California's Electricity System **of the Future**

Governor Gavin Newsom
July 2021

FILSINGER ENERGY PARTNERS

Acknowledgements

California Air Resources Board (CARB)

California Energy Commission (CEC)

California Independent System Operator (CAISO)

California Public Utilities Commission (CPUC)

Governor's Office of Planning and Research (OPR)

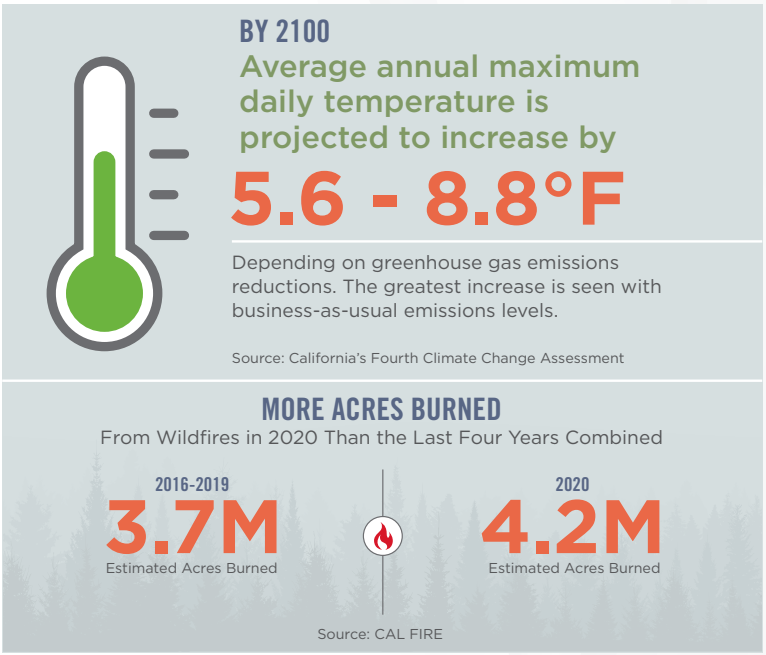
Table of Contents

Executive Summary

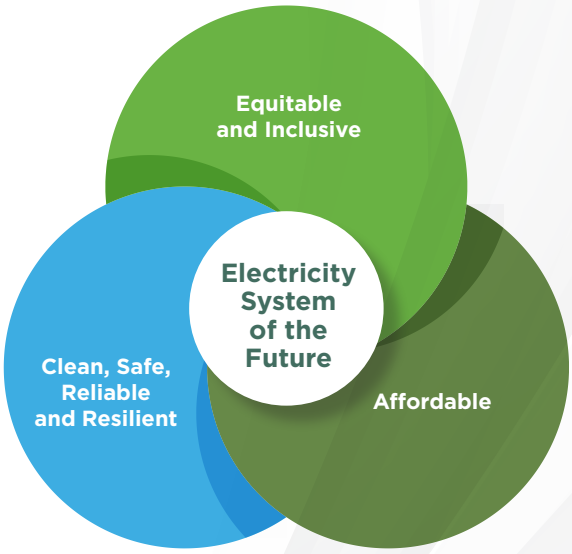
On Saturday, April 24, 2021 at 2:30 PM California experienced a glimpse of the future. The California Independent System Operator (CAISO) reported that a record 95 percent of the instantaneous electricity demand was served by clean energy. The grid did not fail, the lights did not go out, and people went about their day without realizing the fifth largest economy in the world was being powered almost entirely by clean electricity for that fleeting moment. That glimpse is the simple vision for the electricity system of the future:

Clean energy without even thinking about it.

In recent years, Californians have seen the impacts of climate change firsthand. These impacts are arriving more quickly and with greater force than predicted in the form of record heat, extended drought, deadly wildfires, rising sea levels and increased frequency and intensity of floods. Despite significant growth in renewable energy in California, carbon emissions from fossil fuel energy sources continue to represent a significant portion of statewide greenhouse gas emissions.



The electricity system has also been a contributor to recent disasters, with ignitions from electricity infrastructure sparking some of the state's largest and most devastating wildfires. At the same time, California utilities have implemented Public Safety Power Shutoffs (PSPS), shutting power off to large swaths of the grid to mitigate wildfire risk. These PSPS events have disrupted homes, businesses, and even critical healthcare functions. Fire season in California is now year-round and expected to get even worse unless California changes its course. PSPS is not a sustainable solution; neither is the electricity system of today.



The electricity system of the future must operate safely and reliably, deliver clean energy to its customers, and minimize any harmful impacts on communities, especially those living in disadvantaged and Tribal communities. Many communities have been disproportionately impacted by natural gas-fired power plants, internal combustion-powered vehicles, and other fossil fuel resources. These communities must be prioritized in the clean energy transition. The electricity system of the future must address inequities and will embrace these core principles: 1) equitable and inclusive; (2) clean, safe, reliable and resilient, and (3) affordable.

Executive Summary

California is Leading the Way

California has a long-standing role as a leader in the fight against climate change. California's early investment in energy efficiency savings and aggressive appliance and building standards has enabled the state to keep energy bills for residential and industrial customers among the lowest in the nation and it has the 2nd lowest energy consumption per capita.[1] This year, California ranked first among all the states when it comes to energy efficiency according to the American Council for an Energy-Efficient Economy.[2]

California is the top producer of solar, geothermal, biomass renewable energy in the U.S.[3] and has essentially banned investment in new coal-fired generation.[4]

California leads the nation in energy storage projects with nearly 50 GW[5] under development and is starting to phase out natural gas-fired generation.

California also has enforceable targets in place and the regulatory tools needed to decarbonize the energy sector:

- **Assembly Bill 32 and Senate Bill 32** established economy-wide greenhouse gas emission targets, including reducing greenhouse gas emissions to 40 percent below 1990 levels by 2030.
- **Senate Bill 350** established the integrated resource planning process to implement greenhouse gas emissions targets for the energy sector and required a doubling of the rate of energy efficiency savings in buildings by 2030.
- **Senate Bill 100 (SB 100)** required a 60 percent Renewable Portfolio Standard (RPS) by 2030 and 100 percent of all retail electricity sales come from zero-carbon sources by 2045.
- Finally, California has the ambitious goal of reaching economy-wide carbon neutrality no later than 2045.

[1] EIA 2019 Electric Sales, Revenue Average Price, Table 5a https://www.eia.gov/electricity/sales_revenue_price/.
[2] American Council for Energy Efficient Economy (ACEEE) https://www.aceee.org/state-policy/scorecard.
[3] EIA California State Energy Profile, Based upon 2019 data.
[4] Senate Bill 1368 set the standard for long term investments for new power plants or contacts with a greenhouse gas emissions limit at 1,100 pounds of carbon dioxide per megawatt-hour, equal to the emissions of a combined-cycle natural gas plant. This standard created a de facto moratorium on new coal since it could not be met without carbon capture and sequestration.
[5] CAISO Interconnection Queue as of May 3, 2021 report date.

Executive Summary

The Path Forward

California has made tremendous strides toward realizing the electricity system of the future. The state is on the right trajectory to achieve 100 percent clean electricity by 2045, if not sooner. Indeed, it met its interim target of 33 percent of electricity from renewable sources by 2020 two years early. When the percentage of renewables is combined with other sources of carbon-free energy, such as large hydroelectric generation and nuclear, the total percentage of clean electricity is 63 percent.[6] The Newsom Administration has also developed scenarios in the SB 100 Joint Agency Report (SB 100 Report) that show possible paths to reach the 100 percent clean electricity target.[7]

This document outlines the need for clean electricity generation development and explores some of the emerging technologies and electricity system concepts that will better enable the full transition to a 100 percent clean resilient electricity system. The advantages and disadvantages of various clean energy technologies, along with costs, will change over time. California will leverage those technologies to redesign the electricity system of the future.

The technology exists today to achieve California's clean energy goals, but we need to build new resources at an unprecedented pace and scale, and we need to start now. There is also still material opportunity for technological improvement that can better enable a clean, equitable and affordable energy future.

The Governor's vision is not a predetermined outcome of how the future electricity system will play out, nor is it a tacit endorsement of any one technology or company. The Governor's vision for the electricity system of the future is a clear statement that the clean energy transformation is entirely within our reach.

[6] California Energy Commission – https://www.energy.ca.gov/sites/default/files/2019-12/renewable_ada.pdf
[7] CEC - https://www.energy.ca.gov/sb100.

The Vision

The electricity system of today does not meet the needs of the 22nd century and beyond. The future will bring changes in the way we live, work and travel, with electricity increasingly powering these activities.

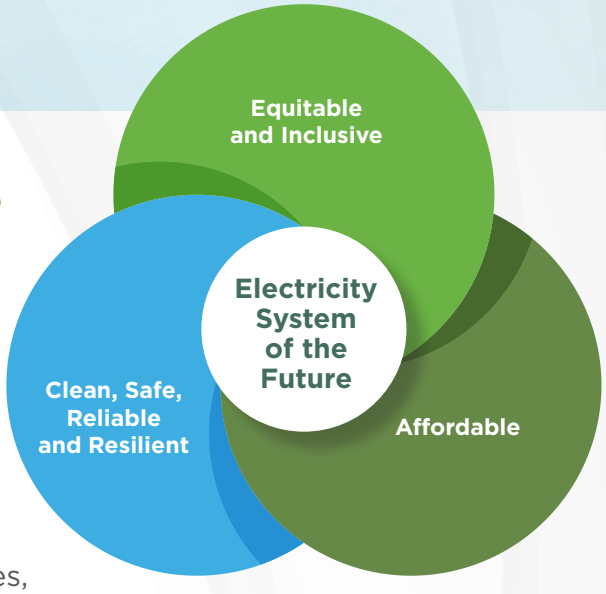
We must remove carbon emissions from our energy sources to support a sustainable future. We must also keep costs down to ensure electricity—an essential service—is accessible to all and can remain competitive as a fuel for a transformed transportation system. The time is now to reimagine the electricity system of the future so that everyone benefits.

Imagine...

- Where you **live** is powered entirely by a clean energy grid.
- Speaking of the **grid** — it's smart. Smart grid technology enables flexible load to provide reliable power and will save you money.
- Your choice of **transportation** is zero-emission. Buses, cars, trucks, and trains plug into the smart grid and serve as mini power sources when not in use.
- Finally, **buildings** across the state are also increasingly electrified, ditching fossil fuel powered HVAC systems for those that run on renewable sources.
- **Industries** are powered by clean energy and don't pollute the air we breathe.

And these are just a few examples of how our lives will be transformed.

The Vision



Principles of the Electricity System of the Future

As we develop the new electricity system of the future, we must keep three principles in mind.

Equitable and Inclusive

The electricity system of the future is all about equity and putting the customer first. In this future vision, the electricity system will no longer be a source of pollution in our communities and instead will enable our energy sources, as well as our cars, trucks, and buildings, to be part of the solution to climate change and lead to cleaner, healthier communities. The transformation must be equitable and inclusive, giving all Californians the opportunity to save money and know that clean energy will be delivered to their homes, schools, and businesses. Every time you turn on a light switch, drive your car, ride the bus, turn on your heating or air conditioning system, or prepare dinner you will know that it is powered by clean energy.

Along the way, the path to the future electricity system must create good jobs in construction, engineering, and other career pathways, as electricity generation, distribution and transmission projects are developed. Underserved communities cannot get left behind and must be able to share in the benefits of clean air and energy.

Clean, Safe, Reliable and Resilient

The grid is being hardened today to reduce the risk of wildfire and frequency of PSPS events. Solutions being implemented now will reduce power outages in the future. Diversity in generation sources and a more segmented grid will increase resiliency. New clean energy generation projects will come online, and energy storage technologies will allow us to store clean renewable energy. Load flexibility measures, including demand response, will become more ubiquitous and automated to best complement the grid.

Affordable

The energy market structure will encourage innovation and the adoption of new technologies, including distributed, community and large-scale projects. Market competition will identify the best and lowest cost clean energy resources. Rapidly declining clean energy technology costs will result in affordable and accessible clean energy. Keeping energy clean and cost effective will help to keep commercial, agricultural, and industrial jobs in the state. Increased electrification across the economy, including in the transportation and building sectors, will reduce costs across the system.

California is Taking Action Now

California is experiencing unprecedented climate-induced weather events. Last summer brought an extreme heat event, stressing the electrical system across the entire western interconnection. Death Valley hit a worldwide record temperature of 130 degrees Fahrenheit on August 16, 2020.[8]

During this time, the CAISO instituted load shed orders, causing power loss to customers on a rolling basis for 15 to 150 minutes on August 14 and between 8 to 90 minutes on August 15.[9] Although these outages were brief, they showed that resiliency actions needed to be expedited immediately. Early in 2021, the Texas ERCOT grid experienced more significant power outages, showing that extreme weather conditions can jeopardize the grid for periods of more than just hours, but rather for days and possibly weeks. Importantly, renewable energy generation was not blamed for these outages; extreme weather caused disruption and stress on the grid in both cases, including natural gas plant derates and outages.[10]

In preparation for the summer ahead California has brought new clean energy resources online, increased the planning reserve margin buffer and made market reform changes to be better prepared for meeting demand this summer.

Specific Actions Include:[11]

- **Improving demand forecasting accuracy** to better analyze extreme heat conditions.
- **Bringing on-line 2.4 GW of new renewable power—**the equivalent of a large nuclear power plant—and 2 GW of battery energy storage.
- **Ordering emergency procurement orders** for this summer to increase the available supply by up to 1.5 GW.
- **Avoiding retirement of 200 MW of existing natural gas-fired generation,** for use in emergency conditions.
- **Addressing transmission issues** related to the California-Oregon Intertie ensuring more reliable imports from the Pacific Northwest.
- **Maximizing regional coordination** between the CAISO, the State Water Project and neighboring balancing authorities in the Energy Imbalance Market to better support regional reliability.
- **Expanding Demand Response programs** to identify additional out-of-market resources with flexibility to drop load under emergency system conditions.
- **Adopting reforms** to the CAISO market to enhance summer readiness.[12]

[8] National Park Service — https://www.nps.gov/deva/learn/news/summer-2020-heat-records.htm
[9] CAISO — http://www.caiso.com/Documents/Final-Root-Cause-Analysis-Mid-August-2020-Extreme-Heat-Wave.pdf, p. 35.
[10] ERCOT. *February 2021 Extreme Cold Weather Event: Preliminary Report on Causes of Generator Outages and Derates*. April 6, 2021.
[11] CPUC — https://docs.cpuc.ca.gov/publisheddocs/published/g000/m373/k973/373973362.pdf. CPUC Energy Division. November 2020. *Status of New Resources Expected.*
[12] CPUC — https://www.cpuc.ca.gov/uploadedFiles/CPUC_Public_Website/Content/Utilities_and_Industries/Energy_-_Electricity_and_Natural_Gas/Summer%202021%20Reliability%20Monthly%20Report%20-%2004.07.21%20-%20Final%20-%20Chart.pdf.

Roadmap to Clean Energy

California is taking immediate actions to address reliability concerns this summer and implementing longer-term actions towards achieving its 100 percent clean electricity goal. Recent actions by the California Public Utilities Commission (CPUC) require retail energy providers to procure 6 GW of clean energy over the next three years and propose an order for procurement of 11.5 GW of new resources—the equivalent of power for approximately 2.5 million homes—to come online in the years 2023–2025.[13]

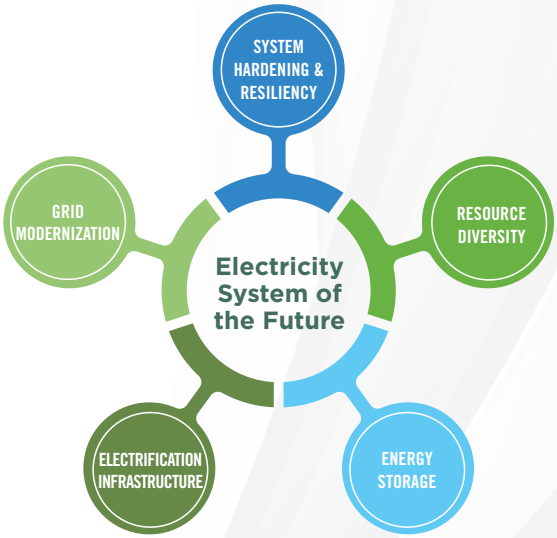
This pace will need to pick up, especially as load grows due to increased electrification of cars, trucks and buildings and rising temperatures extend air conditioning use later into the evening. Indeed, California will need to roughly triple its current electricity power capacity to reach the SB 100 target.[14]

To accelerate progress toward this target, the CPUC should consider adopting a more stringent greenhouse gas emissions target as soon as possible and ensure procurement orders are sufficient to replace retiring resources, meet state goals and maintain reliability. This action will help to increase development of clean electricity generation projects in the near term while further SB 100 assessments continue to examine the scale, magnitude, and pace of procurement needed in the future.[15]

California has already started the SB 100 implementation process with available existing resources technologies. Technology innovation and other resource technologies advancements could potentially offer lower cost and faster ways for achieving 100 percent clean electricity.

California state agencies prioritize low-income and disadvantaged communities throughout their programs and investments. A few examples include:

- **Programs like the California Alternate Rates for Energy (CARE) program** provide a 30-35 percent discount on electric bills for low-income households.[16]
- The CPUC tracks and measures progress in implementing the goals of its comprehensive **Environmental and Social Justice Action Plan**.[17]
- The CEC has invested 68 percent of its research and development funds from the **Electric Power Investment Charge (EPIC) program** for sustainability projects in low-income and disadvantaged communities or benefitting California Native American tribes.[18] The California Clean Energy Jobs Act (Proposition 39) K-12 Program has awarded more than $1.7 billion over the past five years to schools to plan and install energy efficiency upgrades and clean energy generation measures.[19]
- **The Low-Income Home Energy Assistance Program (LIHEAP)** provides low-income households with energy bill assistance as well as funding for home weatherization and outreach and education to help manage energy costs.



[13] CPUC — See https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M385/K382/385382555.PDF; https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M385/K026/385026493.PDF (3,300 MW); https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M385/K026/385026493.PDF (11,500 MW proposed).
[14] https://www.energy.ca.gov/sb100#anchor_report.
[15] See July 9, 2021 letter from Governor Newsom to CPUC President Marybel Batjer. https://www.gov.ca.gov/wp-content/uploads/2021/07/CPUC-Letter_07.09.2021.pdf.
[16] CPUC — https://www.cpuc.ca.gov/lowincomerates/.
[17] CPUC — https://www.cpuc.ca.gov/esjactionplan/.
[18] CEC — https://ww2.energy.ca.gov/2021publications/CEC-500-2021-029/CEC-500-2021-029-CMF.pdf.
The California Energy Commission's Electric Program Investment Charge (EPIC) program invests in scientific and technological research to accelerate the transformation of the electricity sector to meet the state's energy and climate goals.
[19] CEC — https://www.energy.ca.gov/programs-and-topics/programs/california-clean-energy-jobs-act-proposition-39-k-12-program.

Roadmap to Clean Energy

Aligning the electricity system of the future with our clean energy goals is a generational opportunity to uplift underserved communities and address historic environmental injustice. Equity and inclusion must be a guiding principle for the clean energy roadmap.

There are many unknowns as we look ahead at this path—costs, advancements in technology and siting and procurement decisions are still undefined. Yet, our goal is clear. Achieving 100 percent clean energy has never been tried at this large of a scale. **California is leading the way.**

The Roadmap to Clean Energy

1 Grid Hardening and Resiliency

Mendocino Complex Fire 2018
Credit: Author Unknown/Creative Commons

Transmission line next to tree
Credit: Southern California Edison

Communities in California today are threatened by catastrophic wildfires from both natural and man-made causes. Development in the wildland-urban interface has grown rapidly in the past several decades[20] and brought electrical lines with it. California utilities currently have over 250,000 miles of electrical lines spread across a wide and geographically diverse landscape.[21]

Overhead electrical lines increase fire danger and residents in high fire threat communities are on constant alert for strong wind conditions that frequently lead to Public Safety Power Shutoffs (PSPS) events. High tech solutions exist today to mitigate these risks by hardening the system and making it more resilient. Low tech solutions such as tree trimming, and vegetation management are also very effective tools for minimizing wildfire risk. These solutions can also help to protect against other climate induced conditions, such as extreme heat.

Increasing Resiliency

System resiliency is the ability of the system to withstand disasters while ensuring the least possible interruption of electricity and critical social services, and enabling a quick recovery and system restoration. New technologies deployed on the grid enable real-time detection of risks to the lines themselves. For example, if a pole is compromised and begins to fall, smart systems can shut power off to that line before it ever hits the ground, reducing or eliminating wildfire ignition risk and the need for extensive PSPS events.

[20] https://lcau.mit.edu/project/cataloguing-interface-wildfire-and-urban-development-california.
[21] CPUC Infrastructure Report Dec 2018 — https://www.cpuc.ca.gov/infrastructure/.

The Roadmap to Clean Energy

1 Grid Hardening and Resiliency

Microgrids

Microgrids can function independently from the larger grid and can be strategically placed in communities more vulnerable to wildfires and grid isolation. One of the first demonstration projects for the deployment of microgrids is the Blue Lake Rancheria microgrid project. The Blue Lake Rancheria community, located in Humboldt County, is geographically isolated, and is home to a Red Cross Evacuation Center. Thanks to the microgrid project, during a catastrophic event, the Red Cross Evacuation Center will have a reliable source of power to energize critical medical equipment, communication systems and other vital health and safety needs.

Blue Lake Rancheria Microgrid
Credit: Blue Lake Rancheria

System Resiliency

Real Time Fault Detection Device
Credit: Southern California Edison

- **Monitoring technology** installed on transmission and distribution circuits will enable detection of line faults and irregular operations that signal imminent line or device failure. This will enable replacement of equipment prior to failure and allow quick response to potential fire ignition events.
- **Machine learning techniques** enable smart meters to detect and locate line faults that may be related to fire ignition events.
- **Drones and Lidar** improve infrastructure and vegetation inspection capabilities, providing early warning of reliability and fire risks.
- **Automation equipment,** such as Rapid Earth Fault Current Limiter or other innovative technologies, will shut off power in wires-down situations, improving safety and eliminating fire ignition events.

The Roadmap to Clean Energy

1 Grid Hardening and Resiliency

Redwood Coast Airport Renewable Energy Microgrid
Credit: Schatz Energy Research Center

More recently, a larger microgrid was deployed at the Redwood Coast Airport. This microgrid, which is also located in Humboldt County, will help stabilize power fluctuations during normal operation and provide a local power source for emergency response activities in the event of a PSPS event or natural disaster.

Thanks to system hardening projects, smart technologies, targeted microgrids and other emerging solutions, the energy grid of the future will be safer, more reliable, and more resilient. While these improvements in California's electric infrastructure will require investment, those investments will cost less than the potential damages from future wildfires.

Redwood Coast Airport Microgrid

Redwood Coast Energy Authority (RCEA) partnered with the Schatz Energy Research Center (SERC) at Humboldt State University, PG&E, and the County of Humboldt to build a 7-acre, 2.25 MW solar array and battery energy storage system at the California Redwood Coast – Humboldt County Airport (ACV).

RCEA will own and operate the solar and battery systems, PG&E will operate the microgrid circuit, and SERC will be the prime contractor responsible for the project design and technology integration.

The microgrid will include:

- 250 kW net metered system to offset daily electricity usage at the airport
- 2 MW of wholesale power that will feed clean energy directly into the grid
- 2 MW battery storage system providing 8MWh of energy storage
- Microgrid controller providing the ability to "island" from the main grid so the airport and adjacent Coast Guard facility can run fully on solar and batteries if there is a regional power outage
- Electric vehicle charging stations capable of demand response
- Enough solar-generated electricity to power 430 households, and prevent the emission of ~880 metric tons of carbon dioxide

The Roadmap to Clean Energy

2 Resource Diversity

The western United States is blessed with an abundance of renewable energy resources including solar, wind, geothermal and other renewable sources. Diversifying energy resources provides greater resiliency than relying on a single fuel type that could face disruptions. Resource diversity can be represented in terms of the type of resource such as solar and wind, but also in terms of geographic location and it is a critical component of the electricity system of the future.

Solar Panels at Monterey Airport
Credit: California Energy Commission

California's current energy resource mix includes an aging fleet of natural gas-fired power plants that are still needed for reliability. Natural gas power plants are "dispatchable" resources, whereas wind and solar are "non-dispatchable" resources. Generation output levels from dispatchable resources can be controlled by the system operator; non-dispatchable resources cannot. Today, natural gas-fired generation is used to provide generation when intermittent generation from solar and wind is unavailable. Their capability to ramp up as the sun sets ensures reliable power for the system and in local areas, especially as heat events increase in intensity and geographic scope. California's clean energy goals are fundamentally about reducing reliance on these natural gas-fired plants, and investments in clean energy infrastructure are even more urgent because of continued presence of these facilities in communities that are disproportionately low-income and people of color.

In the short term, every effort should be made to minimize impacts of these plants. Actions can be taken to increase efficiencies to enable plants to run less frequently and reduce air emissions. Retail energy providers are also exploring a variety of longer-term possible solutions, including carbon capture and sequestration technology, green hydrogen, and battery hybrid approaches. More broadly, it is imperative to address all sources of pollution in communities surrounding natural-gas fired power plants, including taking action to reduce pollution from cars, trucks and buses.

In the meantime, electricity generation projects that meet California's need for clean energy capacity and reliability must be expedited and increased.

California has led the world in integration of solar, wind resources and energy storage resources onto the power grid and in deployment of energy efficiency and demand response measures. Clean, renewable resources have allowed California to essentially eliminate all use of coal-fired generation and retire approximately 12 GW[22] of natural gas plants. Over time California must continue to bring new generation resources online to replace natural gas generation with clean energy resources.

[22] CAISO Net Qualifying Capacity Reports

The Roadmap to Clean Energy

2 Resource Diversity

California is moving in the direction toward 100 percent clean electricity but must do more. In 2019, the Energy Commission reported that the California reached 36 percent of its RPS requirements and 63 percent of its energy from clean energy sources.[23]

Despite this progress, the SB 100 Report indicates that between 136 GW to 208 GW of clean energy technologies must be built by 2045 to achieve the 100 percent clean electricity goal.[24] This means that solar and wind build rates need to nearly triple and battery storage build rates need to increase by nearly eight-fold. With capacity targets this large, the state must act now to harness all of its resources to facilitate planning, siting, and development of new generation projects. The benefits of the actions we take today to accelerate projects will be enjoyed by generations to come.

Available resources and new technologies that can be used to achieve climate goals and help to keep costs down are discussed below.

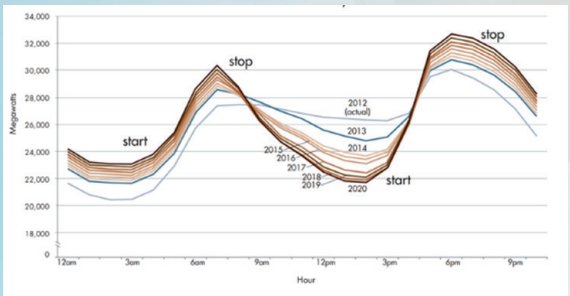
Solar Energy Resources

Solar generation has been, and will continue to be, foundational to the transition to clean energy. California has approximately 15 GW[25] of installed utility scale solar and 10 GW[26] of distributed solar generation as of 2021. There is estimated to be around 109 GW[27] of developable solar resources located within California. Modeling shows that solar projects should continue to increase as the cost of solar continues to decline.[28]

The direct implication of this power system dynamic is that solar must be paired with other resources to meet energy needs in the late afternoon, to avoid increasing reliance on natural gas fired generation. California is rising to this challenge, bringing online new battery energy storage resources, which use renewable energy for charging so the energy is available when we need it most.

The Solar "Duck Curve"

California's electricity system is adjusting to a shift of when energy needs are the greatest. Solar is a great resource in California, but during certain times of the year existing resources produce more solar energy than can be used, especially during the middle of the day. Later in the day, declining solar production creates the need for other power sources to quickly ramp up to meet demand. This shift in the energy needs of the system has pushed peak non-solar power needs into the early evening, making the "net peak" (net of solar) more important for planning purposes.[28]



Credit: California Independent System Operator

[23] CEC – https://www.energy.ca.gov/news/2020-07/new-data-shows-nearly-two-thirds-californias-electricity-came-carbon-free.
[24] SB 100 Joint Agency Report, Page 75.
[25] CEC – https://ww2.energy.ca.gov/almanac/renewables_data/solar/index_cms.php.
[26] https://www.californiadgstats.ca.gov/.
[27] CPUC Energy Division, RPS Calculator User Guide (v. 6.2), Appendix B, p.B-14b (3/15/2016).
[28] SB 100 Joint Agency Report - TN234532_20200831T081744 – Inputs and Assumptions.

The Roadmap to Clean Energy

2 Resource Diversity

Wind Energy Resources

Wind energy corridors located within California and across the West offer additional opportunities to develop more onshore wind projects and just off the coast of California there is a potential offshore wind resource available. The Bureau of Ocean Energy Management and the National Renewable Energy Laboratory estimates that there is up to 112 GW[29] of offshore wind potential across the entire California coastline. Given west coast wind patterns which tend to increase during the early evening hours, this resource could be a complementary resource to solar.

The Newsom Administration has been actively participating in an intergovernmental task force that brings together state, local, and federal agencies and tribal governments to advance offshore wind, including working to open up an offshore lease area in the Central Coast, which currently is not available for development.[30] Additionally, although the North Coast of California is farther from the state's load centers, the Humboldt County coast offers the potential to harness powerful wind resources. Humboldt Bay has an existing deep-water port well-suited for a west-coast offshore wind development hub, and plans for a 100-150 MW floating wind farm project are underway. Both Humboldt and Central Coast should be actively explored as areas for federal lease sales and for port services to support offshore wind build out.

Credit: Vattenfall/Creative Commons

In May 2021, California announced a historic agreement together with the federal government to advance offshore wind along the California coast. This agreement established a 399-square-mile development envelope, which enables the Department of the Interior's Bureau of Ocean Energy Management to proceed with the first lease sales in California, on the Central Coast northwest of Morro Bay and a separate area on the North Coast, off the coast of Humboldt.

[29] Bureau of Ocean Energy Management — https://www.boem.gov/sites/default/files/environmental-stewardship/Environmental-Studies/Pacific-Region/Studies/BOEM-2016-074.pdf.
[30] CEC — https://www.energy.ca.gov/programs-and-topics/topics/renewable-energy/offshore-renewable-energy.

The Roadmap to Clean Energy

2 Resource Diversity

Geothermal Resources

California is home to the largest complex of geothermal power plants in the world. The Geysers, comprising 45 square miles along the Sonoma and Lake County border, is home to thirteen geothermal power plants totaling 725 MW and has been proven to be a reliable baseload renewable resource.[31] The Salton Sea region located in the Imperial Valley is another region rich in natural resources such as geothermal energy and lithium deposits. The Hell's Kitchen 50 MW geothermal project currently under development seeks to utilize geothermal power to extract lithium sustainably from geothermal brine.

Lithium Valley

Credit: Controlled Thermal Resources (CTR)

Pursuant to Assembly Bill 1657 (Garcia, 2020), the California Energy Commission created a special blue-ribbon panel to explore lithium extraction potential in the Lithium Valley. Lithium is a key raw material required for the commercialization of short-duration lithium-ion batteries. California's "Lithium Valley," located in Imperial County, has the potential to unlock a steady, low-cost supply of lithium needed for battery development to power the grid and electric vehicles. The Lithium Valley also is home to large untapped geothermal resource in a renewable energy corridor that requires additional transmission to unlock its clean energy potential. There are currently 345 MW of existing geothermal plants located in the Salton Sea area of the Imperial Valley and an estimated 2 GW of additional geothermal energy potential. Realizing the vision of the Lithium Valley will drive economic development in the Imperial Valley, create jobs, provide a clean, base load resource, and help diversify California's renewable resource mix. The development of geothermal in the area could be leveraged to provide clean energy for lithium extraction, the key raw material required to power California's transition to clean energy.

Source: California Energy Commission, New Energy Nexus, 2020

[31] https://geysers.com/geothermal.

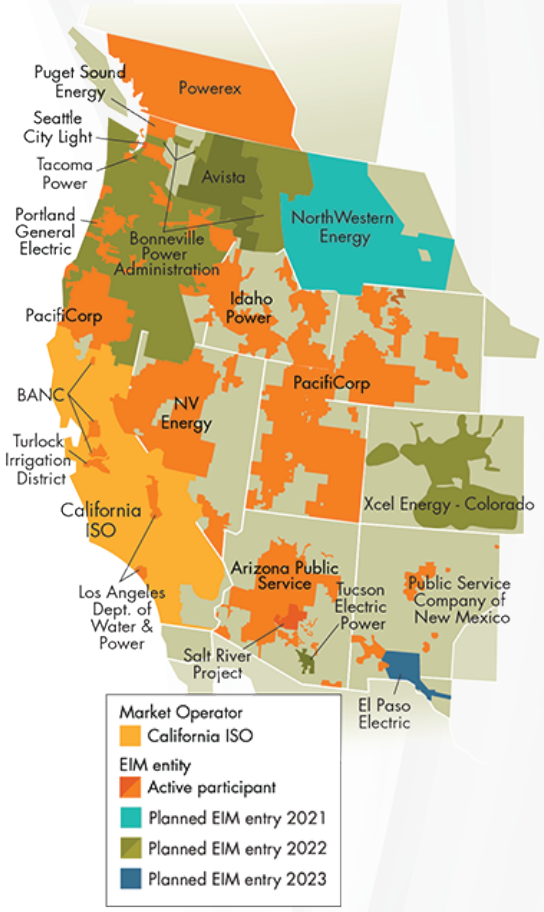
The Roadmap to Clean Energy

2 Resource Diversity

The Regional Grid and Coordinated Operations

The California grid[32] is part of a larger regional grid called the Western Energy Coordinating Council (WECC). California has strong transmission interconnections and regional coordinated planning and operations with neighboring utilities across the West. California's transmission system provides the ability to import hydroelectric power from the Pacific Northwest as well as solar and wind resources from the Desert Southwest.

California is not an electrical island. Historically California has imported approximately a quarter its energy needs from resources located out-of-state.[33] The regional grid allows participants to buy and sell power to match real-time demand and provides reliability and resiliency during system emergencies.



Credit: Western Energy Imbalance Market (EIM)

Other western states have also embraced sustainability and, like California, will be seeking access to renewable resources. Regional and in-state investments in the transmission system will strengthen reliability, resiliency, and enable California to access the large and diverse renewable resources across the entire West. The intermittent nature of wind and solar resources, however, presents a challenge to grid operators and requires planning and coordination between western utilities. The Western Energy Imbalance Market (EIM) is a real-time wholesale trading market administered by the CAISO. The EIM will cover 83 percent of the load in the WECC by 2023 and enables participants to better manage intermittent wind and solar resources. Coordinated operations in the EIM reduce operating costs conducting an economic dispatch from a larger pool of more geographically diverse generating resources. The EIM has saved market participants approximately $1.3 billion since its inception in 2014.[34]

The success of the EIM underscores the importance on maintaining a strong transmission system and the opportunity to further strengthen regional coordination. The EIM has also helped to reduce renewable energy curtailment by approximately 1,400 GWh, which has eliminated the equivalent of approximately 600,000 ton of carbon emissions.[35]

[32] The California grid can be defined as the CAISO, LADWP, BANC, TID, and IID, and other smaller balancing authorities that manage the power grid.
[33] California imported approximately 26 percent of its electricity to serve electric demand in 2020 based upon reported annual production data from the CAISO.
[34] Western Energy Imbalance Market — https://www.westerneim.com.
[35] Western EIM — https://www.westerneim.com/Documents/ISO-EIM-Benefits-Report-Q1-2021.pdf.

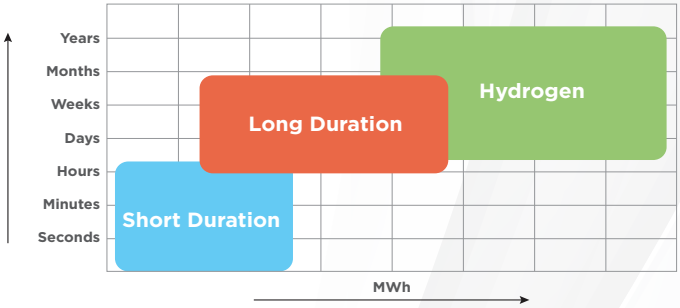
The Roadmap to Clean Energy

3 Energy Storage

Recent breakthroughs in energy storage technology provide a viable option to store intermittent renewable energy and replace natural gas-fired generation.

There are many forms of promising energy storage technologies under development with storage duration intervals ranging from seconds, hours, days, weeks, to even months or more. These include traditional resources, such as pumped storage, as well as emerging technologies, such as Lithium-Ion (Li-Ion) batteries, flow batteries, mechanical energy storage, and thermal energy storage technologies.

The types of energy storage can be grouped into three main categories of short-duration, long-duration, and hydrogen. Diversity of energy storage technologies is also important for maintaining a reliable grid. Layering energy storage with different attributes and storage capabilities provides more resiliency and grid services require to operate the grid. Hydrogen is unique in that it is both a form of energy storage as well as a fuel source and is discussed in the next section. This section outlines the types of commercially available and emerging energy storage technologies needed to achieve 100 percent clean electricity.



Credit: Filsinger Energy Partners

The Roadmap to Clean Energy

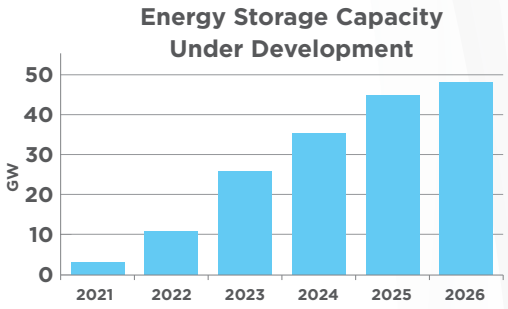
3 Energy Storage

Short-Duration Energy Storage[36]

Commercially ready energy storage technology today is based on lithium-ion battery energy storage system technology and can generally discharge energy for short-durations (one to four hours is common). Li-Ion batteries allow excess renewable energy to be stored typically during the middle part of the day for use later during the early evening peak.

California is already beginning to replace natural gas power plants with a combination of solar and Li-Ion batteries, which is called a hybrid power plant. Hybrid power plants use solar to charge the batteries during the middle of the day and that stored clean electricity can then be discharged in the early evening hours when electricity demand is typically the highest. There is nearly 50 GW[37] of stand-alone energy storage or energy storage in hybrid configuration under development over the next six years. The initial phase of the electricity system transformation will feature an explosive growth of short duration energy storage, primarily dominated by Li-Ion batteries.

Credit: California Energy Commission



Source: CAISO Interconnection Queue

Long-Duration Energy Storage[38]

The goal in California is not to have clean energy some of the time, but rather clean energy all the time. Short-duration energy storage can only discharge energy for a few hours at a time. As the state continues to build renewable energy projects, energy providers must also incorporate projects that are able to store energy and discharge it over longer periods. The commercialization of longer duration storage is a key challenge for achieving 100 percent clean electricity. The layering of both short-duration and long-duration energy storage technologies is important for providing critical grid services like operating reserves, frequency response, system inertia, and system capacity in addition to being able to store large amounts of excess renewable energy. The CPUC has recognized the importance of bringing more long-duration storage onto the grid and encouraged retail providers to procure pumped storage or other storage with the same attributes.[39]

In the section below we will discuss some of the established and emerging long-duration energy storage solutions that will be the ultimate key to achieving 100 percent clean energy.

[36] Short-duration energy storage is defined in this document as having the capability of discharging energy for 8 hours or less.
[37] CAISO Interconnection Queue as of May 3, 2021 report date.
[38] Long-duration energy storage defined in this document as having greater than 8 hours of energy storage capability.
[39] PUC — https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M331/K772/331772681.PDF

The Roadmap to Clean Energy

3 Energy Storage

Mechanical Energy Storage

Mechanical energy storage systems take advantage of kinetic or gravitational forces to store energy. The most common form of long-duration storage used in California today is in the form of mechanical energy storage called pumped storage hydro. A typical pumped hydroelectricity facility uses pumps and generators to move water between an upper and lower reservoir. When electricity is cheap during times of low demand, water is pumped from the lower reservoir to the upper reservoir. During periods of high demand, water is released from the upper reservoir through a generator to produce electricity. The state currently has 4 GW[40] of existing pumped storage capacity located across seven different plants and planning processes have identified pumped storage as a need for retail providers' portfolios.

Credit: Energy Vault

Energy Vault's Gravity Energy Storage Systems store energy by lifting large mobile masses. When the energy is needed back, the mobile masses are lowered, and their kinetic energy activate motor generators that deliver electricity back to the grid. Other innovative technologies employ the use of rail cars that use renewable energy to drive motors that push rail cars up a hill and stored potential energy is released when those rail cars are released downhill.

[40] https://ww2.energy.ca.gov/2016publications/CEC-200-2016-006/CEC-200-2016-006.pdf.

The Roadmap to Clean Energy

3 Energy Storage

San Diego Gas & Electric Vanadium Redox Flow Battery
Credit: San Diego Gas & Electric

Flow Batteries

Flow batteries use an electrochemical process to separate positive and negative ions across a membrane to produce electricity. The power and energy components of the flow battery can be sized independently, a key advantage over Li-Ion batteries. The liquid electrolyte that supplies the energy is stored in tanks that can be made as large as required to provide the desired storage duration. Flow batteries can have different chemistries, the most common is vanadium, and less frequently used zinc-bromine, polysulfide-bromine, and iron-chromium.

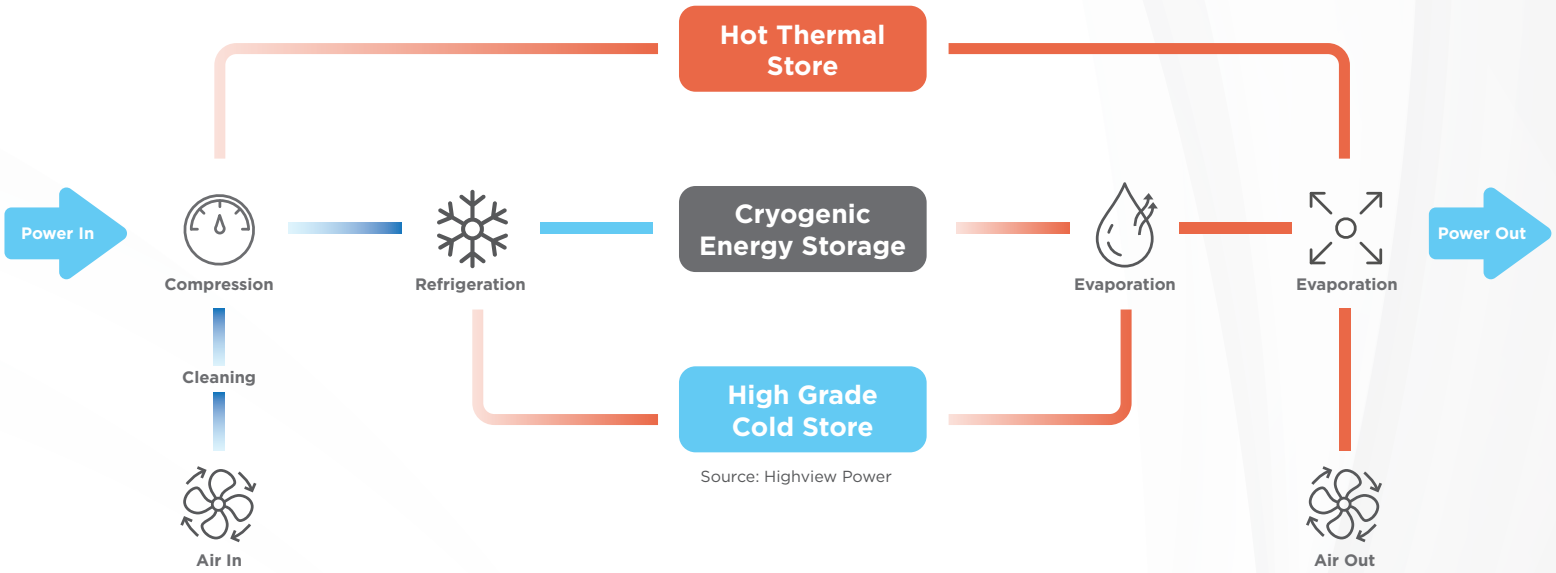
San Diego Gas & Electric has a flow battery demonstration project located in the Bonita community in south San Diego County. This 2 MW flow battery came online in 2019 and can store 8 megawatt hours of energy, which is enough to power the equivalent of about 1,000 homes for up to four hours. Flow batteries can be sized up modularly to provide longer storage capabilities.

The Roadmap to Clean Energy

3 Energy Storage

Thermal Energy Storage

Thermal energy storage is the process of storing excess heat in a liquid or solid medium. Compression of either air or a liquid can be used a method for storing energy. Liquid Air Energy Storage uses electricity to cool air to very low temperatures until it liquefies, stores the liquid air in a tank, brings the liquid air back to a gaseous state and uses that gas to turn a turbine and generate electricity. Temperature differences created during compression or expansion of a medium can be used to generate electricity.



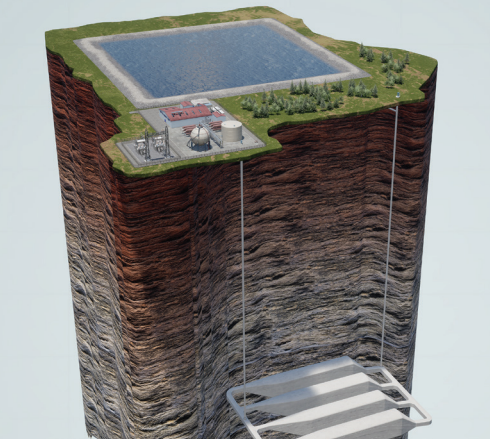
Source: Highview Power

Compressed Air Energy Storage uses a similar concept to compress air and store the compressed air into geological formations such as salt caverns or underground caves.

The Roadmap to Clean Energy

3 Energy Storage

Rosamond Energy Storage Project



The Rosamond Energy Storage Project is a 500 MW utility scale advanced Compressed Air Energy Storage facility that is under active development in Kern County by the storage developer Hydrostor. This project will store excess generation from California solar and wind projects during periods of low customer demand by compressing air and storing it on the project site. During periods of higher customer demand or low supply, this high-pressure air is used to generate emissions-free electricity to meet real-time electrical load and enhance overall grid reliability. The project is designed to generate electricity for at least eight hours at full capacity.

Credit: Hydrostor

Emerging energy storage technology companies such as Energy Vault, Highview Power, and Hydrostor are working to bring to market innovative forms of long duration thermal energy storage.

There are also hybrid options,[41] which use a combination natural gas and renewable energy to compress thermal energy for long-duration storage. Hybrid energy storage systems combine grid-connected thermal electricity generation, renewable and electricity storage media that be in the form of a liquid, solid, or gas. Hybrid thermal storage options using natural gas can improve the efficiency of the underlying natural gas power plant, which reduces fuel use and allows for thermal storage of renewable energy for long-durations.

To advance these technologies, the Energy Commission funds research projects that evaluate different scenarios for the deployment of long-duration storage options.[42] It has provided funding to more than a dozen storage companies, improving the performance of flow batteries, alternative chemistries to lithium ion, flywheels, thermal storage and hydrogen.

[41] Pintail Power — www.pintailpower.com
[42] CEC — https://www.energy.ca.gov/solicitations/2020-01/gfo-19-308-assessing-long-duration-energy-storage-deployment-scenarios-meet.

The Roadmap to Clean Energy

3 Energy Storage

Hydrogen

Find a carbon free fuel to replace natural gas may be the greatest challenge for reaching 100 percent clean electricity. Part of the solution may be found in waste biogas, biomass, synthetic natural gas, and hydrogen. Many of these fuels meet other state policy objectives—such as capturing carbon from manure and municipal and other type of organic waste—and could be useful in applications other than the energy sector. For clean energy and energy storage, hydrogen may be the ultimate solution, but it is also the most expensive and faces the most barriers to bringing the technology to market. The other alternative fuel options are difficult to produce at scale due to limited supply of biomass and biofuels. Eliminating dependency on natural gas as a backstop will be difficult, but not impossible.

Waste biogas	Gasification of biomass	Hydrogen H_2	Synthetic Natural Gas
Sources: Municipal waste, manure	**Sources:** Agriculture and forest residues	**Sources:** Electrolysis + zero-carbon electricity, or steam methane reformation with carbon capture and sequestration*	**Sources:** Renewable hydrogen+ CO2 from biowaste (bi-product of biofuel production) or direct air capture
Constraints: Very limited supply	**Constraints:** Limited supply and competing uses of biofuels	**Constraints:** Limited pipeline blends (7% by energy, 20% by volume) without costly infrastructure upgrades**	**Constraints:** Limited commercialization, low round-trip efficiency

Source: E3/California Energy Commission[43]

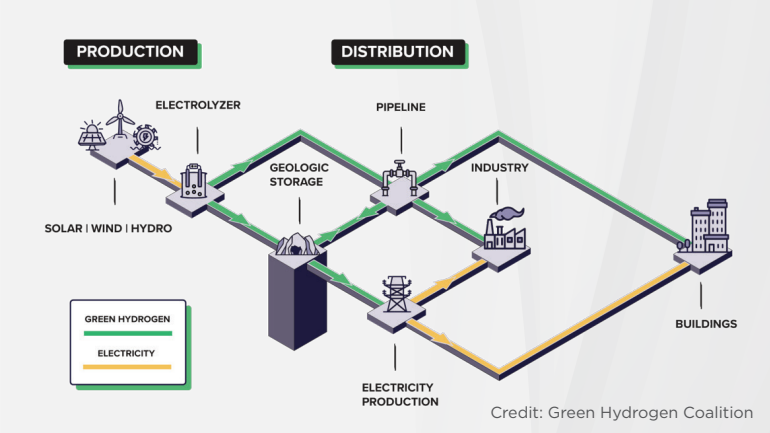
[43] Dan, Amber Mahone, Zack Subin, Michael Mac Kinnon, Blake Lane, and Snuller Price. 2020. *The Challenge of Retail Gas in California's Low-Carbon Future: Technology Options, Customer Costs and Public Health Benefits of Reducing Natural Gas Use.* California Energy Commission. Publication Number: CEC-500-2019-055-F

The Roadmap to Clean Energy

3 Energy Storage

Green Hydrogen Production

Hydrogen has many potential applications across the industrial, transportation and power sectors. Hydrogen can be described in various colors ranging from brown, gray, blue, and green hydrogen. Brown, gray, and blue hydrogen production include the use of carbon emitting fuel sources to produce hydrogen. Green hydrogen is simply hydrogen produced with 100 percent renewable energy. Electrolysis is the process of using electricity to split water into hydrogen and oxygen using an electric current. Hydrogen can be converted into electricity either through a combustion process in a turbine or through a chemical process via a fuel cell. Hydrogen can be used as an energy storage medium by storing the fuel in natural geological formations or other storage methods.



Credit: Green Hydrogen Coalition

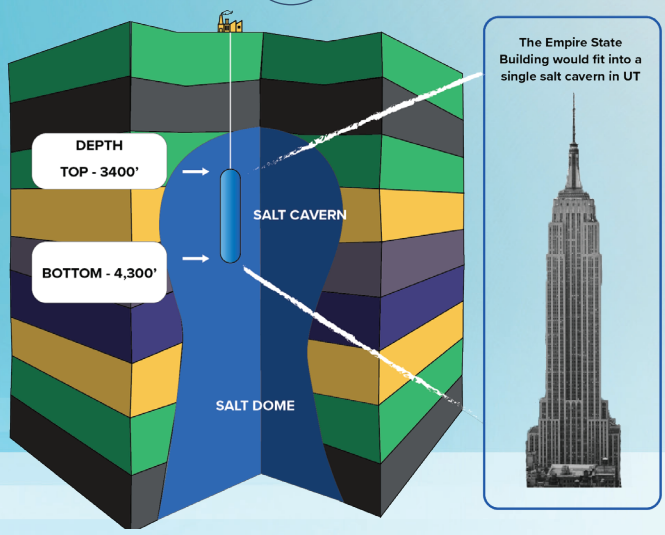
Hydrogen must overcome low efficiency rates currently associated with producing, distributing, and storing hydrogen for industrial, transportation, and power generation end-use. Efficiency losses incurred throughout the full life cycle from production to end-use make the economics of hydrogen challenging in addition to considerations for water use requirements in California. Investment in green hydrogen could lead to rapid decline in production costs similar to the experience seen with solar production and battery energy storage technologies as technologies are scaled up and commercialized.

The Roadmap to Clean Energy

3 Energy Storage

HyDeal Los Angeles is an initiative led by the Green Hydrogen Coalition to achieve at-scale green hydrogen procurement at $1.50/kilogram in the Los Angeles Basin by 2030, creating the nation's first green hydrogen hub. This consortium of organizations includes the Los Angeles Department of Water & Power, Southern California Gas, 174 Power Global, and Mitsubishi Power. HyDeal Los Angeles is the first initiative within HyDeal North America, a commercialization platform which launches regional green hydrogen ecosystems across North America.[44]

Hydrogen Project



LADWP is developing a hydrogen project at the current site of the Intermountain coal plant, which will be retired in 2025. The coal plant will be replaced by a new power plant capable of using hydrogen as a fuel. The plant will initially start with a blend of 30 percent hydrogen and 70 percent natural gas but will transition to 100 percent hydrogen by 2045. Green hydrogen produced by nearby wind plants could be stored in naturally occurring salt caverns in the region.

Credit: Green Hydrogen Coalition

Accelerating Innovation

Many emerging long-duration storage technologies are promising but need further research, and some may never achieve commercial viability. California must become an incubator of early-stage, long-duration storage technologies and help remove the barriers to bring these long-duration energy storage technologies to market. California's planning processes have identified the need for significant new resources and the best, most reliable, most scalable, and the most cost-effective clean technologies will rise to the top. Challenges such as land use, water use, air permitting, environmental impact mitigation, and scalability require California to consider a wide range of long-duration storage technologies instead of placing its bets on a single technology.

[44] Green Hydrogen Coalition — https://www.ghcoalition.org/hydeal-la

The Roadmap to Clean Energy

4 Electrification

The energy system generates carbon emissions across many different sectors including the electric, transportation, commercial, industrial, and agricultural industries. Electrification of all sectors of the California economy allows for significant reduction of carbon emissions.

Source: California Air Resources Board

BlueLA is the world's largest electric car sharing program specifically serving disadvantaged neighborhoods

Transportation

The transportation sector continues to be a significant source of greenhouse gas emissions and other air pollutants in California.[45] In 2020, Governor Newsom took a major step toward decarbonizing the transportation sector by issuing a comprehensive executive order setting targets for clean transportation. The order directs all sales of passenger carsand trucks to be zero-emission by 2035 and all medium- and heavy-duty trucks and buses to be zero-emission by 2045 for all operations where feasible, and by 2035 for drayage trucks. California also continues to lead the wayin regulations to increase electric vehicle deployment, using its unique authority under the Clean Air Act and bringing other states along to adopt California standards.[46]

These actions have brought over 800,000 zero-emission vehicles to California roads, representing 45 percent of the electric vehicle market in the United States. Zero-emission vehicles sales also represent a growing percentage of new car sales, up to 9 percent the first quarter of 2021. An even more striking sign of the future is the fact that zero-emission vehicles are now California's largest export, bringing over $5 billion to the state.[47]

California is already a pioneer in developing shared-use mobility programs in disadvantaged communities.[48] These programs provide clean energy transportation options for those who can least afford it today. Innovative programs such as the BlueLA electric car-sharing program allow underserved communities to share the benefits of clean energy in the transportation sector using a subscription model to provide access to electric vehicles.

[45] 41 percent of the state's greenhouse gas emissions originate from vehicles and over 50 percent of statewide greenhouse gas emissions originate from the transportation sector as a whole, upstream fuel production and refining. Transportation emissions cause more than 80 percent of smog-forming nitrogen oxide pollution and 95 percent of toxic diesel particulate matter. https://ww2.arb.ca.gov/sites/default/files/2021-04/Revised_Draft_2020_Mobile_Source_Strategy.pdf, p. 76., https://ww2.arb.ca.gov/sites/default/files/2020-06/200625factsheet_ADA.pdf

[46] https://www.epa.gov/state-and-local-transportation/vehicle-emissions-california-waivers-and-authorizations#:~:text=The%20Clean%20Air%20Act%20allows%20California%20to%20seek%20authorization%20to,new%20nonroad%20engines%20and%20vehicles. In addition to these measures, California also uses strategies to reduce vehicle miles traveled, or VMT, through programs to develop sustainable communities and promote active transportation. See e.g., https://ww2.arb.ca.gov/resources/documents/carb-2017-scoping-plan-identified-vmt-reductions-and-relationship-state-climate.

[47] https://www.veloz.org/.

[48] CARB — https://ww3.arb.ca.gov/msprog/lct/carsharing.htm.

The Roadmap to Clean Energy

4 Electrification

Credit: California Air Resources Board (CARB)


Credit: Southern California Edison

The state has also invested in programs to replace old diesel school buses in underserved communities, demonstrating the commitment to equity in addressing air quality and moving towards decarbonization.[49] Among other programs, these investments enabled the Sacramento Metropolitan Air Quality Management District to create the largest electric school bus replacement programs in the United States.[50]

The State is also making significant investments in electric vehicle charging and hydrogen re-fueling infrastructure through the Clean Transportation Program at the California Energy Commission, and numerous vehicle incentive programs at the California Air Resources Board support sales of cars, trucks and equipment. These programs are designed to increase affordability and access to electric vehicles, so that all Californians can participate in the transition. Future investments can continue to spur private development in battery electric and hydrogen fuel technologies, create good jobs throughout the state and lead to improvements in air quality, especially in communities that have suffered disproportionately from the impacts of pollution.

The state's utilities are also developing plans to encourage the proliferation of electric vehicles and upgrading infrastructure to accommodate the new large, flexible load to maximize grid benefits. These plans represent a majority of utility investments in zero-emission vehicle infrastructure nationwide and prioritize investments in disadvantaged communities.[51] The incorporation of vehicle to grid (V2G) capabilities will allow electrified vehicles to act as mini energy storage units, returning excess energy to the grid.

[49] CARB — https://ww2.arb.ca.gov/our-work/programs/school-buses/funding-clean-school-buses; https://www.energy.ca.gov/programs-and-topics/programs/school-bus-replacement-program.
[50] http://www.caclimateinvestments.ca.gov/press-releases/2017/5/12/sacramento-aqmd-unveils-nations-largest-zero-emission-electric-school-bus-deployment.
[51] ACEEE — https://www.aceee.org/white-paper/2021/04/siting-electric-vehicle-supply-equipment-evse-equity-mind. In total, 25 states plus DC have approved $2.4 billion in utility investment in EV charging infrastructure. The CPUC has approved about $1.6 billion over the past four years.

The Roadmap to Clean Energy

4 Electrification

The West Coast Clean Transit Corridor Initiative includes utilities and municipal agencies across the West that are studying ways to facilitate the electric charging infrastructure along the entire length of the 1,300-mile I-5 transportation corridor along the West Coast for heavy duty commercial vehicles.

Pacific Gas & Electric Company
Its EV Fleet program will prepare 700 sites for charging infrastructure to support 6,500 electric trucks—a $236 million investment.

San Diego Gas & Electric Company
Its $107 million electrification program was recently approved to support between 3,000 and 6,000 electric trucks.

Southern California Edison
Its Charge Ready Transport program will develop 870 charging sites to support 8,490 electric trucks—a $343 million investment.

Los Angeles Department of Water and Power
LADWP's Charge Up L.A. Program now includes rebate incentives to support installation of Medium Duty and Heavy Duty charging infrastructure for Class 3 through Class 8 Electric Trucks.

Source: West Coast Clean Transit Initiative

Additional Infrastructure Electrification

Electrification is not only limited to transportation. California's electricity system of the future also includes increased electrification and more efficient energy use in buildings and industrial facilities. Residential and commercial buildings are responsible for roughly 25 percent of California's greenhouse gas emissions when accounting for fossil fuels consumed onsite and electricity demand.[52] California's industrial sector is responsible for over 35 percent of the state's natural gas use and contributes approximately 100 million metric tons of carbon dioxide equivalent emissions, which is more than 20 percent of the state's greenhouse gas emissions.

[52] CARB — https://ww2.arb.ca.gov/our-work/programs/building-decarbonization.

The Roadmap to Clean Energy

4 Electrification

The CPUC and CEC have set in motion proceedings to analyze building decarbonization strategies for residential and commercial buildings.[53] Incentive programs also help to build the market for new technologies. For example, the Energy Commission's Building Initiative for Low-Emissions Development (BUILD) Program[54] provide incentives for the deployment of near-zero emissions building technologies in low-income residential buildings.

In 2018 California adopted a first-in-the-nation rooftop solar requirement for construction of new homes,[55] and new building code updates are moving toward greater energy savings and electrification for future construction.[56] These nation-leading building code standards are accelerating deployment of efficient heat pumps for space and water heating based on efficiency gains and decarbonization benefits.

Mary's Village is a transitional housing project in San Bernardino county for homeless men. Partnering with Southern California Edison, Mary's Village will be the model for zero-net energy homes. Mary's Village will have electric water and space heaters, which will be partially powered by rooftop solar panels. The kitchens will also feature clean, precise induction cooktops.

Credit: Southern California Edison

In the industrial sector, targeted investments can increase efficiencies, reducing electricity and natural gas demand, leading to cost savings for California business who fuel the economy and provide jobs throughout the state. Industrial efficiency measures also reduce emissions of criteria pollutants, improving air quality and contributing to community health benefits. The state has funded investments in food processing facilities through CEC's Food Production Investment Program since 2018.[57]

[53] CPUC — https://www.cpuc.ca.gov/BuildingDecarb/.
[54] CEC — https://www.energy.ca.gov/programs-and-topics/programs/building-initiative-low-emissions-development-program.
[55] CEC — https://www.energy.ca.gov/news/2018-05/energy-commission-adopts-standards-requiring-solar-systems-new-homes-first.
[56] CEC — https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards.
[57] https://www.energy.ca.gov/programs-and-topics/programs/food-production-program.

The Roadmap to Clean Energy

5 Grid Modernization and Distributed Energy Resources

In the future, the large-scale generation resources discussed in the previous section will be complemented with an increasing variety of smaller, distributed energy resources (DERs). DERs will have smart grid components such as bi-directional power flow, real-time telemetry, and communications with system operators. DER technology could be enabled with artificial intelligence and machine learning algorithms to save customers money. New platforms for managing distributed energy resources may provide operational savings and could even allow retail customers to interface directly with the real time wholesale power markets.

Credit: Southern California Edison

Distributed Energy Resources

California already leads the nation in installed rooftop solar capacity and this capacity is expected to grow over time. Rooftop solar systems reduce load on the grid during the day and customers are compensated for any excess electricity produced. Customers also have the option of adding battery storage to extend the time the system is able to supply power. Electric vehicles and smart appliances can be used to communicate with the building's power needs and can operate optimally under "Time of Use" rates, designed to drive energy use to mid-day when power supply is greatest.

The Valencia Garden Energy Storage project is in a dense, urban neighborhood located in San Francisco. The Valencia Garden Energy Storage project combines distributed rooftop solar with the front-of-the meter energy storage to provide clean energy and resiliency to an underserved community.

The Roadmap to Clean Energy

5 Grid Modernization and Distributed Energy Resources


Source: California Energy Commission

In the past the grid was designed to accommodate large, centralized power plants that delivered power through transmission lines. The Valencia Gardens project illustrates that there are new ways to bring clean energy to underserved communities, while adding resiliency to the local area.

Smart Grid

Advancements in two-way communications and updated market rules can allow passive and active participation in wholesale power markets by consumers and distributed energy resources. Buildings with electric HVAC and lighting systems can reduce temperatures and power consumption automatically in response to market price signals or system operator instructions. Electric vehicles, including fleets of trucks and buses, plugged into charging stations across California can provide load flexing tools and millions of tiny batteries that could be used to balance out intermittent renewable energy. These advancements are still developing, and their potential can be defined by pilot projects and tested over time.

Source: California Energy Commission

The Roadmap to Clean Energy

5 Grid Modernization and Distributed Energy Resources

Credit: StackExchange/Creative Commons

Demand Response

Demand Response programs allow customers to voluntarily decrease their energy use in response to power market conditions to avoid power outages. These demand response programs also reduce the need to build additional resources since the only thing better than clean energy is energy that is never used in the first place. As system requirements change, California will require different types of demand response in response to those changing requirements. A report[58] produced by Lawrence Berkeley National Laboratory created a term for new demand response grid performance called the 4S's:

SHAPE

Shape captures demand response that reshapes customer load profiles through price response or on behavioral campaigns "load-modifying demand response" with advance notice of months to days.

SHIFT

Shift represents demand response that encourages the movement of energy consumption from times of high demand to times of day when there is a surplus of renewable generation. Shift could smooth net load ramps associated with daily patterns of solar energy generation.

SHED

Shed describes loads that can be curtailed to provide peak capacity and support the system in emergency or contingency event.

SHIMMY

Shimmy involves using loads to dynamically adjust demand on the system to alleviate short-run ramps and disturbances at timescales ranging from seconds up to an hour.

In sum, smaller, smarter, and more distributed resources are part of the modern definition of the grid and play a valuable role in the energy ecosystem. Compared to large coal and natural gas plants, the resources of the future will be smaller and more distributed across the grid. Flexibility of loads, combined with overall load reduction measures, will be a key attribute for the grid of the future as the increasing amounts of intermittent renewable energy are integrated onto the grid. Flexibility will also be a key attribute for large industrial customers. Investments that help those customers reduce and manage their loads will protect jobs and support the clean energy future.[59]

[58] March 1, 2017 Final Report on Phase 2 Results: 2025 California Demand Response Potential Study, Lawrence Berkeley National Laboratory (LBNL)
[59] CARB — https://ww2.arb.ca.gov/sites/default/files/classic//cc/scopingplan/scoping_plan_2017.pdf, pp. 69-70.

Powering Forward

The road to achieving 100 percent clean electricity will be challenging, but it is the most important transformation of our lifetimes. Although California has made great strides in eliminating coal power plants and increasing renewable energy resources, our current electricity system is still producing greenhouse gas emissions and contributing to unhealthy air quality in communities. As we navigate the road to clean energy we must focus on all communities and address the injustices that currently exist. Low-income and disadvantaged communities have borne the burden of polluting fossil-fuel energy sources for too long. As we transition to a clean energy economy, we need to ensure that all communities share in benefits of clean energy—cleaner air, healthier communities, and affordable electricity. The transformation has the added benefit of bringing new career opportunities as Californians are put to work designing, engineering, building, and operating new energy sources and transmission and distribution lines, and hardening the existing system to make it more resilient.

There are many economic, commercial, technological, and regulatory barriers every step of the way that will make it tempting to fall back on fossil fuels to power our vehicles, homes, industries, and businesses.

Despite these challenges, now is the time for California to think big and go all in on clean energy. The future has not been written; this is the opportunity to chart the path forward.

The vision of clean energy for every Californian will take an outside-the-box approach to clean energy planning and an aggressive vision to meet the goal. Moving away from natural gas now will take planning to ensure that emerging technologies will be able to support our 100 percent clean electricity system. Not too long ago, most energy experts believed that solar was too expensive and battery energy storage was not a commercially mature technology due to costs. Look how far we've come.

California must build the bridge to get off the fossil fuel road. Achieving clean energy goals requires us to aim high and explore the off-ramps of emerging technologies such as hydrogen, long-duration energy storage, and electrification of the California economy. Realization of the vision will require support for emerging clean technologies, encouragement of innovation, and a re-imagining of the electricity system of the future.

Appendix: California Joint Action Agencies

California Energy Agencies

The California Energy Commission's (CEC) primary functions include: 1) forecasting electricity and natural gas demand for state planning, 2) siting and licensing thermal power plants of 50 megawatts or greater, 3) investing in energy innovation, 4) investing in zero-emission infrastructure, biofuels, manufacturing and related workforce development, 5) setting the state's appliance and building energy efficiency standards, and 6) planning for and directing state response to energy emergencies. The CEC also publishes the Integrated Energy Policy Report, which provides an assessment of major energy trends and issues facing California's electricity, natural gas, and transportation fuel sectors.

The California Public Utilities Commission (CPUC): 1) regulates services and utilities, 2) protects consumers, 3) safeguards the environment, and 4) assures Californians' access to safe and reliable utility infrastructure and services. The essential services regulated include electric, natural gas, telecommunications, water, railroad, rail transit, and passenger transportation companies. The CPUC performs resource planning for 80 percent of California's electric grid through the Integrated Resource Planning proceeding and implements programs such as the RPS, efficiency incentives, transportation electrification investments, customer solar, and building decarbonization.

The California Air Resources Board's (CARB) mission is to promote and protect public health, welfare, and ecological resources through effective reduction of air pollutants while recognizing and considering effects on the economy. CARB is the lead agency for climate change programs and oversees all air pollution control efforts in California to attain and maintain health-based air quality standards.

Operators of the Electric Power Grid

California's power grid is managed by system operators called Balancing Authorities (BA). The California Independent System Operator (CAISO) maintains reliability for one of the largest and most modern power grids in the world, and operates a transparent, accessible wholesale energy market. Other balancing authorities such as the Los Angeles Department of Water & Power (LADWP), Balancing Authority of Northern California (BANC), Imperial Irrigation District (IID), and Turlock Irrigation District (TID) work collaboratively with power grid operators within California and across the West to manage the transmission system that delivers electricity to customers.

[1] The CPUC has jurisdiction only over privately owned entities, such as the investor-owned utilities (IOUs) and does not directly regulate publicly owned utilities (POUs). The SB 100 report was developed with the intent that all California electricity service provides (ESPs) share the same common goal of reaching carbon neutrality by 2045 in compliance with the SB 100 state legislation.