding cost shifts between ratepayers."[182] The CPUC has initiated a new rulemaking to consider how best to implement SB 1339.[183]

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180 Brockway, A.M., Conde, J., and Callaway, D. (2021). Inequitable Access to Distributed Energy Resources due to Grid Infrastructure Limits in California. *Nature Energy*, 6(9), pp. 892-903.

181 California Public Utilities Commission. (2022). CPUC Issues Solar Tariff Modernization Proposal to Support Reliability and Decarbonization. Accessed 11/29/2022 at: https://www.cpuc.ca.gov/news-and-updates/all-news/cpuc-issues-solar-tariff-modernization-proposal-to-support-reliability-and-decarbonization.

182 California Public Utilities Commission (2020). Order Instituting Rulemaking Regarding Microgrids Pursuant to Senate Bill 1339 and Resiliency Strategies. Available at: https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M342/K195/342195599.PDF.

183 Ortego, J. (ND). Resiliency and Microgrids. *California Public Utilities Commission*. Accessed 11/29/2022 at: https://www.cpuc.ca.gov/resiliencyandmicrogrids.

Self-Generation Incentive Program
SB 700 (Wiener, 2018)

SB 700 extended the administration of the Self-Generation Incentive Program through 2025 and established the requirement that qualifying DERs must contribute to a reduction in greenhouse gas emissions.

The 100 Percent Clean Energy Act of 2018
SB 100 (de León, 2018)

Establishes goal that by 2045 all retail electricity sold in California and state agency electricity needs will be powered by renewable and zero-carbon resources.

Updates Renewables Portfolio Standard to ensure that by 2030 at least 60% of state's electricity is renewable.

Requires CEC, CPUC and CARB to use existing laws to achieve 100% clean electricity and issue joint policy on SB 100 by 2021 and every four years after that.

Read More

Inequitable Access to Distributed Energy Resources Due to Grid Infrastructure Limits in California.
Brockway, A.M. et al. (2021). Nature Energy, 6(9), pp. 892-903.

Assessing the impact of wildfires on the California electricity grid. California's Fourth Climate Change Assessment.
Dale, L. et al. (2018). CEC cA4-CEC-2018-002.

Disproportionate Impacts of Wildfires Among Elderly and Low-Income Communities in California from 2000–2020.
Masri, S. et al. (2021). International Journal of Environmental Research and Public Health, 18(8).

Microgrid Communities: Disclosing the Path to Future System-Active Communities.
Warneryd, M., and Karltorp, K. (2022). Sustainable Futures, 4, pp. 100079.

The Role of Net Metering in the Evolving Electricity System.
Besser, J.B. et al. (2023). National Academy of Sciences.

5

Carbon Capture & Storage

Capturing difficult-to-mitigate emissions.

Overview

Carbon capture and storage* (CCS) is the process of capturing, compressing, transporting, and sequestering carbon dioxide (CO_2). Most proposed applications for CCS involve capturing CO_2 that would have otherwise been released into the atmosphere during industrial processes, particularly fuel combustion. However, new applications are emerging that remove CO_2 from ambient air (known as "**direct air capture**" or DAC). The captured carbon can then be sequestered in geologic formations (see **Figure 5.1**). A small fraction could also be used for other industrial applications (like cement, fuels, or plastic). Much of the cost and complexity of CCS relates to separating CO_2 from other gases, especially oxygen and nitrogen. [184] Where CO_2 is present in higher concentrations, this separation is typically easier and less expensive.

In its proposed scenario for reaching a **net-zero** economy by 2045 (as per AB 1279, Muratsuchi, 2022, 2022), the California Air Resources Board (CARB) includes CCS—and DAC—to limit emissions and minimize leakage from hard-to-decarbonize sectors.[185] This aligns with the findings of multiple studies on climate change that have found few, if any, feasible trajectories to climate stabilization without significant amounts of CCS.[186] However, CCS deployment has been slow. Globally, only 32 commercial CCS facilities are operational; none are in California.[187]

The extent to which California should rely on CCS to achieve its emissions reduction goals has generated much debate. Opponents argue that CCS does not achieve the emissions reductions promised, prolongs the life of polluting industries that are often located in disadvantaged communities, and distracts from opportunities for direct emissions reductions.

184 Congressional Research Service. (2022). Carbon Capture and Sequestration in the United States. Available at: https://sgp.fas.org/crs/misc/R44902.pdf.

185 California Air Resources Board. (2022). 2022 Scoping Plan for Achieving Carbon Neutrality. Available at: https://ww2.arb.ca.gov/sites/default/files/2022-11/2022-sp.pdf.

186 Intergovernmental Panel on Climate Change. (2022). Summary of the 56th Session of the Intergovernmental Panel on Climate Change and the 14th Session of Working Group III: 21 March - 4 April 2022. *Earth Negotiations Bulletin*, 12(795), pp. 1-32.

187 Global CCS Institute. (2018). Facilities Database. Accessed on 11/30/2022 at: https://co2re.co/FacilityData.

* Find **bold** words in the Glossary (Appendix A).

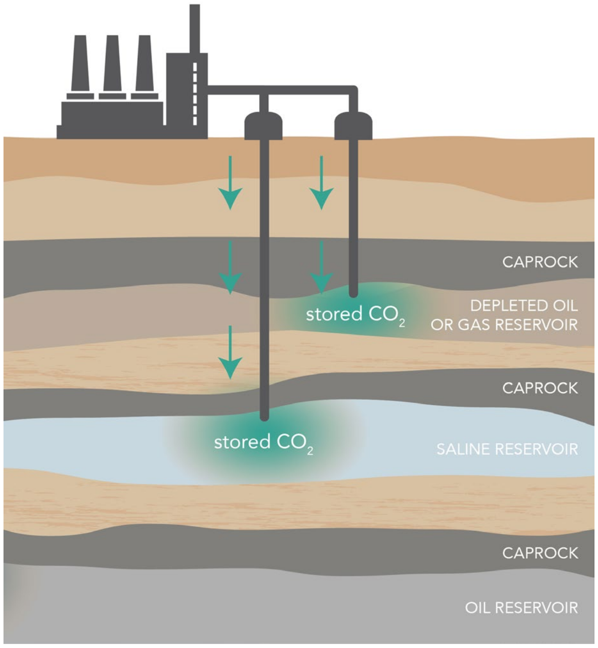

Figure 5.1. Captured CO_2 may be injected into depleted oil and gas reservoirs or saline reservoirs. Adapted from California Air Resources Board. (2022). Carbon Capture and Sequestration.

Available at: https://ww2.arb.ca.gov/our-work/programs/carbon-capture-sequestration/about.

CCS in California

CCS has the potential to reduce carbon emissions by millions of metric tons and may be key to meeting California's climate targets.[188,189,190] In CARB's 2022 Scoping Plan, modeling assumes CCS will capture 25 million metric tons of CO_2 in 2045 from petroleum refineries, cement factories, and the electricity sector. This will require considerable capital investment for the construction and implementation of CCS facilities.[191]

Broad deployment of CCS could reduce emissions associated with hard-to-decarbonize sectors, including the production of ethanol, stone, clay, glass, and cement, and petroleum refining. Without access to CCS, these industries may close or, if demand persists, relocate to other states where they can continue to emit GHGs (known as **leakage**).[192]

More dilute CO_2 streams—like from cement factories and oil refineries—are more expensive to capture,[193] hence the slow deployment of CCS in

188 California Air Resources Board. (2022). 2022 Scoping Plan for Achieving Carbon Neutrality. Available at: https://ww2.arb.ca.gov/sites/default/files/2022-11/2022-sp.pdf.

189 California Council on Science and Technology (CCST). (2015). California's Energy Future: The View to 2050 Summary Report. Available at: https://www.ccst.us/wp-content/uploads/2011energy.pdf. ISBN-13: 978-1-930117-44-0.

190 Baker, S.E. et al. (2020). Getting to Neutral: Options for Negative Carbon Emissions in California. *Lawrence Livermore National Laboratory*, LLNL-TR-796100.

191 National Energy Technology Laboratory. (2019). Cost and Performance Baseline for Fossil Energy Plants Volume 1: Bituminous Coal and Natural Gas to Electricity. Available at: https://netl.doe.gov/projects/files/CostAndPerformanceBaselineForFossilEnergyPlantsVol1BitumCoalAndNGtoElectBBRRev4-1_092419.pdf.

192 California Air Resources Board. (2022). 2022 Scoping Plan for Achieving Carbon Neutrality. Available at: https://ww2.arb.ca.gov/sites/default/files/2022-11/2022-sp.pdf.

193 International Energy Agency. (2022). Levelised Cost of CO2 Capture by Sector and Initial CO2 Concentration. Accessed on 11/29/2022 at: https://www.iea.org/data-and-statistics/charts/levelised-cost-of-co2-capture-by-sector-and-initial-co2-

these industries. Of the 32 commercial CCS facilities worldwide, only 1 is at a petroleum refinery. There are no cement factories with CCS. Conversely, some processes—like ethanol production or hydrogen production via steam methane reformation—generate relatively pure streams of CO_2 and represent opportunities for relatively cost-effective CCS deployment.

In most cases, CCS generates no economic value unless one is created through policy. The lack of sufficient financial incentives has long been viewed as a barrier to large-scale deployment of CCS.[194] The Infrastructure Investment and Jobs Act allocated $3.5 billion for carbon capture demonstrations and large pilots, while the Inflation Reduction Act significantly expanded tax credits for carbon sequestration. The expanded tax credits are believed to make CCS more economically viable for electricity generation and a greater number of industrial applications.[195]

California's Low Carbon Fuel Standard—designed to reduce the **carbon intensity** of transportation fuels in the state—created a pathway for relevant CCS and DAC projects to receive credits starting in 2019.[196] To date, no projects have been approved—or even advanced to public review—under this program.

CCS—either used with hydrogen production (commonly called "**blue hydrogen**") or natural gas plants—could facilitate the production of the clean, **firm power** necessary to manage the intermittency of renewable resources (see **Section 3**), so long as sufficient capture rates can be achieved.

CCS technologies can leverage the existing workforce in refinery operations and oil and gas production. CCS may also support the economic development of other emerging industries like DAC.[197]

California has a geology well-suited to permanently storing large amounts of carbon given the presence of large saline reservoirs and depleted oil and gas reservoirs, which are considered among the best storage sites for carbon (see **Figure 5.2**).[198] The sedimentary rock formations in the Central Valley alone have an estimated storage capacity of at least 17 billion tons of CO_2.[199] Estimates for California's total CO_2 storage capacity exceed that necessary to store 1,000 times the CO_2 emitted from California's electricity sector in 2020.[200] Close proximity to storage sites greatly reduces the need for costly pipeline infrastructure.

The extent to which California should rely on CCS to achieve its emissions reduction goals has generated much debate. Opponents argue that CCS does not achieve the emissions reductions promised, prolongs the life of polluting industries that are often located in disadvantaged communities, and distracts from opportunities for direct emissions reductions. Proponents argue that CCS can be an effective tool for eliminating emissions, that the enormity of the task at hand will require every tool available, and that the slow deployment to date has been due to overly complicated regulations and insufficient and uncertain incentives for CCS. They also argue that there are some applications—such as production of

concentration-2019.

194 U.S. Department of Energy. (2010). Report of the Interagency Task Force on Carbon Capture and Storage. *Office of Fossil Energy and Carbon Management*. Available at: https://www.energy.gov/sites/prod/files/2013/04/f0/CCSTaskForceReport2010_0.pdf.

195 Bright, M. (2022). The Inflation Reduction Act Creates a Whole New Market for Carbon Capture. *Clean Air Task Force*. Accessed on 11/28/2022 at: https://www.catf.us/2022/08/the-inflation-reduction-act-creates-a-whole-new-market-for-carbon-capture/.

196 California Air Resources Board. (2023). Carbon Capture and Sequestration Protocol Under the Low Carbon Fuel Standard. Accessed on 5/24/2023 at: https://ww2.arb.ca.gov/resources/documents/carbon-capture-and-sequestration-protocol-under-low-carbon-fuel-standard.

197 Glenwright, K. (2020). Roadmap for Carbon Capture and Storage in California. *Stanford Earth Matters Magazine*. Accessed on 11/03/2022 at: https://earth.stanford.edu/news/roadmap-carbon-capture-and-storage-california#gs.8754ku.

198 Raza, A. et al. (2019). Significant Aspects of Carbon Capture and Storage–A Review. *Petroleum*, 5(4), pp. 335-340.

199 Baker, S.E. et al. (2020). Getting to Neutral: Options for Negative Carbon Emissions in California. *Lawrence Livermore National Laboratory*, LLNL-TR-796100.

200 California Air Resources Board. (2020). 2020 GHG Emissions by Main Economic Sector. *GHG Emission Inventory Graphs*. Accessed 11/28/2022 at: https://ww2.arb.ca.gov/ghg-inventory-graphs.

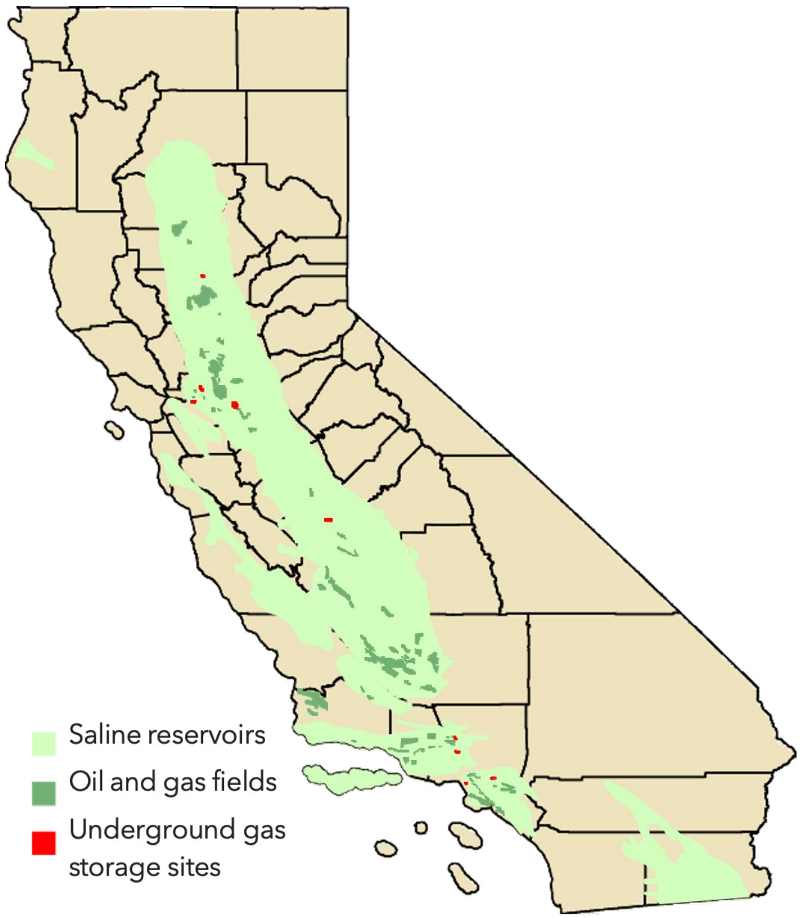

Figure 5.2. Potential storage sites for CO_2 in California include saline reservoirs, oil and gas fields, and underground gas storage sites. Adapted from Energy Futures Initiative and Stanford University. (2020). An Action Plan for Carbon Capture and Storage in California: Opportunities, Challenges, and Solutions.

Available at: https://sccs.stanford.edu/sites/g/files/sbiybj17761/files/media/file/EFI-Stanford-CA-CCS-FULL-rev2-12.11.20_0.pdf.

cement, polymers, liquid fuels, and perhaps clean firm power—that have no cost-effective, scalable alternatives.

Public opposition to CCS presents a significant challenge to its deployment. For example, proposed carbon pipelines in the U.S. Midwest have been met with fierce opposition.[201] The inclusion of CCS in CARB's 2022 Scoping Plan was vehemently opposed by more than 150 environmental justice, climate equity, faith-based, and environmental groups that called CCS an "industry scam" and "a cynical attempt at greenwashing."[202,203]

Carbon capture rates

Current CCS technologies are typically designed to capture an estimated 90% of the carbon produced in targeted emission streams when operating at full capacity (the other 10% is released into the atmosphere).[204] Capture rates are not meant to indicate that a facility's total onsite emissions will be reduced by 90%, rather that up to 90% of the CO_2 from a given emission stream can be captured and removed. Capture rates do not account for total lifecycle emissions, which vary across industrial applications. For example, capture rates do not account for **upstream emissions** associated with the production and distribution of the fossil fuels, which can be substantial. Some facilities have many emission sources. This makes it difficult, if not impossible, to capture all associated emissions, especially when considering retrofits to existing infrastructure.

Relevant State Institutions

- California Air Resources Board (CARB)
- California Energy Commission (CEC)
- California Environmental Protection Agency (CalEPA)
- California Natural Resources Agency (CNRA)
- California Geological Survey
- California Geologic Energy Mgmt. Division (CalGEM)
- California Public Utilities Commission (CPUC)
- California State Lands Commission
- California State Water Resources Board
- The Governor's Office of Tribal Affairs
- Assembly Budget Subcommittee No. 3 Climate Crisis, Resources, Energy, and Transportation
- Assembly Natural Resources Committee
- Assembly Utilities & Energy Committee
- Assembly Committee on Water, Parks, and Wildlife
- Senate Budget Subcommittee No. 2 on Resources, Environmental Protection and Energy
- Senate Energy, Utilities and Communications Subcommittee on Clean Energy Future
- Senate Environmental Quality Committee
- Senate Natural Resources and Water Committee
- Joint Legislative Committee on Climate Change Policies

Permitting at the state level requires approvals from:

- California State Water Resources Board
- California Department of Fish and Game
- California Department of Transportation
- California Public Utilities Commission
- California Energy Commission
- California Geologic Energy Management Division

201 Douglas, L. (2022). U.S. Carbon Pipeline Proposals Trigger Backlash over Potential Land Seizures. *Reuters*. Accessed on 11/28/2022 at: https://www.reuters.com/business/environment/us-carbon-pipeline-proposals-trigger-backlash-over-potential-land-seizures-2022-02-07/.

202 California-Based Groups and National Organizations with Members in California. (2022). A Call for a Climate Change Scoping Plan that Addresses the Needs of the Climate, the People and the Environment. Available at: https://www.foodandwaterwatch.org/wp-content/uploads/2022/06/Group-Letter-Fix-CAs-Climate-Plan-6.21.2292.pdf.

203 Physicians for Social Responsibility Los Angeles and Allies. (2021). Oppose AB 1395–California Climate Crisis Act Opposition Letter. Available at: https://www.deltacouncil.ca.gov/pdf/council-meeting/meeting-materials/2021-11-18-item-9-attachment-1-ab-1395-opposition-letter.pdf.

204 International Energy Agency. (2021). Zero-emission Carbon Capture and Storage In Power Plants Using Higher Capture Rates. Available at: https://www.iea.org/articles/zero-emission-carbon-capture-and-storage-in-power-plants-using-higher-capture-rates.

Additional energy (10–29% more than standard operation requirements[205,206]) is required to power the CCS equipment. As with electrification efforts, the source of the energy matters and will influence net emission reductions achieved. At power plants, this energy demand may be satisfied by the output of the plant on which it's installed, but this reduces the amount of power delivered to the grid. As for any mitigation technology, the life-cycle emissions and environmental impacts must be considered in comparing options.

When the captured carbon is used for **enhanced oil recovery** (i.e., injected into oil reserves to improve extraction of residual oil), the GHG benefits of CCS are likely to be reduced in comparison to CCS projects without enhanced oil recovery.[207] Most older petroleum wells in California currently use steam injection to extend production. Enhanced oil recovery with CO_2 may use comparatively less natural gas while providing the added benefit of carbon sequestration. Recent legislation (SB 905, Caballero, 2022 and SB 1314, Limón, 2022) prohibits the injection of captured carbon for enhanced oil recovery in California.

Accurate carbon accounting is critical for all CCS projects. For example, carbon captured from power plant exhaust could be used in cement manufacturing. Both the power plant and cement facility could theoretically claim GHG reductions, but these benefits should not be double counted. Policymakers may need to critically examine claims of additionality to ensure efficient use of policy incentives. Most incentives implicitly assume that emission reductions would not have occurred if the incentive were not present (i.e., that any GHG reductions generated are additional to a hypothetical business-as-usual scenario). If a CCS project receives funding to support some or all of its construction costs, further policy incentives may not actually provide any additional GHG reductions. That is not to say that a single project cannot or should not receive support from multiple programs, but rather that the GHG benefits should not be counted in full under each program.

Potential risks

Permanent geologic carbon storage may cause induced seismicity—minor earthquakes due to pressure changes that cause repositioning or cracking of stressed rocks.[208] "Microseismicity" (small earthquakes not felt at the surface) are common for geologic carbon storage sites.[209] Whether carbon storage could induce larger earthquakes is debated.[210] Even small seismic events negatively impact public perception and could damage nearby infrastructure.[211] Research suggests that prior oil and gas production at carbon injection sites reduces the risk of induced seismicity.[212]

Though long-term carbon retention rates are expected to be quite high in well-regulated environments (98% over 10,000 years),[213] there is still a risk that geological storage sites may gradually leak CO_2, with ramifications for overall efficacy as a mitigation technique, as well as human health

205 Vasudevan, S. et al. (2016). Energy Penalty Estimates for CO2 Capture: Comparison Between Fuel Types and Capture-Combustion Modes. *Energy*, 103, pp. 709-714.

206 Sgouridis, S. et al. (2019). Comparative Net Energy Analysis of Renewable Electricity and Carbon Capture and Storage. *Nature Energy*, 4(6), pp. 456-465.

207 Farajzadeh, R. et al. (2020). On the Sustainability of CO_2 through CO_2 – Enhanced Oil Recovery. *Applied Energy,* 261, pp. 114467.

208 Cesca, S. et al. (2014). The 2013 September–October Seismic Sequence Offshore Spain: A Case of Seismicity Triggered by Gas Injection? *Geophysical Journal International*, 198(2), pp. 941-953.

209 Vilarrasa, V. et al. (2019). Induced Seismicity in Geologic Carbon Storage. *Solid Earth*, 10(3), pp. 871-892.

210 Vilarrasa, V., and Carrera, J. (2015). Geologic Carbon Storage is Unlikely to Trigger Large Earthquakes and Reactivate Faults Through Which CO2 Could Leak. *Proceedings of the National Academy of Sciences*, 112(19), pp. 5938-5943.

211 Vilarrasa, V. et al. (2019). Induced Seismicity in Geologic Carbon Storage. *Solid Earth*, 10(3), pp. 871-892.

212 Dvory, N. Z., and Zoback, M. D. (2021). Prior Oil and Gas Production can Limit the Occurrence of Injection-Induced Seismicity: A Case Study in the Delaware Basin of Western Texas and Southeastern New Mexico, USA. Geology, 49(10), pp. 1198-1203.

213 Alcalde, J. et al. (2018). Estimating Geological CO2 Storage Security to Deliver on Climate Mitigation. *Nature Communications*, 9(1), pp. 1-13.

and safety.[214,215] Concentrated CO_2 can cause asphyxiation. Leaked CO_2 can also contaminate groundwater because CO_2 causes water to be more acidic and leads to the release of harmful metals.[216] However, most potential CCS reservoirs are in non-potable saline aquifers that are far deeper and geologically isolated from drinkable aquifers. Appropriate site selection, rigorous monitoring, and regulatory oversight will be critical to mitigating these risks.[217]

Pipeline failures also pose safety risks. For example, in 2020, a CO_2 pipeline ruptured outside of Satartia, Mississippi, requiring the evacuation of close to 200 people and causing 45 people to seek medical attention. In response, in May 2022 the U.S. Department of Transportation's Pipeline and Hazardous Materials Safety Administration announced it will be updating safety requirements for CO_2 pipelines.[218] SB 905 (Caballero, 2022) prohibits the transport of CO_2 via pipeline until these new measures take effect.

Environmental Justice and Equity Considerations

The implementation of CCS alone does not necessarily address other harmful pollutants emitted by facilities—including some that are known or suspected to cause cancer and birth defects. Some CCS technologies operate more efficiently if these pollutants are removed beforehand. Because Section 45Q of the U.S. Tax Code—which provides a tax credit for carbon sequestration—is proportional to the amount of CO_2 captured and stored, this provides an incentive for facilities to address these co-pollutants.

Further, the U.S. Environmental Protection Agency has proposed new standards for fossil-fuel power plants which would require substantial reductions in these co-pollutants from such power plants.[219] However, some facilities have multiple emission streams, not all of which are amenable to CCS. Completely eliminating harmful co-pollutants from these facilities would be challenging and would require other technologies including electrification and advanced control technologies.

More than 80 environmental justice and conservation nonprofits urged the U.S. Environmental Protection Agency to deny applications for CCS facilities in California's Central Valley, contending that proposed projects would "resurrect or prolong the life of polluting industrial facilities in predominantly low-income neighborhoods of color that already experience some of the worst air quality in the country."[220]

CARB's Environmental Justice Advisory Committee (EJAC) has raised concerns about CCS, including potential impacts to human health and safety presented by leaks and due to increased industrial activity at carbon capture sites. Instead, EJAC recommends that CARB prioritize direct

214 Bielicki, J.M., Peters, C.A., Fitts, J.P., and Wilson, E.J. (2015). An Examination of Geologic Carbon Sequestration Policies in the Context of Leakage Potential. *International Journal of Greenhouse Gas Control*, 37, pp. 61-75.

215 Vinca, A., Emmerling, J., and Tavoni, M. (2018). Bearing the Cost of Stored Carbon Leakage. *Frontiers in Energy Research*, 6, pp. 40.

216 Little, M.G., and Jackson, R.B. (2010). Potential Impacts of Leakage from Deep CO2 Geosequestration on Overlying Freshwater Aquifers. *Environmental Science & Technology*, 44(23), pp. 9225-9232.

217 Anderson, J. et al. (2005). Underground Geological Storage. *Cambridge University Press*, pp. 195-275.

218 U.S. Department of Transportation. (2022). PHMSA Announces New Safety Measures to Protect Americans from Carbon Dioxide Pipeline Failures After Satartia, MS Leak. Pipeline and Hazardous Materials Safety Administration. Accessed on 11/28/2022 at: https://www.phmsa.dot.gov/news/phmsa-announces-new-safety-measures-protect-americans-carbon-dioxide-pipeline-failures.

219 U.S. Environmental Protection Agency. (2023). Proposed Rule: New Source Performance Standards for Greenhouse Gas Emissions from New, Modified, and Reconstructed Fossil Fuel-Fired Electric Generating Units; Emission Guidelines for Greenhouse Gas Emissions from Existing Fossil Fuel-Fired Electric Generating Units; and Repeal of the Affordable Clean Energy Rule. *National Archives*. Available at: https://www.federalregister.gov/documents/2023/05/23/2023-10141/new-source-performance-standards-for-greenhouse-gas-emissions-from-new-modified-and-reconstructed#citation-366-p33302

220 Center for Biological Diversity. (2022). EPA Urged to Reject Carbon Capture Projects in Central California. Accessed 11/02/2022 at: https://biologicaldiversity.org/w/news/press-releases/epa-urged-to-reject-carbon-capture-projects-in-central-california-2022-06-29/.

emission reductions and natural approaches to carbon sequestration.[221]

In a study of sites identified as potential pilots for carbon sequestration, researchers found that communities expressed the desire to understand the range of technological options and potential risks to be mitigated and to be empowered in the decision-making process to ensure justice or fairness in decisions.[222] Empowerment in the decision-making process is critical as disadvantaged communities may be neglected by local leadership.[223]

Relevant Policies

(Laws/Regulations)

Low Carbon Fuel Standard

Executive Order S-01-07, 2007

The Low Carbon Fuel Standard (LCFS) is administered by CARB. LCFS was launched in 2011 after being formally established by Executive Order S-01-07 and identified by CARB's 2008 Scoping Plan as an early action to reduce greenhouse gas emissions.

LCFS assesses a carbon-intensity (CI) value for transportation fuels based on lifetime GHG emissions associated with the production, transportation, and use of those fuels. All fuels are compared to a declining CI target. Fuels with increasingly lower CIs than the target generate more credits, while fuels with CIs that exceed the target generate deficits.

In 2019, CARB created a pathway for projects that implement CCS or DAC to reduce the CI of transportation fuels to receive credits.

Carbon Sequestration

SB 27 (Skinner, 2021)

SB 27 accelerates removal of atmospheric carbon (carbon sequestration) and strengthens the carbon retention of California's natural working lands. The law also directs CARB to include carbon sequestration targets in the next AB 32 scoping plan.

Carbon Sequestration: Carbon Capture, Removal, Utilization, and Storage Program

SB 905 (Caballero, 2022)

SB 905 established a program to evaluate the efficacy, safety, and viability of carbon capture, utilization, or storage technologies and carbon dioxide removal technologies, and to facilitate the capture and sequestration of carbon dioxide from those technologies. The law also requires certain monitoring and reporting activities to ensure public environmental health and safety.

SB 905 prohibits injection of concentrated carbon dioxide fluid produced through capture, removal, or sequestration into Class II injection wells to enhance recovery of oil resources. SB 905 prohibits the transfer of CO_2 pipelines until the Federal Pipeline and Hazardous Materials Safety Administration has updated the minimum federal safety standards for carbon dioxide pipelines.

Oil and Gas: Class II Injection Wells: Enhanced Oil Recovery

SB 1314 (Limón, 2022)

SB 1314 prohibits the injection of concentrated carbon dioxide fluid produced by a carbon dioxide capture and/or sequestration project into Class II injection wells with the intent of increasing recovery of oil resources, including the enabling of enhanced oil recovery from another well.

221 California Air Resources Board. (2022). Preliminary Draft of EJAC Scoping Plan Recommendations. Available at: https://ww2.arb.ca.gov/sites/default/files/barcu/board/books/2022/031022/ejacrecs.pdf.

222 Wong-Parodi, G., and Ray, I. (2009). Community Perceptions of Carbon Sequestration: Insights from California. *Environmental Research Letters*, 4(3), pp. 034002.

223 Flores-Landeros, H. et al. (2021). Community Perspectives and Environmental Justice in California's San Joaquin Valley. *Environmental Justice* 15(6), pp. 337-345.

California Climate Crisis Act
AB 1279 (Muratsuchi, 2022)

AB 1279 declares the policy of the state to achieve net zero greenhouse gas emissions as soon as possible—but no later than 2045—and to achieve and maintain net negative emissions thereafter.

Further, this law mandates that emissions by 2045 are reduced by 85% below 1990 levels (this is to ensure that direct emission reductions are favored over the broad deployment of carbon removal technologies).

This law requires CARB to work with relevant agencies to 1) ensure scoping plan updates include measures to achieve these policy goals; and 2) identify and implement strategies to enable carbon dioxide removal solutions and carbon capture, utilization, and storage technologies.

Read More

Sharing the Benefits: How the Economics of Carbon Capture and Storage Projects in California Can Serve Communities, the Economy, and the Climate.
Grove, B., and Peridas, G. (2023). Lawrence Livermore National Laboratory.

Getting to Neutral: Options for Negative Carbon Emissions in California.
Baker, S.E., et al. (2020). Lawrence Livermore National Laboratory.

2022 Scoping Plan for Achieving Carbon Neutrality
California Air Resources Board. (2022).

Accounting and Permanence Protocol for Carbon Capture and Geologic Sequestration under Low Carbon Fuel Standard
California Air Resources Board. (2018).

Pathways to Carbon Neutrality in California: Clean Energy Solutions that Work for Everyone
Surles, T., Grossman, T., and Saltzer, S.D. (2021).

An Action Plan for Carbon Capture and Storage in California: Opportunities, Challenges, and Solutions
Stanford Center for Carbon Storage and Stanford Carbon Removal Initiative. Energy Futures Initiative and Stanford University. (2020).

Recommendations for Geologic Carbon Sequestration in California: I. Siting Criteria and Monitoring Approaches, and II. Example Application Case Study
Oldenburg, C.M., Jordan, P.D., and Burton, E. (2017). Lawrence Berkeley National Laboratory.

Permitting Carbon Capture & Storage Projects in California
Peridas, G. (2021). Lawrence Livermore National Laboratory.

6

The Future of the Natural Gas System

Reducing natural gas consumption to meet climate and air quality laws while ensuring a reliable energy supply.

Overview

More natural gas is consumed in California than in any other state except Texas. Of all natural gas consumed in state, approximately 31% is used to generate electricity; 34% is used in industry; 22% is used for residential purposes (e.g., heating and cooking); 12% is used for commercial applications; and 1% is used for vehicle fuel (**Figure 6.1**).[224] Approximately 38% of California's power is derived from natural gas (as of 2021).[225] However, meeting the State's climate and air quality laws requires nearly eliminating consumption of natural gas—other than at facilities with **carbon capture and storage*** (CCS)—by 2045.

Policies are being implemented that reduce California's dependence on natural gas due to its impacts on climate and health (via **electrification**, increasing energy efficiency, building more renewable resources, etc.). Between 2001 and 2022, in-state natural gas use declined by 15%[226] despite a 14% increase in population over the same period.[227] The California Energy Commission (CEC) predicts close to another 12% reduction by 2035 (relative to 2020 levels).[228]

Currently, natural gas is most commonly used as an **energy carrier** for heat production. Renewable electricity can replace natural gas in most of these applications. However, some current uses of natural gas—particularly for **firm power** (i.e., power that can be delivered for as long as needed in the amount needed) and as a

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224 U.S. Energy Information Administration. (2022). California Natural Gas Consumption by End Use. Independent Statistics & Analysis. Accessed on 11/01/2022 at: https://www.eia.gov/dnav/ng/ng_cons_sum_dcu_SCA_a.htm.

225 California Energy Commission. (2021). 2021 Total System Electric Generation. *California Energy Commission*. Available at: https://www.energy.ca.gov/data-reports/energy-almanac/california-electricity-data/2021-total-system-electric-generation.

226 U.S. Energy Information Administration. (2022). Natural Gas Delivered to Consumers in California (Including Vehicle Fuel). Accessed on 11/22/2022 at: https://www.eia.gov/dnav/ng/hist/n3060ca2m.htm.

227 USA Facts. (2022). Our Changing Population: California. Accessed on 12/15/2022 at: https://usafacts.org/data/topics/people-society/population-and-demographics/our-changing-population/state/california?endDate=2021-01-01&startDate=2001-01-01.

228 Javanbakht, H. et al. (2022). Final 2021 Integrated Energy Policy Report, Volume IV: California Energy Demand Forecast. *California Energy Commission*. Publication Number: CEC-100- 2021-001-V4. Available at: https://efiling.energy.ca.gov/GetDocument.aspx?tn=241581

***** Find **bold** words in the Glossary (Appendix A).

feedstock for chemical industries—may not be feasible to replace with renewable electricity. The key challenges for policymakers will be to transition most natural gas uses to lower-carbon alternatives while preserving the capacity to supply the hard-to-replace sectors and reducing the environmental impacts of natural gas extraction, distribution, and use, particularly **methane** leaks and air pollution caused by natural gas combustion.

Climate, health, and safety impacts

Natural gas is primarily composed of methane—a greenhouse gas with nearly 30 times the **global warming potential** of carbon dioxide (over a 100-year time period)[229]—and also contains ethane, propane, carbon dioxide, water vapor, as well as toxic pollutants like benzene.

California imports 90% of the natural gas it consumes through a network of interstate pipelines that leak.[230,231] Approximately 12% of California's methane emissions are attributed to pipeline leaks.[232] Other natural gas infrastructure is also susceptible to large leaks, as in 2015-2016 when Aliso Canyon—a natural gas storage facility outside Los Angeles—leaked approximately 100,000 metric tons of methane over four months,[233] the largest methane leak in the United States to date. Aliso Canyon is still in operation at reduced capacity, though attempts have been made to shut it down (e.g., SB 1486, Stern, 2022). Research suggests that the risks of underground gas storage can be managed with appropriate regulations and careful monitoring.[234]

While less carbon intensive than oil or coal, the combustion of natural gas generates carbon dioxide (along with other pollutants). Natural gas combustion contributed 38% of carbon dioxide emissions in California in 2019.[235] Combustion also produces nitrogen oxides and volatile organic compounds which react in the atmosphere to form **ozone**—a toxic air pollutant, greenhouse gas, and precursor to smog.

Natural gas and oil production facilities are known to emit **hazardous air pollutants**—pollutants known or suspected to cause cancer or other serious health problems.[236,237] For this reason, SB 1137 (Gonzalez, 2022) would prohibit the construction of new oil and gas production facilities within 3,200 feet of homes, daycare centers, schools, hospitals, or other sensitive zones, and requires oil and gas well operators to implement a leak detection and response plan by 2027. This law would have taken effect in January 2023 but was qualified for a veto referendum. It will appear on the ballot in November 2024.

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229 Forster, P. et al. (2021). The Earth's Energy Budget, Climate Feedbacks, and Climate Sensitivity. Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change, pp. 923-1054. Available at: https://www.ipcc.ch/report/ar6/wg1/chapter/chapter-7/.

230 Duren, R.M. et al. (2019). California's methane super-emitters. *Nature*, 575(7781), pp. 180-184.

231 Ersoy D. et al. (2019). Quantifying Methane Emissions from Distribution Pipelines in California. *Gas Technology Institute, California Air Resources Board.* Available at: https://ww2.arb.ca.gov/sites/default/files/2021-01/Final_CARB_Pipeline%20Study_1-14-21.pdf.

232 Jones, M. et al. (2022). Final 2021 Integrated Energy Policy Report, Volume III: Decarbonizing the State's Gas System. *California Energy Commission.* Publication Number: CEC-100-2021-001-V3. Available at: https://efiling.energy.ca.gov/GetDocument.aspx?tn=242233.

233 California Air Resources Board. (2016). Determination of Total Methane Emissions from the Aliso Canyon Natural Gas Leak Incident. Available at: https://ww2.arb.ca.gov/sites/default/files/2020-07/aliso_canyon_methane_emissions-arb_final.pdf.

234 California Council on Science and Technology. (2018). Long-Term Viability of Underground Natural Gas Storage in California. Available at: https://ccst.us/wp-content/uploads/Full-Technical-Report-v2_max.pdf.

235 Jones, M. et al. (2022). Final 2021 Integrated Energy Policy Report, Volume III: Decarbonizing the State's Gas System. *California Energy Commission.* Publication Number: CEC-100-2021-001-V3. Available at: https://efiling.energy.ca.gov/GetDocument.aspx?tn=242233.

236 Garcia-Gonzales, D.A. et al. (2019). Hazardous Air Pollutants Associated with Upstream Oil and Natural Gas Development: A Critical Synthesis of Current Peer-Reviewed Literature. *Annual Review of Public Health*, 40, pp. 283-304.

237 U.S. Environmental Protection Agency. (ND). Oil and Natural Gas Production Facilities: National Emission Standards for Hazardous Air Pollutants (NESHAP). Accessed on 11/01/22 at: https://www.epa.gov/stationary-sources-air-pollution/oil-and-natural-gas-production-facilities-national-emission.

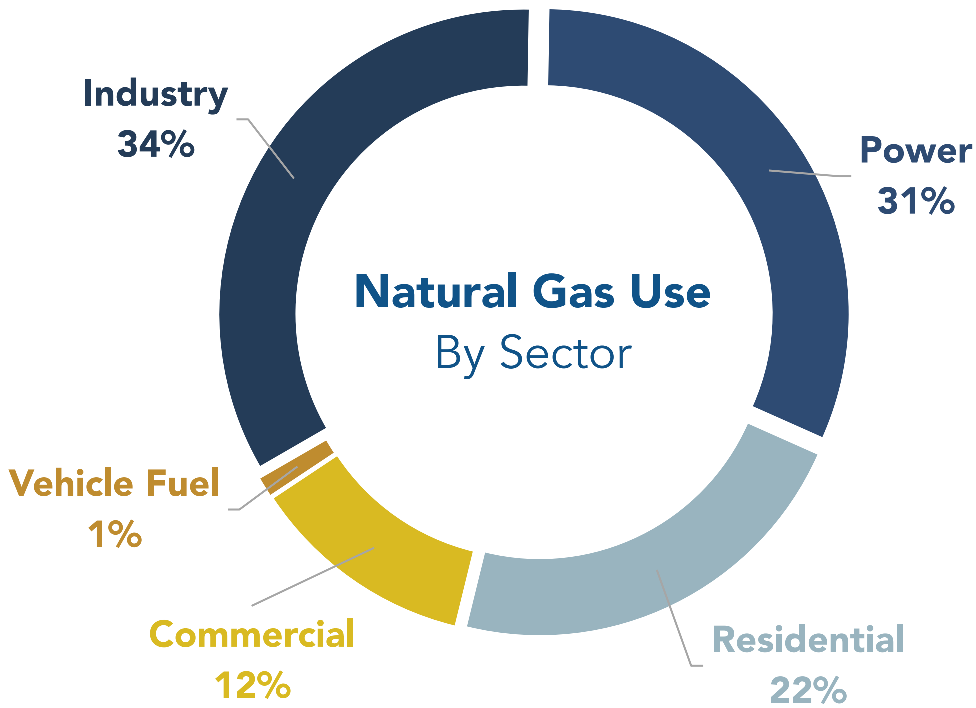

Figure 6.1. Natural gas use across sectors in California in 2021. Data are from the U.S. Energy Information Administration. (2022). Natural Gas Consumption by End Use.

Available at: https://www.eia.gov/dnav/ng/ng_cons_sum_dcu_SCA_a.htm.

Approximately 70% of Californian households currently cook with natural gas (compared to 38% nationwide).[238] Without proper ventilation,[239] cooking with natural gas introduces hazardous air pollutants—including particulate matter, nitrogen dioxide, carbon monoxide, and formaldehyde—into the home. Studies have linked natural gas stoves to higher rates of asthma and other respiratory illnesses in children.[240,241] The use of a natural gas stove without proper ventilation can elevate nitrogen dioxide concentrations within households to levels considered by the U.S. Environmental Protection Agency[242] to be "unhealthy for sensitive groups" in a matter of minutes.[243] Furthermore, a small amount of natu-

238 U.S. Energy Information Agency. (2022). In 2020, Most U.S. Households Prepared at least one Hot Meal a Day at Home. Accessed on 5/30/2023 at: https://www.eia.gov/todayinenergy/detail.php?id=53439.

239 Singer, B.C. et al. (2021). Effective Kitchen Ventilation for Healthy Zero Net Energy Homes with Natural Gas. *California Energy Commission.* Publication Number: CEC-500-2021-005. Available at: https://www.energy.ca.gov/sites/default/files/2021-05/CEC-500-2021-005.pdf.

240 Lin, W., Brunekreef, B., and Gehring, U. (2013). Meta-Analysis of the Effects of Indoor Nitrogen Dioxide and Gas Cooking on Asthma and Wheeze in Children. *International Journal of Epidemiology*, 42(6), pp. 1724-1737.

241 Zhu, Y. et al. (2020). Effects of Residential Gas Appliances on Indoor and Outdoor Air Quality and Public Health in California. *UCLA Fielding School of Public Health, Department of Environmental Health Sciences*. Available at: https://ucla.app.box.com/s/xyzt8jc1ixnetiv0269qe704wu0ihif7.

242 Office of Air and Radiation. (2011). Air Quality Guide for Nitrogen Dioxide. *U.S. Environmental Protection Agency.* Available at: https://www.airnow.gov/sites/default/files/2018-06/no2.pdf.

243 Lebel, E.D. et al. (2022). Methane and NOx Emissions from Natural Gas Stoves, Cooktops, and Ovens in Residential Homes. *Environmental Science & Technology*, 56(4), pp. 2529-2539.

ral gas is continuously leaked into the home even when appliances are turned off.[244] Thus, even when proper ventilation is used while cooking, the presence of natural gas stoves in homes still poses certain health risks.[245]

Decarbonizing buildings

The building decarbonization strategy in California calls for enhancing energy efficiency, electrifying end uses, increasing demand flexibility, and supplying more renewable energy[246]—all of which will reduce natural gas consumption in the commercial and residential sectors.

Natural gas-powered space and water heating represent the bulk of greenhouse gas emissions produced on-site,[247] but there are efficient electric alternatives available. The Technology and Equipment for Clean Heating (TECH) Initiative—established as part of SB 1477 (Stern, 2018)—incentivizes the adoption of low-emission electric **heat pump** technologies for space heating, air conditioning, and water heating in existing single and multifamily homes in California.

The Equitable Building Decarbonization Program, established by AB 209 (Committee on Budget, 2022), will invest close to $1 billion over the next two years to support building decarbonization efforts, including support for the direct installation of electric appliances for low-income residents. The 2022 Energy Code encourages heat pump technologies for newly constructed single-family homes, multifamily buildings, and select commercial buildings.[248]

The California Air Resources Board (CARB) 2022 Scoping Plan recommends that a) 100% of new residential and 100% of new commercial buildings be outfitted for electrical appliances by 2026

244 Lebel, E.D. et al. (2022). Methane and NOx Emissions from Natural Gas Stoves, Cooktops, and Ovens in Residential Homes. *Environmental science & technology*, 56(4), pp. 2529-2539.

245 Lebel, E.D. et al. (2022). Composition, Emissions, and Air Quality Impacts of Hazardous Air Pollutants in Unburned Natural Gas from Residential Stoves in California. *Environmental Science & Technology*, 56(22), pp. 15828-15838.

246 Kenney, M. et al. (2022). Final 2021 Integrated Energy Policy Report, Volume I: Building Decarbonization. *California Energy Commission*. Publication Number: CEC-100-2021-001- V1. Available at: https://efiling.energy.ca.gov/GetDocument.aspx?tn=241599.

247 Kenney, M. et al. (2022). Final 2021 Integrated Energy Policy Report, Volume I: Building Decarbonization. *California Energy Commission*. Publication Number: CEC-100-2021-001- V1. Available at: https://efiling.energy.ca.gov/GetDocument.aspx?tn=241599.

248 California Energy Commission. (2021). 2022 Building Energy Efficiency Standards Summary. Available at: https://www.energy.ca.gov/sites/default/files/2021-08/CEC_2022_EnergyCodeUpdateSummary_ADA.pdf.

and 2029, respectively; and b) new appliance sales be 80% electric by 2030 and 100% electric by 2045. As per the 2022 Energy Code, all new homes built in California are required to be electric-ready (effective January 2023).

As of 2021, more than 40 cities and counties in California have adopted regulations that restrict or discourage natural gas in new construction.[249] Berkeley, California, was the first U.S. city to ban natural gas hookups for new developments. While Berkeley's ban was overturned by a federal appeals court in April 2023, regulations in other jurisdictions that differ in their structure may not be similarly impacted.[250] In September 2022, the California Public Utilities Commission (CPUC) voted to eliminate subsidies for natural gas hookups for new buildings (effective July 2023).[251]

Relevant State Institutions

- California Air Resources Board (CARB)
- California Energy Commission (CEC)
- California Geologic Energy Mgmt. Division (CalGEM)
- California Independent System Operator (CAISO)
- California Public Utilities Commission (CPUC)
- Assembly Budget Subcommittee 3 on Climate Crisis, Resources, Energy, and Transportation
- Assembly Natural Resources Committee
- Assembly Utilities and Energy Committee
- Senate Budget Subcommittee 2 on Resources, Environmental Protection and Energy
- Senate Energy, Utilities and Communications Subcommittee on Clean Energy Future
- Senate Environmental Quality Committee
- Senate Natural Resources and Water Committee
- Joint Legislative Cmte. on Climate Change Policies

Natural gas infrastructure

One challenge introduced by electrification is determining how best to manage existing natural gas infrastructure even as demand for natural gas declines. One approach, known as **pruning**, is to strategically retire parts of the gas system as buildings served by each segment are fully electrified. Pruning would minimize costs borne by ratepayers and mitigate inequitable outcomes (see Environmental Justice and Equity Considerations, below). For example, rather than replacing an aging gas line, pruning the line can avert this cost. Savings can be used to upgrade the electric distribution system or to support incentives that mitigate electrification costs for consumers (such as those introduced by the early retirement of natural gas heaters).

The CEC has awarded grants for two pilot projects on gas system decommissioning in the Pacific Gas & Electric[252] and Southern California Gas service areas.[253] These pilots will inform data-driven tools that could help optimize gas system decommissioning.[254]

The production of plastic, hydrogen, and ammonia (as well as a few other chemical industries) require the methane molecules themselves rather than the energy they carry. These industries will continue to need a safe, reliable, and cost-effective supply of methane. The uses that are likely to

249 Faddoul, K. (2021). California's Cities Lead the Way on Pollution-Free Homes and Buildings. *Sierra Club*. Accessed on 11/01/22 at: https://www.sierraclub.org/articles/2021/07/californias-cities-lead-way-pollution-free-homes-and-buildings.

250 Har, J. (2023). Court Tosses Berkeley Gas Ban, but Wider Impact is Unclear. *Associated Press.* Accessed on 5/23/2023 at: https://apnews.com/article/berkeley-california-natural-gas-ban-overturned-court-3546acbaec5db011c89a610baa42cebc.

251 California Public Utilities Commission. (2022). CPUC Decision Makes California First State in Country to Eliminate Natural Gas Subsidies to Accelerate Building Decarbonization. Available at: https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M496/K979/496979465.PDF.

252 Energy and Environmental Economics, Inc. (2022). E3 Undertakes Analysis of Targeted Decommissioning of Natural Gas Infrastructure in California. Accessed on 12/02/22 at: https://www.ethree.com/e3-undertakes-analysis-of-targeted-decommissioning-of-natural-gas-infrastructure-in-california/.

253 California Energy Commission. (2021). Staff Workshop on Strategic Pathways and Analytics for Tactical Decommissioning of Portions of Natural Gas Infrastructure. Available at: https://www.energy.ca.gov/event/workshop/2021-11/staff-workshop-strategic-pathways-and-analytics-tactical-decommissioning.

254 California Energy Commission. (2023). Development of a Data-Driven Tool to Support Strategic and Equitable Decommissioning of Gas Infrastructure. Accessed on 11/01/2022 at: https://www.energy.ca.gov/solicitations/2021-11/gfo-21-504-development-data-driven-tool-support-strategic-and-equitable.

require methane for the foreseeable future tend to occur at larger, industrial scales. They can likely be satisfied even as California extensively prunes its natural gas distribution network.

Meeting electricity demand

Demand for natural gas in the electricity sector is predicted to decline due to SB 100 (de León, 2018), which requires 100% of retail electricity sold in the state to be obtained from renewable or zero-carbon resources by 2045.[255]

California needs clean, firm power that can meet demand when renewable resources are insufficient. Natural gas currently provides much of the firm power necessary to balance the state's energy load during peak demand periods and during the winter when wind and solar capacities decline significantly. Energy storage, **demand response**, and grid regionalization can alleviate some, but likely not all, of the needs for firm power.

Peaker plants—natural gas plants that only operate when needed to meet periods of high demand—have grown more numerous in California over the last two decades, from 29 plants in 2001 to 74 in 2020.[256] Peaker plants can be quickly deployed when there is need for additional power, but they emit more greenhouse gases than typical natural gas plants.[257] The majority of these plants are in **disadvantaged communities**.[258] SB 338 (Skinner, 2017) requires energy providers to identify clean, low-cost alternatives to meeting peak demand, though CARB's 2022 Scoping Plan acknowledges that "fossil gas generation will continue to play a critical role in grid reliability until other clean, dispatchable alternatives are available and can be deployed at scale."[259]

Modeling conducted for the 2021 SB 100 Joint Agency Report suggests that maintaining "significant gas capacity" in the power sector is the most economical path to ensuring adequate resources are available to meet demand. One possible solution is to deploy CCS at natural gas plants to facilitate the production of firm, low-carbon electricity. Please see **Section 3** for a discussion of firm power alternatives.

Reducing carbon intensity

Some demand for natural gas or other gaseous energy carriers in industry, transportation, and the building sector will likely remain, even in a highly decarbonized future.[260] The substitution of natural gas with renewable gas alternatives—like renewable hydrogen or **biomethane**—would reduce the lifecycle emissions associated with hard-to-electrify applications. However, there are challenges with these alternatives.

For example, like fossil gas, hydrogen and biomethane produce nitrogen oxides when burned. Because biomethane is chemically identical to methane, it is also a potent greenhouse gas though it has a lower lifecycle **carbon intensity** (see more below). Hydrogen is known to be an indirect greenhouse gas—this means that while it is not a greenhouse gas itself, hydrogen interacts with other molecules in the atmosphere in a process that ultimately causes methane and sometimes ozone to remain in the atmosphere longer than they would otherwise.[261] For biomethane or

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255 California ISO. (2022). 20-Year Transmission Outlook. Available at: http://www.caiso.com/InitiativeDocuments/Draft20-YearTransmissionOutlook.pdf.

256 Roy, S., Sinha, P., and Ismat Shah, S. (2020). Assessing the Techno-Economics and Environmental Attributes of Utility-Scale PV with Battery Energy Storage Systems (PVS) Compared to Conventional Gas Peakers for Providing Firm Capacity in California. *Energies*, 13(2), pp. 488.

257 McNamara, W. (2020). Issue Brief - Energy Storage to Replace Peaker Plants. *Sandia National Laboratories.* Available at: https://www.sandia.gov/app/uploads/sites/163/2022/04/Issue-Brief-2020-11-Peaker-Plants.pdf.

258 Krieger, E.M., Casey, J.A., and Shonkoff, S.B. (2016). A framework for Siting and Dispatch of Emerging Energy Resources to Realize Environmental and Health Benefits: Case Study on Peaker Power Plant Displacement. *Energy Policy*, 96, pp. 302-313.

259 California Air Resources Board. (2022). 2022 Scoping Plan for Achieving Carbon Neutrality. Available at: https://ww2.arb.ca.gov/sites/default/files/2022-11/2022-sp.pdf.

260 Jones, M. et al. (2022). Final 2021 Integrated Energy Policy Report, Volume III: Decarbonizing the State's Gas System. *California Energy Commission.* Publication Number: CEC-100-2021-001-V3. Available at: https://efiling.energy.ca.gov/GetDocument.aspx?tn=242233.

261 Warwick, N. et al. (2022). Atmospheric Implications of Increased Hydrogen Use. *Crown.* Available at: https://assets.

As Californians transition away from natural gas, those who remain on the natural gas system risk being burdened with an increasingly larger share of the "fixed costs" associated with infrastructure maintenance through their energy bills.[40]

renewable hydrogen to provide the envisioned greenhouse gas reduction benefits, infrastructure leaks must be strictly controlled. The demand for these alternatives is likely to be much less than current natural gas demand and concentrated in fewer high-volume customers.

As per SB 1440 (Hueso, 2018), the CPUC has set procurement requirements for biomethane for the large **investor-owned utilities** providing gas service in California—Southern California Gas, Pacific Gas & Electric, San Diego Gas & Electric, and Southwest Gas—as a means for reducing methane emissions in the state.[262] These procurement targets may not be sufficient to spur the development of projects necessary to support long-term biomethane demand in the state nor the deployment of anaerobic digesters necessary to meet California's methane emission reduction targets.

Biomethane qualifies for Low-Carbon Fuel Standard (LCFS) credits when used to replace natural gas for transportation. Biomethane produced from anaerobic digesters at livestock operations has been assigned an extremely low, typically negative, carbon intensity, which results in large financial incentives for dairy farmers to participate. This low carbon intensity rating assumes manure would otherwise generate methane that gets released into the atmosphere. In 2022, biomethane represented only around 1% of transportation fuel in

publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1067144/atmospheric-implications-of-increased-hydrogen-use.pdf.

262 California Public Utilities Commission. (2022). Decision Implementing Senate Bill 1440 Biomethane Procurement Program. Available at: https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M454/K335/454335009.PDF.

California yet generated the third largest number of LCFS credits out of all transportation fuels.[263]

A petition has been filed against the inclusion of biomethane derived from dairy and swine farms in the LCFS. The petition argues that these facilities negatively impact nearby communities and that—because other manure management alternatives exist that could reduce methane emissions from livestock operations—LCFS inflates the emissions reductions achieved through this biomethane production pathway.[264]

As electric vehicle technology has improved over the last decade, the consensus among energy system experts is that biomethane is no longer needed as part of the transportation fuel portfolio. See **Section 7** for more on decarbonizing transportation.

Blending hydrogen into existing natural gas pipelines and infrastructure is being explored as a potential solution that could reduce the carbon intensity of gas systems and expedite the production, storage, and use of renewable hydrogen. However, preliminary results suggest that hydrogen blending— especially at concentrations greater than 5%—creates a range of challenges that must be addressed before implementation.[265] In mid-December 2022, the CPUC called for more pilot projects to inform possible standards for hydrogen blending in natural gas pipelines.[266]

Alternatively, hard-to-electrify sectors might be able to implement carbon capture and storage (see **Section 5**) to reduce the carbon impacts of their operations while continuing to use natural gas.

For those applications that require methane as a chemical feedstock, biomethane—produced from the anaerobic digestion of organic waste or the gasification of agricultural or woody biomass—presents a compelling low-carbon alternative. Biomethane production pathways can differ greatly in the carbon intensities of their respective lifecycles.[267] Most biomethane pathways have lower life cycle carbon intensities than fossil natural gas. However, as with most renewable fuels, the greenhouse gas impact is seldom zero. The carbon intensities of each pathway will need to be factored carefully into California's plans to reach net-zero. More research is needed to better understand how biomethane supplies compare to projected demand.

Environmental Justice and Equity Considerations

More than half of California's natural gas power plants are in communities ranked among the 25% most disadvantaged (according to CalEnviroScreen—an online mapping tool used by the California Environmental Protection Agency to identify communities in California most vulnerable to pollution).[268]

Low-income households tend to have worse indoor pollution created by natural gas stoves

263 California Air Resources Board. (2023). 2022 LCFS Reporting Tool (LRT) Quarterly Data Summary: Report No. 4. Available at: https://ww2.arb.ca.gov/sites/default/files/2023-04/Q4%202022%20Data%20Summary_042823.pdf.

264 California Air Resources Board. (2021). Petition for Reconsideration of the Denial of the Petition for Rulemaking to Exclude all Fuels Derived from Biomethane from Dairy and Swine Manure from the Low Carbon Fuel Standard Program. Available at: https://ww2.arb.ca.gov/sites/default/files/2022-04/2022-03-28%20-%20Petition%20for%20Reconsideration%20%28TOC%20Updated%29.pdf.

265 Miroslav, P. et al. (2022). Hydrogen Blending Impacts Study Final Report. *California Public Utilities Commission*. Available at: https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M493/K760/493760600.PDF.

266 California Public Utilities Commission. (2022). Decision Directing Biomethane Reporting and Directing Pilot Projects to Further Evaluate and Establish Pipeline Injection Standards for Clean Renewable Hydrogen. Available at: https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M500/K055/500055657.PDF.

267 Rai, S. et al. (2022). Comparative Life Cycle Evaluation of the Global Warming Potential (GWP) Impacts of Renewable Natural Gas Production Pathways. *Environmental Science & Technology*, 56(12), pp. 8581-8589.

268 PSE Healthy Energy. (2017). Natural Gas Power Plants in California's Disadvantaged Communities. Available at: https://www.psehealthyenergy.org/wp-content/uploads/2017/04/CA.EJ_.Gas_.Plants.pdf.

because they are smaller, have a higher occupant density, and are more likely to have substandard ventilation equipment.[269]

As Californians transition away from natural gas, those who remain on the natural gas system risk being burdened with an increasingly larger share of the "fixed costs" associated with infrastructure maintenance through their energy bills.[270] If such a transition occurs without pruning, a shrinking pool of consumers using the gas system must pay to maintain it. Often, those that remain on the gas system do so not as a choice but as a matter of circumstance, such as renters or low-income consumers.

Electrification may lead to long-term savings, but there are often higher upfront costs that may be infeasible for socioeconomically disadvantaged groups. Programs have been developed to help address barriers to electrification. For example, the TECH Initiative directs 40% of program benefits to low-income and disadvantaged communities.

Relevant Policies
(Laws/Regulations)

Building Energy Efficient Standards
(Energy Code) – Title 24

Standards to lower carbon emissions of new and renovated buildings to a) encourage heat pump technology; b) establish electric-ready requirements; c) expand solar photovoltaic and battery storage; and d) strengthen ventilation standards.

Renewables Portfolio Standard (RPS) Program
SB 1078 (Sher, 2002)

The RPS Program mandated an initial 20% of electricity retail sales to come from renewable resources by 2017. SB 1078 defined eligible renewables to include small hydropower, solar, wind, and geothermal, among others. SB 350 (de León, 2015) introduced interim annual RPS targets with three-year compliance periods and requires 65% of RPS procurement to be derived from long-term contracts of 10 or more years.

SB 100 (de León, 2018) increased the RPS target to 60% by 2030 and requires that 100% of electricity retail sales come from renewable and carbon-free resources by 2045.

Clean Energy and Pollution Reduction Act
SB 350 (de León, 2015)

SB 350 increases California's renewable electricity procurement goal from 33% by 2020 to 50% by 2030, thus supporting greater use of resources eligible for the Renewables Portfolio Standard. SB 350 mandates doubling statewide energy efficiency savings for electricity and natural gas end uses by 2030.

SB 350 requires large utilities to submit integrated resource plans on how they will meet consumers' needs, reduce greenhouse gas emissions, and increase use of clean energy resources.

The 100 Percent Clean Energy Act of 2018
SB 100 (de León, 2018)

SB 100 establishes a goal that by 2045 all retail electricity sold in California and procured to meet state agency electricity needs will be powered by renewable and zero-carbon resources. SB 1020 (Laird, 2022) added interim targets for renewable electricity retail sales.

269 Zhao, H. et al. (2021). Indoor Air Quality in New and Renovated Low-Income Apartments with Mechanical Ventilation and Natural Gas Cooking in California. *Indoor Air*, 31(3), pp. 717-729.

270 Aas, D. et al. (2020). The Challenge of Retail Gas in California's Low-Carbon Future: Technology Options, Customer Costs and Public Health Benefits of Reducing Natural Gas Use. *California Energy Commission*. Publication Number: CEC-500-2019-055-F. Available at https://www.energy.ca.gov/sites/default/files/2021-06/CEC-500-2019-055-F.pdf.

SB 100 updated the Renewables Portfolio Standard to ensure that by 2030 at least 60% of the state's electricity is from RPS eligible resources.

SB 100 requires the CEC, CPUC, and CARB to use existing laws to achieve 100% clean electricity and issue a joint policy report on SB 100 by 2021 and every four years after that.

Clean Energy, Jobs, and Affordability Act of 2022
SB 1020 (Laird, 2022)

SB 1020 added interim targets for renewable energy and zero-carbon electricity retail sales as legislated in SB 100 (de León, 2018) (90% by 2035 and 95% by 2040). SB 1020 requires state agencies to use 100% renewable energy and zero-carbon resources by 2030 and establishes a Climate and Equity Trust fund to manage rising electricity rates that threaten affordability.

California Global Warming Solutions Act
AB 32 (Nunez, 2006)

AB 32 requires California to reduce greenhouse gas emissions to 1990 levels by 2020 and is designed to mitigate risks of climate change, improve energy efficiency, expand renewable energy, support cleaner transportation, and reduce waste. AB 32 requires CARB to develop a Scoping Plan (e.g., the 2022 Scoping Plan) that delineates strategies for achieving this goal. The Act also requires convening an Environmental Justice Advisory Committee to advise on Scoping Plans and climate programs. SB 32 (Pavley, 2016) expanded emissions targets to reflect a 40% reduction from 1990 levels by 2030.

Low Carbon Fuel Standard (LCFS)
Executive Order S-01-07, 2007

The Low Carbon Fuel Standard (LCFS) is administered by CARB. LCFS was established following Executive Order S-01-07 and was identified by CARB's 2008 Scoping Plan as an early action to reduce greenhouse gas emissions.

LCFS assesses a carbon-intensity (CI) value for transportation fuels based on lifetime greenhouse gas emissions associated with the production, transportation, and use of those fuels. All fuels are compared to a declining CI target. Fuels with increasingly lower CIs than the target generate more credits, while fuels with CIs that exceed the target generate deficits. This incentivizes fuel providers to procure low-carbon fuels to sell credits to fuel providers generating deficits. The LCFS requires the average carbon intensity of all transportation fuels to decline over time, beginning with a quarter of a percent in 2011 and targeting a 20% reduction by 2030.[271] CARB is currently considering increasing the 2030 CI reduction target from 20% to 25%, 30%, or 35%.[272]

Integrated Resource Plan: Peak Demand
SB 338 (Skinner, 2017)

This law requires utilities to consider the role of existing clean energy resources (e.g., energy efficiency, energy storage, demand response) in helping to ensure that energy and reliability needs can be met during peak demand period, reducing the need for new generation and transmission infrastructure.

271 California Air Resources Board. (2022). Low Carbon Fuel Standard. Accessed on 11/30/2002 at: https://ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard.

272 California Air Resources Board. (2022). Low Carbon Fuel Standard—Public Workshop: Concepts and Tools for Compliance Target Modeling. Accessed on 11/30/2022 at: https://ww2.arb.ca.gov/sites/default/files/2022-11/LCFSPresentation.pdf.

Zero-Emissions Buildings and Sources of Heat Energy
AB 3232 (Friedman, 2018)

AB 3232 requires the California Energy Commission (CEC) to analyze the potential for reducing greenhouse gas emissions from the state's residential and commercial building stock by at least 40% below 1990 levels by 2030. The law further requires the CEC to include data on the emissions of greenhouse gases associated with energy supplied to these buildings in all integrated energy policy reports starting in 2021.

Energy: Biomethane: Biomethane Procurement
SB 1440 (Hueso, 2018)

SB 1440 requires the CEC, in consultation with CARB, to consider adopting biomethane procurement requirements for gas corporations.

Oil and Gas Operations Location Restrictions
SB 1137 (Gonzalez, 2022)

New oil and gas developments are prohibited within 3,200 feet (1 kilometer) of schools, hospitals, homes, or other sensitive establishments and includes restrictions on noise as well as release of toxic gases from storage tanks.

California Climate Crisis Act
AB 1279 (Muratsuchi, 2022)

AB 1279 declares the policy of the state to achieve net-zero greenhouse gas emissions as soon as possible—but no later than 2045—and to achieve and maintain net negative emissions thereafter. Further, this law mandates that emissions by 2045 are reduced by 85% below 1990 levels (this is to ensure that direct emission reductions are favored over the broad deployment of carbon removal technologies). This law requires CARB to work with relevant agencies to 1) ensure scoping plan updates include measures to achieve these policy goals; and 2) identify and implement strategies to enable carbon dioxide removal solutions and carbon capture, utilization, and storage technologies.

Read More

2022 Scoping Plan for Achieving Carbon Neutrality.
California Air Resources Board (2022)

Biomethane in California Common Carrier Pipelines: Assessing Heating Value and Maximum Siloxane Specifications.
California Council on Science and Technology. (2018).

Long Term Viability of Underground Natural Gas Storage in California.
California Council on Science and Technology. (2018).

20-year Transmission Outlook.
California ISO (2022)

California Integrated Energy Policy Report Volume I Building Decarbonization.
California Energy Commission (2022)

Integrated Energy Policy Report Volume III Decarbonizing the State's Gas System.
California Energy Commission (2022)

Methane and NOx Emissions from Natural Gas Stoves, Cooktops, and Ovens in Residential Homes.
Lebel, E.D., Finnegan, C.J., Ouyang, Z., and Jackson, R.B. (2022). Environmental Science & Technology, 56(4), pp. 2529-2539.

The Challenge of Retail Gas in California's Low-Carbon Future.
California Energy Commission (2020)

Decarbonizing Transportation

Transitioning to zero-emission vehicles and reducing vehicle miles traveled.

Overview

The transportation sector accounts for about 37%[273] of California's greenhouse gas (GHG) emissions (50% if including emissions from fuel production), 80% of smog-forming nitrogen oxide emissions, and 95% of diesel particulate matter emissions.[274]

Achieving **net-zero*** greenhouse gas emissions by 2045 (as per AB 1279, Muratsuchi, 2022) requires the vast majority of the transportation sector to transition to vehicles that can be powered by zero, or near-zero carbon energy. Zero-emission vehicles (ZEVs) probably cannot satisfy every transportation demand, so California has adopted a portfolio approach to decarbonizing the transportation sector.

Critical complementary strategies include supporting markets for low- and carbon-free fuels, improving access to active transportation through safe pedestrian and bicycle pathways, optimizing city planning, and mitigating barriers to public transportation and decarbonization technologies in lower income and rural communities.

The transition to carbon-neutral transportation is likely to provide significant co-benefits, including improvements to air pollution, public health, environmental equity, and economic development.

273 California Air Resources Board. (2022). Current California GHG Emission Inventory Data. Accessed on 12/01/2022 at: https://ww2.arb.ca.gov/ghg-inventory-data.

274 California Air Resources Board. (2021). Advanced Clean Trucks: Accelerating Zero-Emission Truck Markets. Accessed on 12/01/2022 at: https://ww2.arb.ca.gov/sites/default/files/2021-08/200625factsheet_ADA.pdf.

***** Find **bold** words in the Glossary (Appendix A).

Decarbonizing vehicles and fuels

In support of Executive Order (EO) N-79-20 (2020), the California Air Resources Board's (CARB) Advanced Clean Cars II Regulations (ACC2) require that all new passenger cars, trucks, and SUVs sold in California be zero-emission by 2035. Passenger vehicles currently account for 70% of transportation-related emissions.[275] This mandate is predicted to cut GHG emissions from the passenger vehicle sector by 35% and nitrogen oxide (NOx) emissions by 80%.[276]

EO N-79-20 further requires that medium- and heavy-duty trucks be 100% zero-emission (where feasible) by 2045. CARB's Advanced Clean Trucks regulation requires truck manufacturers to sell an increasing percentage of medium- and heavy-duty ZEVs between 2024 and 2045. CARB's Advanced Clean Fleets regulation requires large fleets to transition to ZEV vehicles.

The Innovative Clean Transit regulation requires all transit authorities to purchase only zero-emission buses by 2029, to fully transition to 100% zero-emission fleets by 2040, and to submit Zero-Emission Bus Rollout Plans detailing how they intend to comply.[277] Rollout plans reflect a diversity of approaches ranging from 100% battery electric buses to 100% hydrogen fuel cell buses, with many proposed mixed fleets in between (more on these technologies below).

The Clean Miles Standard and Incentive Program, established by SB 1014 (Skinner, 2018), requires that rideshare companies (like Uber and Lyft) begin to electrify their fleets and meet annual GHG emission targets. SB 500 (Min, 2021) prohibits the operation of emission-producing autonomous vehicles starting in 2030.

The Low-Carbon Fuel Standard (LCFS), launched in 2011, uses a **carbon-intensity** (CI) standard coupled with credit trading to incentivize the use of low-carbon transportation fuels, thereby

275 California Air Resources Board. (2022). California Greenhouse Gas Emission Inventory - 2022 Edition. Data available at: https://ww3.arb.ca.gov/cc/inventory/data/data.htm.

276 Office of Governor Gavin Newsom. (2020). Governor Newsom Announces California will Phase Out Powered Cars and Drastically Reduce Demand for Fossil Fuel in California's Fight Against Climate Change. Available at: https://www.gov.ca.gov/2020/09/23/governor-newsom-announces-california-will-phase-out-gasoline-powered-cars-drastically-reduce-demand-for-fossil-fuel-in-californias-fight-against-climate-change/.

277 California Air Resources Board. (2022). ICT-Rollout Plans. Accessed on 12/01/2022 at: https://ww2.arb.ca.gov/our-work/programs/innovative-clean-transit/ict-rollout-plans.

Passenger vehicles currently account for 70% of transportation-related emissions.[237]

reducing GHG emissions associated with transportation. The LCFS requires the average CI of all transportation fuels to decline over time, currently targeting a 20% reduction (from a 2010 baseline) by 2030.[278] CARB is currently considering increasing the 2030 CI reduction target from 20% to 25%, 30%, or 35%.[279]

Since its implementation, LCFS has reduced the CI of fuel in California by 12.63% (as of 2022).[280] Given the number of credits predicted to be generated by the expanding ZEV market, LCFS may need to be reorganized to effectively support markets for alternative fuels in the future.[281]

Zero-emission vehicles (ZEVs)

Battery electric vehicles (**BEVs**) are powered by batteries alone and are recharged when plugged into a source of electricity. **Plug-in hybrid electric vehicles** (**PHEVs**) are powered by a blend of fuel and electric power. Typically, PHEVs drive on electric power until their battery is depleted, then run the engine using liquid fuels (like gasoline or diesel) to provide additional range.

In addition to providing zero-emission transportation, batteries used in electric vehicles have the potential to provide energy resilience to consumers by providing extra mobile energy storage during power outages.[282] BEV charging can be

278 California Air Resources Board. (2022). Low Carbon Fuel Standard. Accessed 12/01/2022 at: https://ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard.

279 California Air Resources Board. (2022). Low Carbon Fuel Standard—Public Workshop: Concepts and Tools for Compliance Target Modeling. Accessed on 12/01/2022 at: https://ww2.arb.ca.gov/sites/default/files/2022-11/LCFSPresentation.pdf.

280 California Air Resources Board. (ND). LCFS Data Dashboard. Accessed on 5/30/2023 at: https://ww2.arb.ca.gov/resources/documents/lcfs-data-dashboard.

281 Brown, A.L. et al. (2021). Chapter 9: Fuel Technology and Policy to Support a Carbon-Neutral Transportation System *in* Driving California's Transportation Emissions to Zero. *UC Institute of Transportation Studies*. Available at: https://escholarship.org/uc/item/3np3p2t0.

282 Office of Energy Efficiency and Renewable Energy. Bidirectional Charging and Electric Vehicles for Mobile Storage. (ND). *US*

optimized to **load shift** and draw power from the grid only during times of low demand or high renewable energy production. Vehicle-to-grid integration allows ZEVs to discharge stored power back to the grid, thereby improving grid resilience to energy shortfalls. See **Section 3** for further discussion of load shifting.

Fuel cell electric vehicles (**FCEVs**) are powered by hydrogen fuel cells, which combine hydrogen fuel (pure H_2) with oxygen pulled from the air and generate electricity in the process. FCEVs are refueled at hydrogen stations rather than recharged. FCEVs can be refueled much more quickly than current BEVs can be recharged and produce only water vapor at the tailpipe.[283] Hydrogen fuel can be produced by renewable energy resources, such as electrolysis of water using renewable electricity or from **biomethane**.

CARB's Advanced Clean Cars II Regulations (ACC2) clarify that full battery electric vehicles, fuel cell electric vehicles, and plug-in hybrid electric vehicles (with an all-electric range of at least 50 miles) will count towards zero-emission passenger vehicle requirements for automakers.[284] No more than 20% of an automakers' ZEV requirements can be met by plug-in hybrids. Plug-in hybrids with longer electric ranges, like those that qualify as ZEVs under ACC2, typically rely on electricity for about 60-65% of their total travel range, though this number may increase as more charging options become available and drivers become accustomed to ZEVs.[285]

When measuring lifecycle emissions (also known as well-to-wheel emissions)—i.e., the total emissions related to fuel production, processing, distribution, and use—the source of electricity is important for BEVs and PHEVs because charging from fossil-fueled sources results in higher emissions than charging from renewable energy.[286] For FCEVs, the pathway by which the hydrogen was produced and how the hydrogen was transported impact lifecycle emissions.

The roles of BEVs versus FCEVs in the clean energy transition can be a divisive topic. The market for BEVs is inarguably more advanced, leading some to assert that California need not support the nascent FCEV market. Others argue that FCEVs can fill niches not yet successfully electrified by BEVs—including long haul transport, maritime, rail, and aviation. Further, having some portion of passenger vehicles be FCEVs could alleviate some of the predicted strain on the grid from vehicle electrification (see **Section 1**).

With current technology, hydrogen fuel is inefficient to produce and there are significant challenges associated with distributing hydrogen to fueling stations. Hydrogen can be compressed and transported via pipelines with relatively high efficiency, but this would likely require extensive upgrades to natural gas infrastructure. Further, because hydrogen is known to be an indirect greenhouse gas, any leaks from these pipelines would need to be strictly monitored and controlled.[287] Alternatively, hydrogen can be liquified and transported to stations by truck, though cooling to the temperatures required for liquefaction consumes energy equal to about 30% of that contained in the hydrogen.[288]

Department of Energy. Accessed on 12/01/2022 at: https://www.energy.gov/eere/femp/bidirectional-charging-and-electric-vehicles-mobile-storage.

283 California Energy Commission. (2022). Hydrogen Vehicles and Refueling Infrastructure. Available at: https://www.energy.ca.gov/programs-and-topics/programs/clean-transportation-program/clean-transportation-funding-areas-1.

284 California Air Resources Board. (2022). California Moves to Accelerate to 100% New Zero-Emission Vehicle Sales by 2035. Accessed on 12/01/2022 at: https://ww2.arb.ca.gov/news/california-moves-accelerate-100-new-zero-emission-vehicle-sales-2035.

285 Raghavan, S.S. and Tal, G. (2020). Plug-in Hybrid Electric Vehicle Observed Utility Factor: Why the Observed Electrification Performance Differ from Expectations. *International Journal of Transportation*, 16(2), pp. 105-136.

286 Office of Energy Efficiency and Renewable Energy. Emissions from Electric Vehicles. (ND). Accessed on 12/01/2022 at: https://afdc.energy.gov/vehicles/electric_emissions.html.

287 Warwick, N., et al. (2022). Atmospheric Implications of Increased Hydrogen Use. *Crown*. Available at: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/1067144/atmospheric-implications-of-increased-hydrogen-use.pdf.

288 Department of Energy. (2009). Energy Requirements for Hydrogen Gas Compression and Liquefaction as Related to Vehicle Storage Needs. Available at: https://www.hydrogen.energy.gov/pdfs/9013_energy_requirements_for_hydrogen_gas_compression.pdf.

Supporting the electric vehicle transition

California's transition to ZEVs necessitates significant investment in electric vehicle charging and hydrogen fueling infrastructure. Executive Order B-48-18 (2018) called for the installation of 200 hydrogen fueling stations by 2025.

An estimated 1.2 million public passenger vehicle chargers and 157,000 medium- and heavy-duty vehicle chargers will be required by 2030.[289] For context, California currently has 69 hydrogen refueling stations[290] and 37,113 public electric vehicle chargers[291] (as of May 2023).

The Clean Transportation Program—established by AB 8 (Perea, 2013) and managed by the CEC—invests about $100 million annually for infrastructure to support electric vehicles, hydrogen refueling, low-carbon fuels, advanced technology for medium- and heavy-duty vehicles, and economic development related to clean technologies.[292] About 35% of the investments target underserved, low-income, or disadvantaged communities, as these communities are disproportionately impacted by emissions from fossil-fuel transportation.[293]

The California Electric Vehicle Infrastructure Project (CALeVIP) coordinates charging infrastructure investments and streamlines charger installations with a $164 million grant from the Clean Transportation Program.

California will receive an estimated $384 million over the next five years from the National Electric Vehicle Infrastructure Program, funded by the federal Infrastructure Investment and Jobs Act.[294]

Relevant State Institutions

- California Air Resources Board (CARB)
- California Energy Commission (CEC)
- California Strategic Growth Council
- California Transportation Commission
- Metropolitan Planning Organizations & Regional Transportation Planning Agencies
- Assembly Budget Subcommittee No. 3 Climate Crisis, Resources, Energy, and Transportation
- Assembly Natural Resources Committee
- Assembly Transportation Committee
- Senate Budget Subcommittee No. 2 on Resources, Environmental Protection and Energy
- Senate Budget Subcommittee No. 5 on Corrections, Public Safety, Judiciary, Labor, and Transportation
- Senate Environmental Quality Committee
- Senate Governance and Finance
- Senate Transportation Committee
- Joint Leg. Committee on Climate Change Policies

CARB administers several ZEV incentive programs, including the Clean Vehicle Rebate Project (CVRP), the Clean Cars 4 All (CC4A) Program, the Clean Vehicle Assistance Program (CVAP), and the Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP). These incentive programs are all supported by Cap-and-Trade revenue (see **Section 8**). Owners of non-residential chargers receive LCFS credit for charging ZEVs, as do utilities that supply homes where ZEVs are charged. Revenue from LCFS credits

289 Fauble B. et al. (2022). California's Deployment Plan for the National Electric Vehicle Infrastructure Program. *California Department of Transportation, California Energy Commission*. Available at: https://dot.ca.gov/-/media/dot-media/programs/sustainability/documents/nevi/2022-ca-nevi-deployment-plan-a11y.pdf.

290 California Energy Commission. (2023). Hydrogen Refueling Stations in California. Available at: https://www.energy.ca.gov/data-reports/energy-almanac/zero-emission-vehicle-and-infrastructure-statistics/hydrogen-refueling.

291 California Energy Commission. (2023). Electric Vehicle Chargers in California. Available at: https://www.energy.ca.gov/data-reports/energy-almanac/zero-emission-vehicle-and-infrastructure-statistics/electric-vehicle.

292 California Energy Commission. (2022). Transforming Transportation. Accessed on 12/01/2022 at: https://www.energy.ca.gov/about/core-responsibility-fact-sheets/transforming-transportation.

293 California Energy Commission. (2022). Transforming Transportation. Accessed on 12/01/2022 at: https://www.energy.ca.gov/about/core-responsibility-fact-sheets/transforming-transportation.

294 Fauble B. et al. (2022). California's Deployment Plan for the National Electric Vehicle Infrastructure Program. California Department of Transportation, California Energy Commission. Available at: https://dot.ca.gov/-/media/dot-media/programs/sustainability/documents/nevi/2022-ca-nevi-deployment-plan-a11y.pdf.

from ZEV charging must be spent to support vehicle electrification. These funds are commonly used to reduce the cost of ZEV charging, provide incentives for charger installation, conduct public education campaigns, and support rebates for ZEV purchase.

The last two budget cycles (2021-2023) have been marked by historic investments in clean transportation funding. A cumulative $10 billion has been earmarked for ZEV-related investments over the next three to five years.

In November 2022, CARB approved a $2.6 billion investment plan for clean transportation incentives for the 2022-2023 fiscal year.[295] The CPUC will invest $1 billion over five years to support a transportation electrification program, with 70% earmarked for charging infrastructure for medium- and heavy-duty vehicles.[296]

Low-carbon fuels

While ZEVs are likely to provide the largest share of GHG emission reductions from the transportation sector, other technologies will need to play a complementary role. The rate of ZEV deployment is effectively capped by the number of new vehicle sales and the retirement of conventional vehicles out of the fleet.

Even if Advanced Clean Cars II is successful, in 2035, California's vehicle fleet is still likely to include almost 5 million light-duty and 500,000 medium- and heavy-duty conventional vehicles. Collectively, these vehicles will require roughly 2.5 billion gallons per year of liquid fuels.[297] Achieving carbon neutrality would be impossible if this demand were met by petroleum gasoline and diesel. Similarly, achieving or significantly exceeding California's current target of 5 million ZEVs by 2030 may not generate sufficient emission reductions from the transportation sector to reach targets established by SB 32 (Pavley, 2016).

California will also need to deploy a significant amount of low-carbon alternative fuels capable of reducing emissions from conventional gasoline and diesel engines (known as "drop-in" fuels). At present, only biofuels have demonstrated the capacity to reach market at commercial scale. However, a significant fraction of such fuels at present (and likely through the next decade) use crop-based feedstocks, which provide only modest GHG benefits compared to petroleum. Several technologies— including cellulosic fuels, e-fuels synthesized using renewable electricity, and fuels made from algae—have emerged as candidates to supply large volumes of liquid fuels that reduce GHG emissions by 60% or more compared to petroleum. However, these technologies have yet to demonstrate successful operation at commercial scale and will need continued policy support if they are to fulfill this role in California's fuel portfolio.

Some applications—such as aviation, marine, long-distance freight rail, and emergency backup power—are not well-suited for electrification and will likely need other technologies. Long-distance aviation in particular is likely to need liquid fuels due to energy density and operational safety requirements.

In recent years, alternative jet fuel made from "hydrotreated" fats, oils, and greases has started to enter the California market. Almost 12 million gallons of these fuels were consumed in California in 2022.[298] These alternative aviation fuels use the same feedstocks as renewable diesel and are often produced at the same refinery, suggesting there is likely to be some competition between the two.

295 California Air Resources Board. (2022). Fiscal Year 2022-23 Funding Plan for Clean Transportation Incentives. Accessed on 12/01/2022 at: https://ww2.arb.ca.gov/sites/default/files/2022-11/funding_plan_key_proposals_final.pdf.

296 California Public Utilities Commission. (2022). CPUC Adopts Transportation Electrification Program to Help Accelerate Electric Vehicle Adoption. Accessed on 12/01/2022 at: https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M498/K953/498953325.PDF.

297 Brown, A.L. et al. (2021). Chapter 9: Fuel Technology and Policy to Support a Carbon-Neutral Transportation System *in* Driving California's Transportation Emissions to Zero. *UC Institute of Transportation Studies.* Available at: https://escholarship.org/uc/item/3np3p2t0.

298 California Air Resources Board. (2023). Low Carbon Fuel Standard Reporting Tool Quarterly Summaries. Accessed on 05/29/2023 at: https://ww2.arb.ca.gov/resources/documents/low-carbon-fuel-standard-reporting-tool-quarterly-summaries.

While ZEVs are likely to provide the largest share of GHG emission reductions from the transportation sector, other technologies will need to play a complementary role.

To date, most renewable diesel and hydrotreated aviation fuel consumed in California has been made from waste oils (e.g., used cooking oil and tallow from food processing). Supplies of these waste products are, for the most part, already fully exploited in North America. Thus, any future growth in renewable diesel or hydrotreated aviation fuel would need to come from other resources, like agricultural residue, forest residue, and crop oils. Attempts to produce fuels using agricultural and forest residues as feedstock at commercial scale have not yet been successful.

Waste- and residue-based fuels offer substantial GHG benefits, while using crops for feedstock may cause inadvertent harm to food markets or cause emissions from expansion of agricultural land. As the shift to ZEVs continues, the amount of liquid fuel needed for on-road transportation will decline, offering an opportunity to shift some of the fuel supply from that market to aviation.

Reducing vehicle miles traveled

SB 375 (Steinberg, 2008) directed California's 18 regional metropolitan planning organizations to develop plans to reduce per capita **vehicle miles traveled** (**VMT**), or how much the average Californian drives.

These plans—Sustainable Communities Strategies—consider the interactions between transportation, land use, and housing decisions that impact driving patterns (e.g., proximity of housing to key destinations like parks, schools, and jobs). However, according to CARB's Draft 2022 Progress Report, per capita VMT have increased rather than decreased.

This is in part because of the challenge involved in changing personal travel behavior in relatively fixed urban environments, and partly because local planning agencies have been unwilling or unable to overcome objections to higher-density, more sustainable land use plans. Improved implementation will require more concerted funding mechanisms and greater alignment across state, regional, and local actions.[299]

In an effort to minimize sprawl and encourage development conducive to walking and biking, SB 743 (Steinberg, 2013) updated CEQA to use a VMT metric—rather than congestion—to assess the transportation impacts of projects (effective 2020). This shift alleviates a potential hurdle to more compact development which will reduce the amount of driving overall but affect local congestion.

SB 99 (Committee on Budget and Fiscal Review, 2013) established the Active Transportation Program to encourage active modes of mobility by developing safe pathways. In addition to supporting decarbonization, this program provides health benefits and is targeted at diverse users, including those in **disadvantaged communities**. The program has been "incredibly oversubscribed"[300] since its inception.[301] In response, the State Budget Act of 2022 (SB 154, Skinner) allocated an additional $1.05 billion to the program. The Electric Bicycle Incentive Project, launching early 2023, will leverage $10 million in funding to help low-income Californians purchase e-bikes.[302]

Environmental Justice and Equity Considerations

Non-white and low-income communities are more likely to be located near highways[303] and experience disproportionate exposure to vehicle-related pollution.[304] For example, a study in Los Angeles found that low-income communities have twice the road density as the wealthiest neighborhoods.[305]

Areas with lower household incomes and Black and Hispanic majority populations are less likely to have access to public chargers in California.[306] Further, disadvantaged communities and Black-identifying households are more likely to confront grid infrastructure limits that complicate the grid interconnection necessary to install home chargers.[307]

Despite the numerous incentive programs available in California, low-income consumers may still experience financial barriers to purchasing new or even used ZEVs.[308] Research demonstrates that rebates like the Clean Vehicle Rebate Program have been disproportionately allocated to higher income, more educated consumers living in less-polluted areas.[309] Equity-focused provi-

299 California Air Resources Board. (2022). Draft 2022 Progress Report: California's Sustainable Communities and Climate Protection Act. Accessed on 12/01/2022 at: https://ww2.arb.ca.gov/sites/default/files/2022-06/2022_SB_150_Main_Report_Draft_1.pdf.

300 Waters, L. et al. (2022). Active Transportation Program. *California Transportation Commission*. Accessed on 12/01/2022 at: https://catc.ca.gov/programs/active-transportation-program.

301 Waters, L. et al. (2022). Active Transportation Program. *California Transportation Commission*. Accessed on 12/01/2022 at: https://catc.ca.gov/programs/active-transportation-program.

302 California Air Resources Board. (2022). Nonprofit Administrator Selected to Implement New Statewide, Income-Based Electric Bicycle Incentive Project. Accessed on 12/01/2022 at: https://ww2.arb.ca.gov/news/nonprofit-administrator-selected-implement-new-statewide-income-based-electric-bicycle.

303 US Department of Transportation. (2013). Health and Equity. Accessed on 12/01/2022 at: https://www.transportation.gov/mission/health/health-equity.

304 Boeing, G. et al. (2021). Race, Class, and the Production of and Exposure to Vehicular Pollution in Los Angeles. *Pacific Southwest Region University Transportation Center.* Available at: https://rosap.ntl.bts.gov/view/dot/59264.

305 Houston, D. et al. (2004). Structural Disparities of Urban Traffic in Southern California: Implications for Vehicle-Related Air Pollution Exposure in Minority and High-Poverty Neighborhoods. *Journal of Urban Affairs,* 26(5), pp 565-592.

306 Hsu, C. W., and Fingerman, K. (2020). Public Electric Vehicle Charger Access Disparities Across Race and Income in California. *Transport Policy,* 100, pp 59-67.

307 Brockway, A.M., Conde, J., and Callaway, D. (2021). Inequitable Access to Distributed Energy Resources due to Grid Infrastructure Limits in California. *Nature Energy*, 6(9), pp. 892-903.

308 Hardman, S. et al. (2021). A Perspective on Equity in the Transition to Electric Vehicles. MIT Science Policy Review. Available at: https://sciencepolicyreview.org/2021/08/equity-transition-electric-vehicles/.

309 Ju, Y. et al. (2020). An Equity Analysis of Clean Vehicle Rebate Programs in California. Climate Change, 162(4), pp 2087-2105.

sions, like tiered rebate structures (implemented for the Clean Vehicle Rebate Program in 2016) helped address, but did not eliminate, these disparities.[310] Implementing additional equity-focused design elements could further improve equitable allocation of ZEV incentives. Point-of-sale discounts or grants (like that provided by the Clean Vehicle Assistance Program) may be more helpful as they don't require low-income consumers to front the capital for a ZEV before receiving a rebate. A limited number of low-interest loans are also available through the Clean Vehicle Assistance Program. Ultimately, since lower-income Californians almost exclusively buy used vehicles, deployment of ZEVs in lower-income communities may be contingent upon there being enough ZEVs entering the used vehicle market.

Other barriers to decarbonized transportation options include concerns for personal safety, including fear of crime and injury during shared or active transportation; exposure to infectious diseases like COVID-19 on public transit; poor access to alternative transportation modes within communities, including limited hours or inconvenient routes of transport options; unaffordability; lack of access to funding for clean transportation and mobility projects; limited awareness of clean transportation options; and a lack of permanent long-term funding for transportation.[311]

While disadvantaged communities clearly face challenges that complicate efforts to address environmental justice problems, California's progress toward carbon neutrality is likely to help. Many air quality problems facing disadvantaged communities are due to the combustion of fossil fuels; emissions from diesel-fueled vehicles are a significant source of their pollution burden.

The LCFS has led to over 40% of California's diesel fuel being replaced by renewable diesel, which offers some air quality advantages compared to petroleum. The transition to ZEVs across the transportation sector will yield even bigger improvements in air quality for communities near roads. Modeling studies have indicated that broad adoption of renewable fuels and clean energy is likely to improve air quality and reduce the size of racial and income-based disparities in air pollutant exposure.[312]

Relevant Policies

(Laws/Regulations)

California Global Warming Solutions Act

AB 32 (Nunez, 2006)

AB 32 requires California to reduce greenhouse gas emissions to 1990 levels by 2020 and is designed to mitigate risks of climate change, improve energy efficiency, expand renewable energy, support cleaner transportation, and reduce waste. SB 32 (Pavley, 2016) expanded emissions targets to reflect a 40% reduction from 1990 levels by 2030.

Alternative Fuel and Vehicle Technologies

AB 118 (Núñez, 2007)

AB 118 established the Clean Transportation Program (formerly the Alternative and Renewable Fuel and Vehicle Technology Program). The program supports innovation and development of advanced transportation and fuel technologies. AB 8 (Perea, 2013) restructured and extended the program through January 1, 2024, with a provision to allocate funds from the Clean Transportation Program to create public hydrogen refueling stations.

The program supports fueling and charging stations for low- and zero-emission vehicles; development and implementation of alternative fuel and advanced technology vehicles; production of

310 Ju, Y. et al. (2020). An Equity Analysis of Clean Vehicle Rebate Programs in California. Climate Change, 162(4), pp 2087-2105.

311 California Air Resources Board. (2018). Low-Income Barriers Study, Part B: Overcoming Barriers to Clean Transportation Access for Low-Income Residents. Available at: https://ww2.arb.ca.gov/sites/default/files/2018-08/sb350_final_guidance_document_022118.pdf.

312 Li, Y. et al. (2022). Future Emissions for Particles and Gases that Cause Regional Air Pollution in California under Different Greenhouse Gas Mitigation Strategies. *Atmospheric Environment*, 273, pp. 118960.

low-carbon renewable fuels; and relevant workforce training in the manufacturing sector.

Low Carbon Fuel Standard
Executive Order S-01-07, 2007

The Low Carbon Fuel Standard (LCFS) is administered by CARB. LCFS was launched in 2011 after being formally established by Executive Order S-01-07 and identified by CARB's 2008 Scoping Plan as an early action to reduce greenhouse gas emissions.

LCFS assesses a carbon-intensity (CI) value for transportation fuels based on lifetime GHG emissions associated with the production, transportation, and use of those fuels. All fuels are compared to a declining CI target. Fuels with increasingly lower CIs than the target generate more credits, while fuels with CIs that exceed the target generate deficits. This incentivizes fuel providers to procure low-carbon fuels to sell credits to fuel providers generating deficits. The LCFS requires the average CI of all transportation fuels to decline over time, beginning with a quarter of a percent in 2011 and targeting a 20% reduction by 2030.[313] CARB is currently considering increasing the 2030 CI reduction target from 20% to 25%, 30%, or 35%.[314]

Transportation Planning: Travel Demand Models: Sustainable Communities Strategy
SB 375 (Steinberg, 2008)

SB 375 requires metropolitan planning organizations to develop strategies for reducing greenhouse gas emissions associated with passenger vehicles as part of their regional transportation plans. Greenhouse gas emission reduction targets would be provided by CARB. These plans—Sustainable Communities Strategies—outline strategies to reduce vehicle miles traveled by considering the interactions between transportation, land use, and housing decisions that impact driving patterns (e.g., proximity of housing to key destinations like parks, schools, and jobs).

Active Transportation Program (ATP)
SB 99 (Cmte. on Budget and Fiscal Review, 2013)

ATP encourages active modes of transportation (such as walking and biking) by increasing safety and mobility options. The program provides a range of projects to benefit diverse users including disadvantaged communities.

Environmental Quality: Transit Oriented Infill Projects
SB 743 (Steinberg, 2013)

Among other things, SB 743 updated the California Environmental Quality Act guidelines to consider the impacts of development on vehicle-miles traveled. This was enacted with the intent to better balance the state's goal of reducing vehicle miles traveled with that of reducing traffic congestion.

Electric Vehicle Charging
AB 1236 (Chiu, 2015)

AB 1236 requires local governments to develop streamlined ordinances for electric vehicle charging infrastructure.

Clean Energy Pollution Reduction Act
SB 350 (de León, 2015)

SB 350 mandated that the CEC study barriers to clean energy technologies confronted by low-income and disadvantaged communities. The Low-Income Barriers Study, Part B analyzed barriers to clean transportation access.

The Road Repair and Accountability Act
SB 1 (Beall, 2017)

SB 1 provides funding for transportation development, including at the local level, to provide more transportation choices and preserve and enhance communities. The act significantly augments funding provided when the Active Transportation Program was established in 2013.

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313 California Air Resources Board. (2022). Low Carbon Fuel Standard. Accessed on 12/01/2022 at: https://ww2.arb.ca.gov/our-work/programs/low-carbon-fuel-standard.

314 California Air Resources Board. (2022). Low Carbon Fuel Standard—Public Workshop: Concepts and Tools for Compliance Target Modeling. Accessed on 12/01/2022 at: https://ww2.arb.ca.gov/sites/default/files/2022-11/LCFSPresentation.pdf.

California Clean Miles Standard and Incentive Program: Zero-emission Vehicles
SB 1014 (Skinner, 2018)

SB 1014 establishes the California Clean Miles Standard and Incentive Program. This law requires CARB to establish annual per-passenger-mile emission reduction targets for transportation network companies.

Autonomous Vehicles: Zero Emissions
SB 500 (Min, 2021)

SB 500 prohibits the operation of emission-producing autonomous vehicles starting in 2030.

Advanced Clean Cars II (ACCII)

ACCII requires that 100% of in-state sales of new passenger cars, trucks, and SUVs be zero-emission vehicles by 2035. Full battery electric vehicles, hydrogen fuel cell electric vehicles, and plug-in hybrid electric vehicles (with an all-electric range of at least 50 miles) will count towards zero-emission requirements for automakers.[315] No more than 20% of an automakers' zero-emission vehicle requirements can be met by plug-in electric hybrids.

Read More

Driving California's Transportation Emissions to Zero
Brown et al. (2021). UC Inst. of Transp. Studies.

Distribution Grid Impacts of Electric Vehicles: A California Case Study
Jenn, A., and Highleyman, J. (2022). iScience, 25(1).

Enhancing Equity while Eliminating Emissions in California's Supply of Transportation Fuels
Deschenes, O. et al. (2021). UC Santa Barbara.

Factors Affecting Plug-in EV Sales in California
University of California Los Angeles. (2017).

Emissions Associated with EV Charging: Impact of Electricity Generation Mix, Charging Infrastructure Availability, and Vehicle Type
McLaren, J. et al. (2016). National Renewable Energy Lab. Tech. Report: NREL/TP-6A20-6485-2.

315 California Air Resources Board. (2022). California Moves to Accelerate to 100% New Zero-Emission Vehicle Sales by 2035. Accessed on 12/01/2022 at: https://ww2.arb.ca.gov/news/california-moves-accelerate-100-new-zero-emission-vehicle-sales-2035.

8

Cap-and-Trade

Leveraging market mechanisms to incentivize decarbonization through 2030 (and beyond?).

Overview

As part of its implementation of AB 32 (Nunez, 2006), the California Air Resources Board (CARB) launched the statewide Cap-and-Trade Program in late 2012. The program initially covered greenhouse gases (GHGs)—including carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O)—produced by the industrial and electricity sectors. Emissions associated with transportation fuels and natural gas distributors were added to the program in 2015.

Currently about 75% of statewide emissions are covered by the cap, including emissions from electricity imports and fuel imported and consumed in the state.[316] As a result of implementation decisions, the direct contributions of Cap-and-Trade to emission reductions achieved in California are suspected to be modest in comparison with other programs.[317] Expenditures from the Greenhouse Gas Reduction Fund (GGRF) supported by Cap-and-Trade auction proceeds contribute additional emission reductions (see **Figure 8.1**).[318] The future role of Cap-and-Trade in driving emission reductions through 2030 (when the program is currently set to expire) is uncertain. Analysts have cautioned that excessive **banked allowances*** jeopardize California's ability to reach 2030 emission reduction targets.[319,320]

Compared to the 2017 Scoping Plan, CARB's 2022 Scoping Plan predicts a much more modest role for Cap-and-Trade in driving future reductions in GHG emissions. However, the Independent Emissions Market Advisory Committee—established by AB 398 (Eduardo Garcia, 2017) to analyze the performance of Cap-and-Trade—has recommended several reforms that could make the program play a larger role in driving emission reductions.

Facilities regulated by Cap-and-Trade are disproportionately located in communities with greater numbers of residents of color and residents living in poverty. Environmental justice advocates argue the program inadvertently leads to increased pollution in these communities, because it does not require these facilities to directly reduce emissions if the operating firms satisfy their compliance obligations in other ways.

316 California Air Resources Board. (2022). Mandatory Greenhouse Gas Reporting, 2021 Emissions Year Frequently Asked Questions. Available at: https://ww2.arb.ca.gov/sites/default/files/classic/cc/reporting/ghg-rep/reported-data/2021mrrfaqs.pdf.

317 Legislative Analyst's Office. (2019). Assessing California's Climate Policies. Available at: https://lao.ca.gov/handouts/resources/2019/Assessing-California-Climate-Policies-022019.pdf.

318 California Climate Investments. (2023). 2023 Annual Report: Cap-and-Trade Auction Proceeds. Available at: https://ww2.arb.ca.gov/sites/default/files/auction-proceeds/cci_annual_report_2023.pdf.

319 Legislative Analyst's Office. (2017). Cap-and-Trade Extension: Issues for Legislative Oversight. Available at: https://lao.ca.gov/Publications/Report/3719.

320 Burtraw, D. et al. (2022). 2021 Annual Report of the Independent Emissions Market Advisory Committee. Available at: https://calepa.ca.gov/wp-content/uploads/sites/6/2022/01/2021-IEMAC-Annual-Report.a.pdf.

* Find **bold** words in the Glossary (Appendix A).

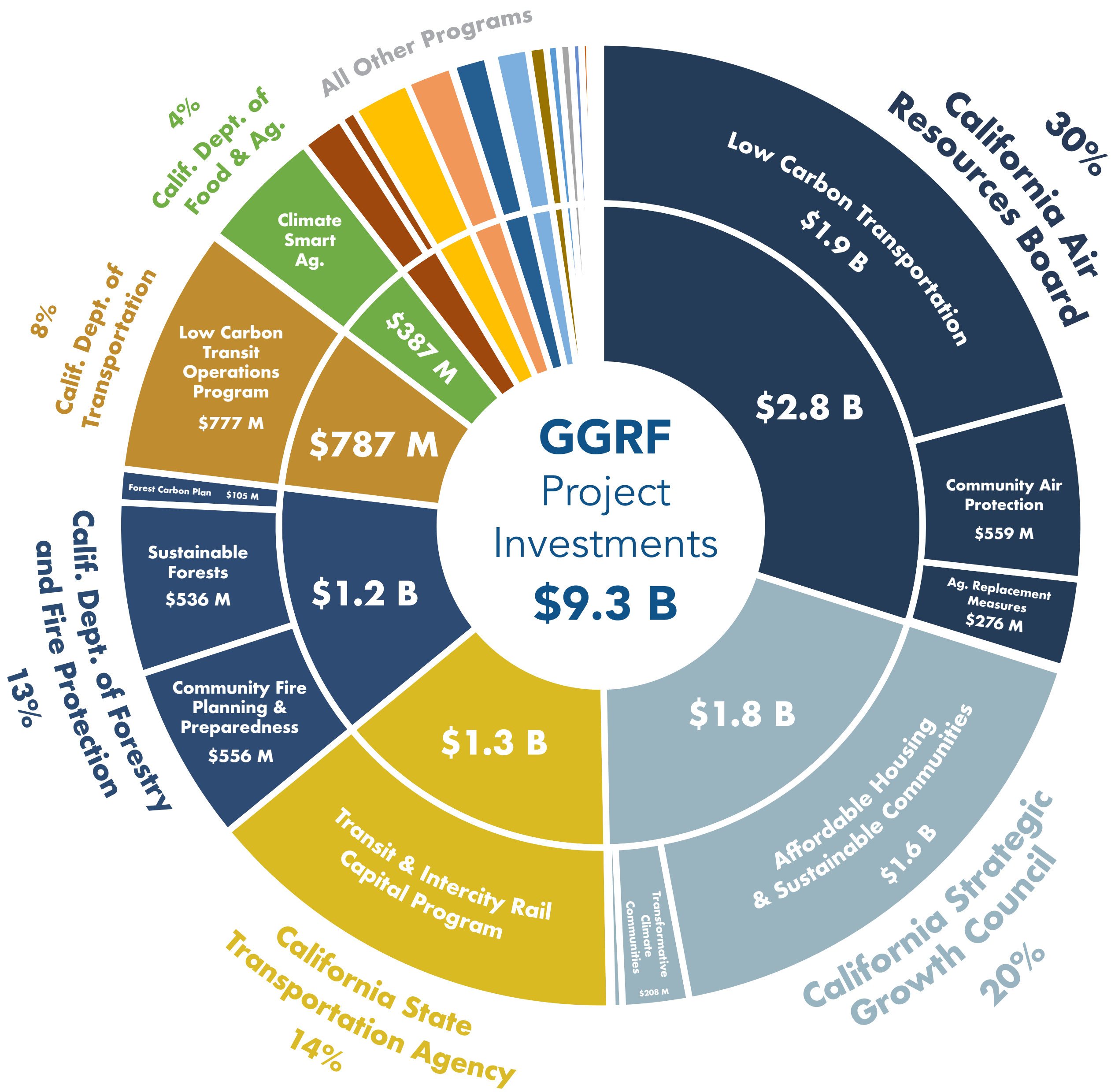

Figure 8.1. Greenhouse Gas Reduction Fund project investments by agency and program, all-time (as of Nov. 30, 2022). Data are for "implemented" projects, notably not including the in-process High Speed Rail Project ($5.4 B). Data are from the California Climate Investments Data Dashboard by CARB. (2023). Smaller categories may not be visible here. View online for full data.

Available at: https://public.tableau.com/app/profile/california.air.resources.board/viz/CaliforniaClimateInvestmentsDataDashboard/AppropriatedFunds.

Cap-and-Trade Fundamentals

Under California's Cap-and-Trade Program, a soft cap or limit is set on emissions, which grows more stringent over time. For every metric ton of GHGs allowed, CARB makes available an equivalent number of **allowances**. Some allowances are given directly to facilities ("free allowances") while others are introduced as tradeable permits that are auctioned on the open carbon market to covered GHG emitters and other market participants. To be in compliance with the program, covered entities—which include electric power plants, large industrial plants, and fuel distributors—must surrender one permit for every metric ton of GHGs they emit. If emissions exceed the supply of allowances, covered entities must buy additional ones at a specified maximum price (this has not happened to date). California's Cap-and-Trade Program is linked with a program in Quebec for carbon trading.

Entities may also trade for **offset credits** (i.e., credits generated by projects that reduce GHG emissions from sectors outside of California's climate policy jurisdiction) to meet compliance obligations. As of 2021, 4% of an entity's total emissions can be accounted for with offset credits; this will increase to 6% in the period 2026-2030.[321] As per AB 398 (Eduardo Garcia, 2017), at least 50% of an entity's offset credits must be generated by projects with direct environmental benefits for California.

Whether California's Cap-and-Trade Program should include offset credits has generated much debate. The impact on climate change remains the same whether emissions reductions occur in California or elsewhere. Offsets may play an important role in global climate policy by supporting GHG reduction projects elsewhere that may not have otherwise occurred due to political opposition, market failures, or lack of resources. Furthermore, offset credits can reduce the cost of compliance with the Cap-and-Trade program. However, ensuring that offset credits produce emission reductions that are permanent (lasting at least 100 years) and additive (resulting in more GHG reduction benefits than would have occurred otherwise) remains a challenge.[322] Some projects credited to date do not appear to have met these criteria.[323] Further, direct emissions reductions often generate other co-benefits (e.g., reductions in harmful air pollution) that some argue should accrue to **disadvantaged communities** in "California First."[324]

Relevant State Institutions

- California Air Resources Board (CARB)
- California Environmental Protection Agency (CalEPA)
- Independent Emissions Market Advisory Committee (IEMAC)
- Governor's Office of Business and Economic Development
- Assembly Budget Subcommittee No. 3 Climate Crisis, Resources, Energy, and Transportation
- Assembly Natural Resources
- Senate Budget Subcommittee No. 2 on Resources, Environmental Protection and Energy
- Senate Environmental Quality Committee
- Senate Natural Resources and Water Committee
- Joint Leg. Committee on Climate Change Policies

Cap-and-Trade is designed to provide a steadily increasing **price signal** that will encourage entities to make long-term investments to reduce their GHG emissions. This is accomplished through the combination of an established minimum price

321 Garcia, E. (2017). AB 398. California Global Warming Solutions Act of 2006: Marked-Based Compliance Mechanisms. *California State Legislature*. Available at: https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201720180AB398.

322 Burtraw, D. et al. (2022). 2021 Annual Report of the Independent Emissions Market Advisory Committee. Available at: https://calepa.ca.gov/wp-content/uploads/sites/6/2022/01/2021-IEMAC-Annual-Report.a.pdf.

323 Badgley, G. et al. (2021). Systematic Over-Crediting in California's Forest Carbon Offsets Program. *Global Change Biology*. 28(4), pp 1433-1445.

324 Lueders, J. et al. (2014). The California REDD+ Experience: The Ongoing Political History of California's Initiative to Include Jurisdictional REDD+ Offsets within its Cap-and-Trade System. *Center for Global Development*. Available at: https://www.cgdev.org/sites/default/files/CGD-Climate-Forest-Paper-Series-13-Lueders-Horowitz-et-al-California-REDD.pdf.

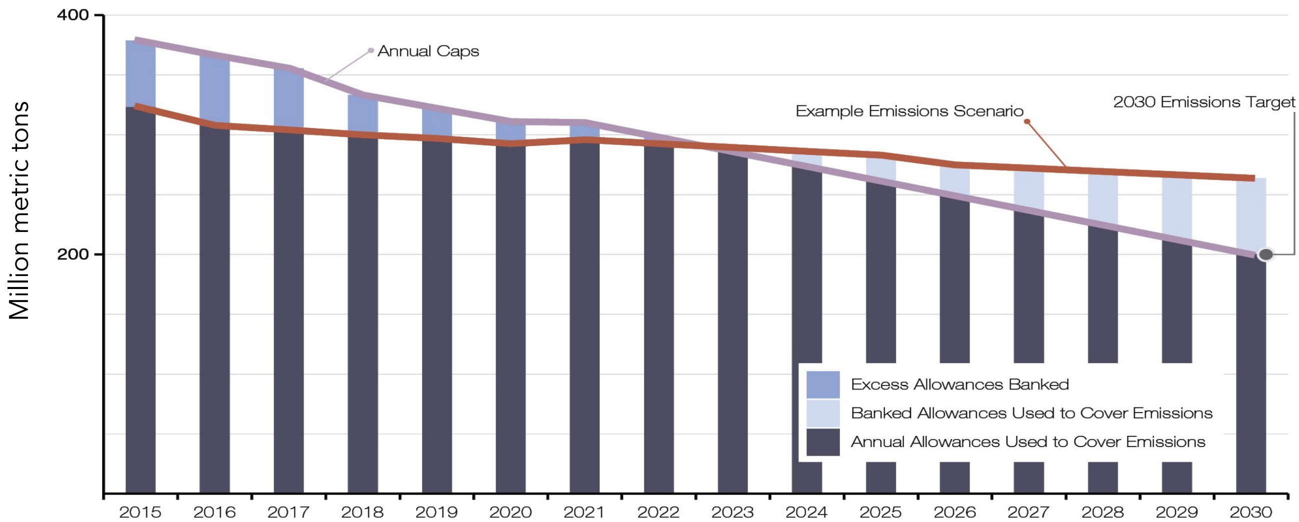

Figure 8.2. Scenario illustrating how the accumulation of banked allowances increases risk of exceeding GHG target.

Source: Brown, R. (2017). Cap-and-Trade Extension: Issues for Legislative Oversight. *Legislative Analyst's Office*. Available at: https://lao.ca.gov/Publications/Report/3719.

(or "price floor") that increases each year and a declining emissions cap. The program has a mechanism to remove unsold allowances from circulation under certain market conditions, but this mechanism has predominantly served to temporarily remove unsold allowances that have later been reintroduced in the market.

Cap-and-Trade lets the market determine carbon prices (within the bounds of price floors and ceilings set by CARB) and provides covered entities flexibility in identifying the cheapest options for reducing emissions, but a surplus of allowances (relative to emissions) has kept prices in the market at or near the price floor through much of the program's lifetime (see Challenges below).[325,326]

State proceeds from Cap-and-Trade auctions are deposited into the Greenhouse Gas Reduction Fund, which support projects funded by a range of programs included in the California Climate Investments Program. AB 1550 (Gomez, 2016) requires that at least 35% of the revenue from the auctions is directed towards projects that are located in or near, or provide benefits to, low-income and disadvantaged communities (defined in SB 535, de León, 2012).[327] Since the program began, $11.4 billion dollars of revenue has been invested, with at least $5.4 billion benefitting communities as defined in AB 1550 (as of May 2022).[328] The Climate Investment Program has resulted in an estimated 78.6 million metric tons (MMT) of emission reductions.[329]

325 Taylor, M. (2017). The 2017-18 Budget: Cap-and-Trade. The Legislative Analyst's Office. Available at: https://lao.ca.gov/reports/2017/3553/cap-and-trade-021317.pdf.

326 California Air Resources Board. (2023). Cap-and-Trade Program Data Dashboard: Carbon Allowance Prices. Accessed on 5/24/2023 at: https://ww2.arb.ca.gov/our-work/programs/cap-and-trade-program/program-data/cap-and-trade-program-data-dashboard#Figure7.

327 California Environmental Protection Agency. (2022). California Climate Investments to Benefit Disadvantaged Communities. Accessed on 12/01/2022 at: https://calepa.ca.gov/envjustice/ghginvest/.

328 California Air Resources Board. (2022). California Climate Investments 2022 Mid-Year Data Update. Available at: https://ww2.arb.ca.gov/sites/default/files/auction-proceeds/cci_2022_mydu_cumulativeoutcomes.pdf.

329 California Air Resources Board. (2022). California Climate Investments 2022 Mid-Year Data Update. Available at: https://ww2.

Challenges

Other regulatory programs—as well as the Great Recession[330]—led to emissions reductions greater than what was anticipated when Cap-and-Trade was introduced. For example, emissions from the electricity sector have been reduced by 64% (from 93.4 MMT in 2013 to 59.5 MMT of CO_2 in 2020),[331] largely due to the Renewables Portfolio Standard Program and other cross-sectoral policies.[332] This effectively led to a surplus of emission allowances, which has kept prices at or near the price floor (up until around August 2021) and weakened the ability of the market to drive any further emission reductions.[333]

Entities can bank unused allowances to meet emissions requirements in later years. The relatively low cost of allowances, combined with predicted cost increases in the future (that would be driven by the increasingly stringent emission reduction requirements) created an incentive to purchase excess allowances to be banked for future use. By the end of 2020, banked allowances exceeded the cumulative emissions reductions Cap-and-Trade was meant to deliver through 2030.[334] Thus, if these banked allowances are used for compliance for the next seven years, entities could still be in technical compliance with the program while collectively emitting above program caps (see **Figure 8.2**).[335]

Thus far, CARB has not taken action to address the issue of banked allowances. In 2021, CARB prepared a report for the California legislature that details their justification for not having acted on the matter.[336] However, CARB is currently evaluating potential changes to Cap-and-Trade that would better align the program with the increased stringency necessary to achieve the new emissions reductions mandated by AB 1279 (Muratsuchi, 2022). They will be considering in this evaluation the potential impact of banked allowances.

Because of the high amount of electricity imported into California, the Cap-and-Trade system is susceptible to resource shuffling—a type of "**leakage**" where apparent reduced in-state emissions correspond with increased out-of-state emissions (where the Cap does not apply), and thus no net reduction in emissions actually occurs.[337] For example, resource shuffling would occur if a utility purchases power from a less-carbon intensive power generator to meet emissions standards, but the carbon-intensive generator with whom they were previously contracted continues to provide power to another utility outside of California not covered by the program. CARB has taken steps to reduce the potential for resource shuffling,[338] though some assert resource shuffling likely remains a problem.[339] Expanding the scope of climate policies (either by direct linkage with programs

arb.ca.gov/sites/default/files/auction-proceeds/cci_2022_mydu_cumulativeoutcomes.pdf.

330 Mastrandrea, M. D. et al. (2020) Assessing California's Progress Toward its 2020 Greenhouse Gas Emissions Limit. *Energy Policy,* 138, 111219.

331 California Air Resources Board. (2022). California Greenhouse Gas Emission Inventory - 2022 Edition. Available at: https://ww3.arb.ca.gov/cc/inventory/data/data.htm.

332 Petek, G. (2020). Assessing California's Climate Policies – Electricity Generation. *Legislative Analyst's Office*. Available at: https://lao.ca.gov/reports/2020/4131/climate-policies-electricity-010320.pdf.

333 Burtraw, D. et al. (2022). 2021 Annual Report of the Independent Emissions Market Advisory Committee. Available at: https://calepa.ca.gov/wp-content/uploads/sites/6/2022/01/2021-IEMAC-Annual-Report.a.pdf.

334 Burtraw, D. et al. (2022). 2021 Annual Report of the Independent Emissions Market Advisory Committee. Available at: https://calepa.ca.gov/wp-content/uploads/sites/6/2022/01/2021-IEMAC-Annual-Report.a.pdf.

335 Legislative Analyst's Office. (2017). Cap-and-Trade Extension: Issues for Legislative Oversight. https://lao.ca.gov/Publications/Report/3719.

336 California Air Resources Board. (2021). BR 18-51 Cap-and-Trade Allowance Report. Available at: https://ww2.arb.ca.gov/sites/default/files/cap-and-trade/Allowance%20Report_Reso18_51.pdf

337 Pauer, S. U. (2018). Including Electricity Imports in California's Cap-And-Trade Program: A Case Study of a Border Carbon Adjustment in Practice. *The Electricity Journal*, 31(10), pp 39-45.

338 California Air Resources Board. (2020). Review of Potential for Resource Shuffling in the Electricity Sector. Available at: https://ww2.arb.ca.gov/sites/default/files/cap-and-trade/guidance/resource_shuffling_faq.pdf.

339 Burtraw, D. et al. (2022). 2021 Annual Report of the Independent Emissions Market Advisory Committee. Available at: https://

in other jurisdictions or by other jurisdictions adopting policies of comparable stringency) is another way to reduce leakage.

Environmental Justice and Equity Considerations

Facilities regulated by Cap-and-Trade are disproportionately located in communities with greater numbers of residents of color and residents living in poverty.[340] Evidence is mixed whether such communities have benefited from or been harmed by Cap-and-Trade. For example, one study found that Cap-and-Trade benefits have disproportionately accumulated in wealthier neighborhoods, while disadvantaged communities and communities with greater percentages of people of color have experienced fewer air quality improvements, and in some cases, worsened air quality.[341]

However, other research—including an analysis by the Office of Environmental Health Hazard Assessment—has found that Cap-and-Trade has been correlated with air quality improvements for disadvantaged communities and a narrowing of the "**pollution gap**" though inequities persist.[342,343]

CARB has been working to address pollution inequities through a variety of other programs, including the California Climate Investment Program.[344] The Environmental Justice Advisory Committee (EJAC)—which advises CARB on the scoping plan—recommends that "no-trade zones" be established in pollution hotspots. Facilities in no-trade zones would be required to demonstrate direct emission reductions rather than being able to meet compliance with purchased allowances.[345]

EJAC has suggested that CARB eliminate the allocation of free allowances (currently required by AB 398, Eduardo Garcia, 2017) and the option to meet emissions targets with carbon offsets. Should carbon offsets continue, EJAC recommends that offset-generating projects should be restricted to the same vicinity where the emissions occur.

Relevant Policies
(Laws/Regulations)

California Global Warming Solutions Act
AB 32 (Nunez, 2006)

AB 32 established the State Air Resources Board (now the California Air Resources Board, or CARB) with responsibility to monitor and regulate sources of greenhouse gas emissions. AB 32 required CARB to limit the statewide greenhouse gas emissions to 1990 levels by 2020. AB 32 authorized CARB to include the use of market-based compliance mechanisms to meet these aims. SB 32 (Pavley, 2016) expanded emissions targets to reflect a 40% reduction from 1990 levels by 2030.

calepa.ca.gov/wp-content/uploads/sites/6/2022/01/2021-IEMAC-Annual-Report.a.pdf.

340 Cushing, L. J. et al. (2016). A Preliminary Environmental Equity Assessment of California's Cap-and-Trade Program. Available at: https://dornsife.usc.edu/assets/sites/242/docs/Climate_Equity_Brief_CA_Cap_and_Trade_Sept2016_FINAL2.pdf.

341 Pastor, M. et al. (2022). Up in the Air: Revisiting Equity Dimensions of California's Cap-and-Trade System. Available at: https://dornsife.usc.edu/assets/sites/1411/docs/CAP_and_TRADE_Updated_2020_v02152022_FINAL.pdf.

342 Plummer, L. et al. (2022). Impacts of Greenhouse Gas Emissions Limits within Disadvantaged Communities: Progress Toward Reducing Inequities. *Office of Environmental Health Hazard Assessment*. Available at: https://oehha.ca.gov/media/downloads/environmental-justice//impactsofghgpoliciesreport020322.pdf.

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In response, CARB developed and adopted Cap-and-Trade regulations in 2011 for an emissions trading scheme launched in 2012. Compliance obligations for electricity generators and large industrial facilities began in 2013.

California Global Warming Solutions Act of 2006: Greenhouse Gas Reduction Fund
SB 535 (de León, 2012)

SB 535 mandated that proceeds of Cap-and-Trade auctions be directed towards funding investments in disadvantaged communities (DACs). Recognizing that low-income communities suffer disproportionate levels of pollution, SB 535 also charged the California Environmental Protection Agency (CalEPA) to designate DACs, using "geographic, socioeconomic, public health, and environmental hazard criteria," but with broad discretion. In May 2022, CalEPA finalized its Designation of Disadvantaged Communities.

Public Resources
SB 1018 (Cmte. on Budget and Fiscal Review, 2012)

SB 1018 established the Greenhouse Gas Reduction Fund within the State Treasury, where Cap-and-Trade auction proceeds are deposited for the California Climate Investments Program.

Greenhouse Gases: Investment Plan: Disadvantaged Communities
AB 1550 (Gomez, 2016)

AB 1550 updated investment targets set in SB 535 (de León, 2012) for funds generated from Cap-and-Trade auctions. AB 1550 requires that 1) at least 25% of the revenue to go to projects located in and that benefit disadvantaged communities (defined in SB 535, de León, 2012); 2) 5% be directed to projects located in or that benefit low-income communities; and 3) 5% be directed to projects located within or that benefit households within 0.5 miles of a disadvantaged communities.

California Global Warming Solutions Act of 2006: Emissions Limit
SB 32 (Pavley, 2016)

SB 32 mandated that CARB reduce greenhouse gas emissions to 40% of 1990 levels by 2030.

California Global Warming Solutions Act of 2006: Market-based Compliance Mechanisms: Fire Prevention Fees
AB 398 (Eduardo Garcia, 2017)

AB 398 extended Cap-and-Trade to 2030, added a price ceiling for compliance, restricted the number of offset credits that could be met by projects without direct environmental benefits to California to less than 50%, and added preemption of location regulation of CO_2 for facilities under the Cap. AB 398 also established the Independent Emissions Market Advisory Committee which meets at least once a year to analyze the performance of Cap-and-Trade and delivers its findings to CARB and the Joint Legislative Committee on Climate Change Policies.

CARB amended Cap-and-Trade in 2018 to address cost containment, offsets, allocation, phase-out of exemptions, administrative issues, and the delinked program with the Canadian province of Ontario.

Community Air Protection Program
AB 617 (Garcia, 2017)

AB 617 reduces pollution exposure in communities based on environmental, health, and socioeconomic information. This inaugural statewide effort requires community air monitoring, community emission reduction plans, and incentive funding to deploy the cleanest technologies in the most impacted areas.

Read More

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A

Glossary

Allowances: Each allowance is worth one metric ton of carbon dioxide-equivalent emissions in California's Cap-and-Trade program. The California Air Resources Board sets the total emissions cap for each year and introduces a corresponding number of allowances. Some allowances are provided directly to entities while the remainder of allowances are sold at quarterly auctions. Entities are permitted to emit GHGs equivalent to allowances held.

Banked allowances: An allowance that has been purchased but not used in the current year can be banked for future use. California's Cap-and-Trade program allows participants to save allowances for future emissions to alleviate price volatility in the market.

Base load: The minimum amount of power that must be supplied to grid over a given time frame is referred to as the "base load." Base load resources supply the grid with a consistent amount of power.

Battery electric vehicles (BEVs): Vehicles powered solely by the chemical energy stored in rechargeable battery packs with no other source of propulsion.

Behind-the-meter (BTM): Behind-the-meter refers to the position of energy resources in relation to the energy user's electric meter. BTM resources are located onsite and do not require transmission or distribution infrastructure to reach the consumer (as opposed to front-of-meter energy resources supplied by the power grid).

Biomethane: Biomethane (or renewable natural gas) is produced from decaying organic matter through anaerobic digestion by microorganisms. When biomethane is created from organic matter that would have otherwise released methane into the atmosphere (such as from landfills or wastewater treatment facilities), it is often considered to be carbon neutral or carbon negative. Biomethane is chemically identical to natural gas and can be readily substituted for all natural gas applications.

Blue hydrogen: Because of the high reactivity of hydrogen atoms, pure hydrogen (H_2) rarely exists in nature and instead must be produced. There are a variety of different methods for generating pure hydrogen. Blue hydrogen is created from natural gas in a process that includes carbon capture and storage.

Carbon capture and storage (CCS): CCS is the process of capturing, compressing, transporting, and sequestering carbon dioxide (CO_2). Most proposed applications for CCS involve capturing CO_2 that would have otherwise been released into the atmosphere during industrial processes, particularly fuel combustion.

Carbon intensity: Carbon intensity is a measure of how much carbon dioxide (or equivalent greenhouse gas) was emitted during the production of a given unit of electricity, transportation fuel, or some other good. For example, carbon intensities of different energy resources may be provided as kg of CO_2 per megawatt-hour (MWh) of electricity.

Curtail: To curtail is to reduce power generation to balance supply and demand on the grid. Curtailment is necessary when power generators are producing more power than is required by customers or can be absorbed by energy storage systems.

Demand response: Demand response is a method of grid management where consumers are signaled to adjust their energy use in response to grid conditions. Flex Alerts issued by the California Independent System Operator (CAISO) are an example of demand response where consumers are signaled to reduce their energy use (by adjusting their thermostat, avoiding the use of their ovens, etc.).

Disadvantaged communities (DACs): Disadvantaged communities are legally defined by the California Environmental Protection Agency as per SB 535 (de León, 2012). They are identified as those communities throughout California that suffer the most from a combination of economic, health, and environmental burdens, including poverty, high unemployment, air and water pollution, hazardous waste, and high incidence of asthma and heart disease.

Distributed energy resources (DERs): Distributed energy resources are small-scale assets that either generate electricity (e.g., rooftop solar panels), store energy (e.g., 4-hour lithium batteries), or influence energy use (e.g., demand response technologies and energy efficiency). DERs are typically behind-the-meter but may be aggregated and coordinated to provide benefits to the grid.

Duck curve: Coined by the California Independent System Operator (CAISO), the term "duck curve" refers to a chart that displays the difference between energy demand and available renewable energy (known as net demand) over the course of a single day, which roughly resembles the shape of a duck.

Electrification: Electrification refers to the process of replacing fossil fuel-powered technologies or systems with ones powered by electricity. For example, cooking can be electrified by replacing natural gas stoves with electric ovens.

Energy burden: Energy burden refers to the proportion of household income spent on energy costs. Low-income households generally have higher energy burdens.

Energy carrier: Energy carriers allow energy to be moved between systems or places. The energy they carry is then used to generate heat or mechanical work.

Enhanced oil recovery (EOR): EOR involves the injection of gas, heat, or chemicals into reservoirs to extract oil that would otherwise be unrecoverable.

Feeder circuits: Feeder circuits are composed of the main distribution lines that carry electricity from distribution substations to be delivered to large groups of consumers within a given area (e.g., multiple city blocks).

Firm power: Firm power refers to sources of energy that can be delivered reliably and for a long duration (as opposed to intermittent resources that are not consistently available).

Fuel cell electric vehicles (FCEVs): Also known as hydrogen fuel cell vehicles, FCEVs use oxygen pulled from the air and compressed hydrogen to generate electricity via a fuel cell to power the engine.

Gigawatt (GW): Gigawatts are a unit of electric power equal to 1,000 megawatts or 1 million kilowatts. For context, during the September 2022 heat wave, the total demand for electricity in California peaked at roughly 52 GW (setting an all-time record).

Global warming potential (GWP): Global warming potential is a unit of measurement that was created to allow the comparison of global warming effects from different greenhouse gases. GWP is the amount of energy (or heat) that 1 ton of an emitted gas would absorb in the atmosphere over a given period of time compared to 1 ton of carbon dioxide.

Hazardous air pollutants: Hazardous air pollutants are designated by the U.S. Environmental Protection Agency as substances known or suspected to cause cancer or other serious health problems, including reproductive or birth defects and adverse environmental effects. Hazardous air pollutants are designated as toxic air contaminants in the state of California.

Heat pump: Heat pumps are highly efficient electric appliances that provide air conditioning, space heating, or water heating. Heat pumps operate by using electricity to transfer heat from one material to another. For example, heat pump water heaters capture heat from ambient air and transfer that heat to water in the tank (rather than using electricity to heat the water directly).

Hosting capacity: Hosting capacity indicates the number of distributed energy resources that can be reliably supported on a local distribution network before upgrades to the circuit are required.

Intermittency: Intermittency refers to irregularity or inconsistency. In energy, intermittent resources are those that are not continuously available such as solar and wind power.

Investor-owned utilities (IOUs): IOUs are privately held companies that provide public utility services. California has six electric IOUs: Bear Valley Electric Service, Liberty Utilities, PacifiCorp, Pacific Gas and Electric (PG&E), San Diego Gas and Electric (SDG&E), and Southern California Edison (SCE). The latter three—PG&E, SDG&E, and SCE—are the largest in the state and participate in the California Independent System Operator (CAISO) service territory. PG&E, SDG&E, Southwest Gas, and Southern California Gas (SoCalGas) are the four largest IOUs providing natural gas service in the state.

Leakage (Carbon leakage): Leakage occurs when companies or industries relocate from one geographic area (with more strict climate policies) to another area. Emissions appear to decrease in the geographic area with strict policies, but increase elsewhere, resulting in no net change.

Load balancing: Load balancing is the act of ensuring energy supplied to the grid matches that required to meet energy demand, resulting in a consistent electric frequency.

Load shifting: Load shifting is a form of demand response where electricity consumption is shifted from one time period to another. For example, some electric water heaters can be configured to proactively heat water during the day when electricity is cheapest and renewable energy generation greatest, rather than heating water in the evening during peak net demand.

Kilowatt (kW): This unit of electric power is equal to 1,000 watts. Electric bills are usually expressed in kilowatt hours, or the amount of electricity equivalent to 1 kilowatt delivered for 1 hour. For reference, the average household in California consumes a little more than 6,000 kWh per year.

Megawatt (MW): This unit of electric power is equal to 1 million watts. According to the California Independent System Operator (CAISO), 1 MW is roughly equivalent to the amount of electricity needed to meet the simultaneous demand of 750 homes.

Methane: Methane (CH_4) is a short-lived greenhouse gas and the second most abundant human-generated greenhouse gas after carbon dioxide (CO_2). Methane is emitted from a variety of anthropological sources including landfills, dairy farms, and oil and gas operations. Methane is the primary component of natural gas. According to the International Panel on Climate Change, methane has a global warming potential 80 times and 29.8 times higher than CO_2 over a 20-year and 100-year time span, respectively.

Microgrids: Microgrids are collections of distributed energy resources that can supply energy to consumers independent from the main power grid. They typically include a local source of energy generation, a means of storing energy, electrical cables to connect end-users, and a control system to manage energy.

Natural lands: SB 1386 (Wolk, 2016) defines natural lands as forests, grasslands, deserts, freshwater and riparian systems, wetlands, coastal and estuarine areas, watersheds, wildlands, wildlife habitat. Also included are in this definition are lands used for recreation like parks, urban and community forests, trails, greenbelts, etc.

Net demand: Net demand is a measure of total energy demand minus renewable energy generation. In California, net demand tends to be highest during the evening (from about 4:00 - 6:00 pm) as solar resources go offline.

Net-zero: Net-zero greenhouse gas emissions indicates that any emission of greenhouse gases is balanced by the removal of equivalent greenhouse gases from the atmosphere. Though similar in meaning, the term "net-zero greenhouse gas emissions" is typically considered broader in scope than "carbon neutrality," which technically only refers to a balance in carbon emissions and removals. Achieving net-zero greenhouse gas emissions by 2045 was declared the policy of the state by AB 1279 (Muratsuchi, 2022).

Offset credits: Offset credits are an alternative to allowances purchased from the Cap-and-Trade market. Offset credits are generated by projects that either prevent greenhouse gas emissions from being released or that capture emissions from ambient air. Each offset credit represents one ton of CO_2 or other equivalent greenhouse gas.

Ozone: Ozone is a greenhouse gas and toxic air pollutant, as well as the primary component of smog. Ozone is created when nitrogen oxides (NOx) and volatile organic compounds (which are emitted by vehicles, industrial plants, and consumer products) interact in the presence of sunlight and heat.

Peak demand: Peak demand refers to the largest amount of power (in MW or GW) required to meet customer demand within a specified time period.

Plug-in hybrid electric vehicles (PHEVs): PHEVs are powered by both a battery-powered electric motor and a gasoline- or diesel-powered internal combustion engine. The engine will draw on battery power for shorter trips. For longer trips, the PHEV will use on-board fuel to achieve similar driving ranges to conventional internal combustion engines.

Pollution gap: Pollution gap refers to the difference in pollution exposure experienced by different communities (for example, between disadvantaged communities in California and the general population).

Price signal: Price signals convey information to either consumers or producers (via cost adjustments) that results in adjustments to behavior. For example, if electricity rates are more expensive during peak net demand, consumers may decide to use less electricity during those windows of time.

Pruning: With respect to the natural gas system, pruning is the strategic decommissioning or retirement of parts of the natural gas distribution network after households have been fully electrified. Pruning may be more cost effective than paying to maintain natural gas pipelines that are underutilized.

Public safety power shutoff (PSPS): Utilities may intentionally cut power to specific parts of the electric grid to mitigate the risk of wildfire ignitions caused by electric infrastructure. These intentional outages are called public safety power shutoffs or "de-energization."

Retail rates: Retail rates are state-regulated prices for the sale of electricity to consumers by utilities. Retail rates reflect the bundled costs of generating, transmitting, and distributing electricity to consumers. These costs include things like new infrastructure construction, wildfire mitigation, personnel wages, and other overhead costs.

Upstream emissions: Upstream emissions reflect greenhouse gas emissions that occur prior to the combustion or use of a fuel. For example, upstream emissions of oil include the emissions generated during the extraction, refining, and transportation of that oil before it reaches its final destination.

Vehicle miles traveled (VMT): Vehicle miles traveled (VMT) is a cumulative measure of how much people in a given area drive. Per capita VMT is how much the average person drives. Reducing VMT—by encouraging mass transit or walking, for example—is one method for reducing greenhouse gas emissions from the transportation sector.

Well-to-wheel emissions: Well-to-wheel is an estimate of the total cumulative emissions produced during the lifetime of a transportation fuel, from its production to use by the final consumer.

Working lands: SB 1386 (Wolk, 2016) defines working lands as those used for farming, grazing, or the production of forest products.

B

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Key Challenges for

CALIFORNIA'S ENERGY FUTURE

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