2018 IEPR UPDATE

VOLUME II

The *2018 Integrated Energy Policy Report Update* is dedicated to

NANCY MCFADDEN

1959 –2018

Nancy McFadden was the executive secretary to former Governor Edmund G. Brown Jr., a role comparable to chief of staff, from January 2011 to March 2018. Before that, she held positions as a senior vice president at PG&E, a senior advisor to former Governor Gray Davis, deputy chief of staff for the Office of Vice President, and general counsel for the U.S. Department of Transportation.

Former Governor Brown called her "the best chief of staff a governor could ever ask for." He said, "She understood government and politics, she could manage, she was a diplomat, and she was fearless."

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PREFACE

Senate Bill 1389 (Bowen, Chapter 568, Statutes of 2002), as amended, requires the California Energy Commission to prepare a biennial integrated energy policy report that assesses major energy trends and issues facing the state's electricity, natural gas, and transportation fuel sectors and provides policy recommendations to conserve resources; protect the environment; ensure reliable, secure, and diverse energy supplies; enhance the state's economy; and protect public health and safety (Public Resources Code § 25301[a]). The Energy Commission prepares updates to these assessments and associated policy recommendations in alternate years (Public Resources Code § 25302[d[). Preparation of the *Integrated Energy Policy Report* involves close collaboration with federal, state, and local agencies and a wide variety of stakeholders in an extensive public process to identify critical energy issues and develop strategies to address those issues.

ABSTRACT

The *2018 Integrated Energy Policy Report Update* provides the results of the California Energy Commission's assessments of a variety of energy issues facing California. Many of these issues will require action if the state is to meet its climate, energy, air quality, and other environmental goals while maintaining reliability and controlling costs.

The *2018 Integrated Energy Policy Report Update* covers a broad range of topics, including decarbonizing buildings, energy efficiency, energy equity, integrating renewable energy, updates on Southern California electricity reliability, climate adaptation activities for the energy sector, and the *California Energy Demand Forecast*.

Keywords: California Energy Commission, decarbonizing buildings, energy efficiency, energy equity, Senate Bill 350, electricity demand forecast, climate adaptation and resiliency, Southern California reliability, Aliso Canyon, resiliency, renewable integration

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EXECUTIVE SUMMARY

California's energy system is instrumental to daily life — from heating and cooling homes and delivering water, to powering manufacturing and transporting goods and people. California is working to fundamentally and seamlessly change how energy is produced, delivered, and consumed to drastically reduce greenhouse gas (GHG) emissions that cause climate change. What is not changing is the commitment to safely, reliably, and affordably maintain energy services and ensure that the benefits reach all Californians, particularly those in low-income and disadvantaged communities.

California has already made progress in shifting away from fossil fuels to reduce GHGs and needs to do much more to help avoid the worst impacts of climate change. Over the last 40 years, California has implemented cost-effective appliance and building energy efficiency standards that have saved consumers well over $100 billion. In 2018, about 34 percent of the electricity used to serve California was produced from renewable resources. Californians have purchased almost half of the zero-emission vehicles in the United States. The state has achieved these successes while growing its economy 46 percent since 2010. As former Governor Edmund G. Brown Jr. said at the Global Climate Action Summit in September 2018, "We're getting it done but we have a very tall mountain to climb," adding, "The metaphor I use is, we're at the base camp of Mount Everest, and we're looking up at the long way we still have to go."

Impacts of Climate Change

To help plan for the impacts of climate change, the Governor's Office of Planning and Research, the California Natural Resources Agency, and the Energy Commission released *California's Fourth Climate Change Assessment* (Fourth Assessment, see Figure ES-1). California's Fourth Assessment translates the global climate models into regionally relevant reports to help identify and plan for the impacts of the changing climate on a local scale. The results show a future punctuated by severe wildfires, rising sea levels, increased flooding, coastal erosion, extreme heat events, and more frequent and longer droughts. (Figure ES-2 shows changes in extreme heat in four regions of California.)

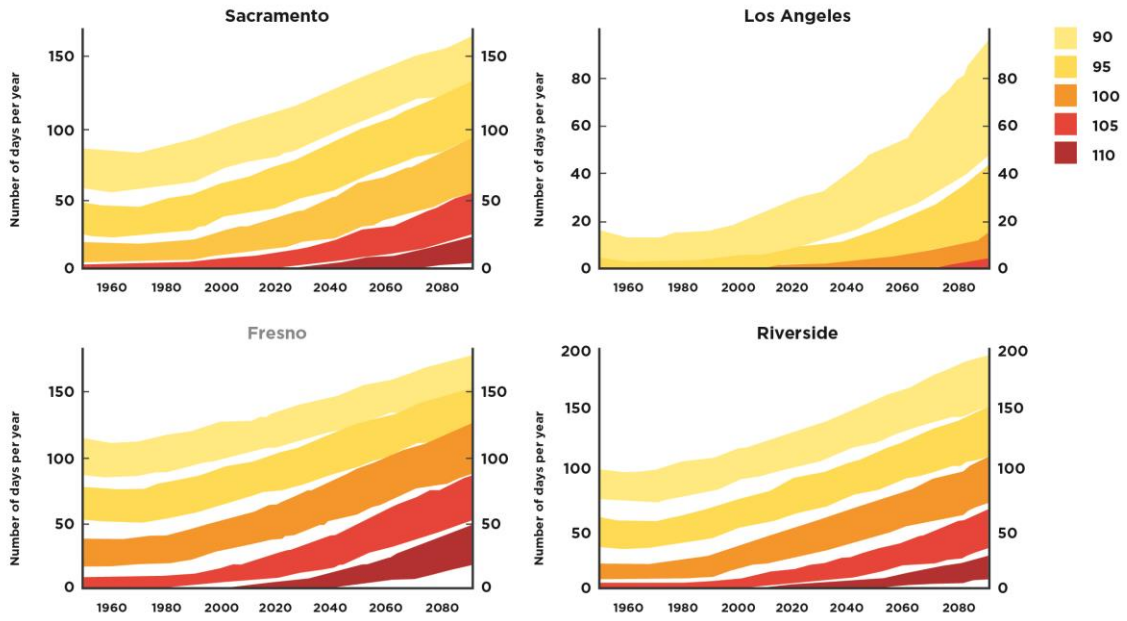
Figure ES-1: *California's Fourth Climate Change Assessment*
Rigorous Science Made Accessible

KEY FINDINGS	A concise summary of the Fourth Assessment's most important findings and conclusions.
STATEWIDE SUMMARY	An in-depth report on how California's people, built environment, and ecosystems will be impacted by climate change and how we can proactively adapt, based on the Fourth Assessment's findings.
SUMMARIES FOR REGIONS AND COMMUNITIES	Reports summarizing Fourth Assessment findings to provide a state of the science for nine regions, the ocean and coast, tribal communities, and climate justice in California.
ORIGINAL RESEARCH TO INFORM POLICY AND ACTION	Academic research that provides robust and detailed results on resilience and vulnerability to climate change.
ASSESSMENT FOUNDATION: UPDATED CLIMATE PROJECTIONS AND DATA	A shared foundation of updated climate change projections, data and ecosystem models developed for use by Assessment authors to permit cross-comparability of results and ensure the findings consider a robust range of future climate conditions. This data is available to the public via Cal-Adapt.org.

Source: California Natural Resources Agency

California is already feeling the effects of climate change with five of the deadliest, seven of the most destructive (in terms of structures destroyed), and four of the largest wildfires in California's history occurring in 2017 and 2018 alone, preceded by a four-year drought. The Fourth Assessment provides insights on the impacts to the energy system and the needs for adaptation and resilience, particularly as a result of increases in the severity and frequency of wildfires.

Figure ES-2: Heat Waves Projected to Increase:
Number of Days at Extreme Heat Threshold or Above (°F)



Source: D. Pierce, Scripps Institute of Oceanography

More work is needed to protect the state's most vulnerable populations and to develop flexible and adaptive strategies to increase resilience. Continued advancements in science and planning are critical to supporting California's continued leadership on actions to address climate change and safeguard the state's people, economy, and resources.

Key Energy Policies

Former Governor Brown's 2015 inaugural address included the following goals for 2030 to reduce GHG emissions. These goals continue to guide the state's energy policy:

- Increase from one-third to 50 percent the state's electricity derived from renewable sources.
- Reduce petroleum use in cars and trucks by up to 50 percent.
- Double the efficiency of existing buildings while making heating fuels cleaner.
- Reduce the relentless release of methane, black carbon, and other potent pollutants across industries.
- Manage farm and rangelands, forests, and wetlands so they can store carbon.

Senate Bill 350 (De León, Chapter 547, Statutes of 2015) codified the Governor's renewable and energy efficiency goals. It also took steps to ensure the benefits of clean

energy transformation are realized by all Californians, especially those in the most vulnerable communities.

In 2016, Senate Bill 32 (Pavley, Chapter 249, Statutes of 2016) set a statewide requirement to reduce California's GHG emissions 40 percent below 1990 levels by 2030, building on the Assembly Bill 32 (Núñez, Chapter 488, Statues of 2006) requirement to reduce GHG emissions to 1990 levels by 2020. Assembly Bill 197 (Garcia, Chapter 250, Statutes of 2016) emphasized equitably implementing state climate change policies such that the benefits reach disadvantaged communities. In addition, Senate Bill 1383 (Lara, Chapter 395, Statutes of 2016) set a goal that California reduce methane and hydrofluorocarbon (HFC) refrigerants to 40 percent below 2013 levels by 2030.

Recognizing that in California the transportation sector is the largest source of GHG emissions and pollutants that directly harm human health, the state is advancing zero-emission and near-zero-emission vehicles. The electricity sector accounted for about 16 percent of statewide GHG emissions in 2016 (the most recent data available), and the transportation sector accounted for about 50 percent when including emissions from refineries. In 2012, then-Governor Brown signed Executive Order B-16-2012 to set a long-term goal of reaching 1.5 million zero-emission vehicles on California's roadways by 2025. In January 2018, former Governor Brown issued Executive Order B-48-18 to put at least 5 million ZEVs in California by 2030 and spur the installation and construction of 250,000 plug-in electric vehicle chargers, including 10,000 direct current fast chargers, and 200 hydrogen refueling stations by 2025.

2018 Legislation to Reduce Carbon Emissions From the Transportation Sector and Other Climate-Related Bills

AB 2127 (Ting) supports the state's goal of achieving 5 million ZEVs on the road by 2030 by affirming the Energy Commission's authority to assess the need for charging infrastructure to support adoption of zero-emission vehicles, including freight and off-road vehicles.

AB 2885 (Rodriguez) continues the legislative priority of ensuring that California's incentive programs serve all communities, by extending the requirement that the California Air Resources Board (CARB) conduct outreach to low-income households and communities as part of the Clean Vehicle Rebate Project and continue to prioritize rebates to low-income applicants until January 1, 2022.

SB 1000 (Lara) requires the state to assess whether vehicle-charging infrastructure is sufficient to encourage the purchase of electric vehicles, and ensures that plug-in electric vehicles and zero-emission vehicles have equal access to charging infrastructure.

SB 1072 (Leyva) establishes a regional climate collaborative program to assist under resourced communities with accessing statewide public and other grant money for climate change mitigation and adaptation-related projects. The bill also requires the Strategic Growth Council to develop technical assistance best practices that state agencies may use and identify state grants that could benefit from technical assistance best practices.

SB 1477 (Stern) establishes two incentive programs aimed at reducing emissions from buildings – one to provide financial incentives for the deployment of near-zero emission building technologies and a second to offer incentives for installing low-emission space and water heating equipment for new and existing buildings.

For a more complete listing of these and other bills signed by the Governor to address climate change, see https://www.gov.ca.gov/2018/09/13/aboard-hybrid-electric-ferry-on-the-san-francisco-bay-governor-brown-signs-bills-to-promote-zero-emission-vehicles-reduce-carbon-emissions/

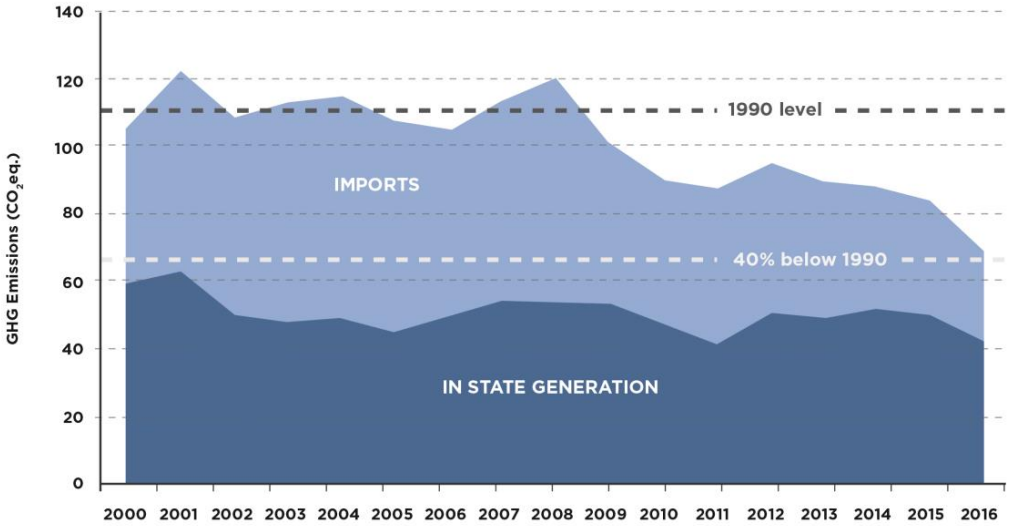
In 2018, Senate Bill 100 (De León, Chapter 310, Statutes of 2018) set a planning target of 100 percent zero-carbon electricity resources by 2045 and increased the 2030 renewables target from 50 percent to 60 percent. On the same day of signing SB 100, then-Governor Brown signed Executive Order B-55-18 with a new statewide goal to achieve carbon neutrality (zero-net GHG emissions) by 2045 and to maintain net negative emissions thereafter. The executive order covers all sectors of the economy and includes consideration of carbon sequestration in natural and working lands. Executive Order B-55-18 follows the spirit of what is required at a global scale to achieve the climate goals of the Paris Agreement, in which signatory nations worldwide agree to sufficiently reduce GHG emissions to avoid catastrophic climate change. This is also consistent with a special report by the Intergovernmental Panel on Climate Change, which found that to avoid catastrophic climate change, global carbon dioxide emissions must decline by about 45 percent below 2010 levels by 2030 and reach net zero by about 2050.

In September 2018, then-Governor Brown signed a comprehensive package of new climate-related bills into law, including bills to advance zero-emission transportation (see box), as well as two bills to block new offshore oil drilling off California's coast: Senate Bill 834 (Jackson, Chapter 309, Statutes of 2018) and Assembly Bill 1775 (Muratsuchi, Chapter 310, Statutes of 2018). Also, the Global Climate Action Summit, cochaired by former Governor Brown, showcased actions underway by states, regions, cities, businesses, investors, and non-governmental organizations to address climate change and resulted in bold new commitments, building momentum to accelerate action on this critical issue.

California's Electricity Sector Leads the Way

The electricity sector is leading the state's efforts to reduce GHG emissions. Although AB 32 and SB 32 goals are economywide, in 2016, the electricity sector surpassed the 2020 goal and nearly met the 2030 goal. In 2016, GHG emissions from the electricity sector were 37.6 percent *below* 1990 levels. (See Figure ES-3.) These gains are largely attributable to advancements in energy efficiency, increased use of renewable energy resources, and reduced use of coal-fired electricity. To further reduce GHG emissions, California is increasingly using renewable resources to produce electricity while planning for increased demand from transportation electrification and other opportunities for electrification.

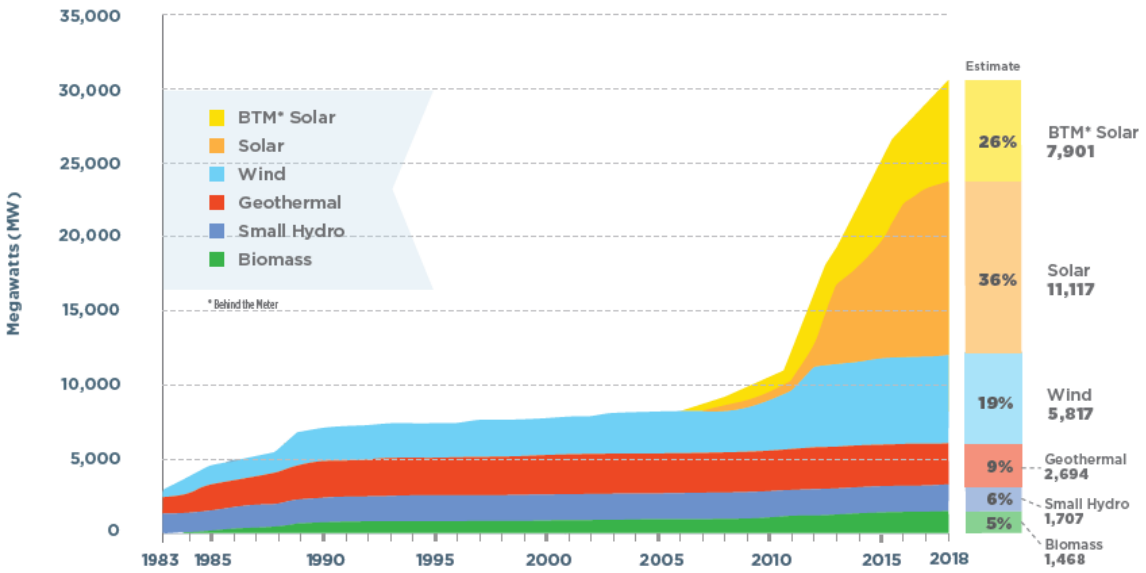
Figure ES-3: GHG Emissions From California's Electricity Sector Continue to Decline (Million Metric Tons)



Source: California Energy Commission using data from the California Air Resources Board

In 2017, solar outstripped all other renewable resources in California for the first time, accounting for 36 percent of the state's renewable generation. (See Figure ES-4.) The increase in solar and other renewables is a success story in reducing GHG emissions but also creates operational challenges. Grid operators must manage the ramp-up of solar generation as it peaks midday and then ramps down at sunset while electricity demand remains high.

Figure ES-4: Annual Cumulative Installed Renewable Capacity Since 1983 (Including Behind-the-Meter Solar)



Source: California Energy Commission, Tracking Progress, Renewable Energy, updated December 2018

Increasing Flexibility to Integrate More Renewable Energy

Some progress has been made in deploying the supply-side and demand-side tools available to help manage the daily and minute-to-minute changes in solar generation. For example, the North American Electric Reliability Corporation and the California Independent System Operator (California ISO) have made progress in developing performance standards for inverter-connected solar and wind power plants that will help improve reliability and increase services to the grid. There are also a greater understanding and ability to plan for the performance of older inverter-connected power plants.

The need for energy storage that can absorb excess energy and reinject it into the grid when needed continues to increase. As the global market for electric vehicles expands, there is a growing opportunity to take advantage of vehicle batteries for energy storage in the electricity sector. Grid regionalization is a promising solution that has not yet been fully realized, but the Western Energy Imbalance Market (EIM) continues to grow (the Western EIM allows for real-time energy transfers in the West), and further opportunities to exchange power with the Bonneville Power Administration are being explored.

Increasing the flexibility of loads is also important, and options include implementing time-of-use rates (to encourage better alignment of energy use with resource availability) and expanding the participation of demand response in energy markets (to reliably and quickly ramp energy load up or down in response to price signals). As these low- and zero-GHG solutions continue to be developed, some strategically located natural gas

power plants that can quickly ramp up and down to compensate for changes in renewable energy production are still needed.

The Changing Market Structure

Increasingly, Californians are making household choices about how and from where they get their electricity. Large numbers of Californians are deciding to generate and possibly store their own electricity or purchase energy services from sources other than their utility, such as from local providers called *community choice aggregators*. Historically, California has had a fairly centralized electricity market. Policies to advance energy efficiency, renewables, and research and development, for example, have been implemented largely by the utilities as directed by the state. This changing model provides new opportunities and raises questions about how the state's energy and climate policies will be realized.

California's Energy Demand Forecast

The Energy Commission's update to its electricity demand forecast is aimed to reflect the changes to and help meet the evolving planning needs of the electricity market. The forecast is used in various proceedings, including the California Public Utilities Commission's (CPUC's) Integrated Resource Plan process and resource adequacy proceeding, as well as the California ISO's annual Transmission Planning Process.

Consistent with previous updates, the analysis refreshes economic and demographic drivers used in the prior *Integrated Energy Policy Report* (*IEPR*) forecast with the most current projections and adds a year of historical data. As a reflection of the changing electricity system, the *2018 IEPR Update* is the first to include refreshed projections of solar photovoltaic system adoptions, plug-in electric vehicle adoptions, community choice aggregators, and time-of-use rate impacts. This update improves upon the hourly load model that was developed in 2017, allowing for a forecast of monthly peak loads to be adopted by the Energy Commission alongside its standard forecasts of consumption and annual peak load. The forecast extends to 2030, comparing across mid demand scenarios. Updated forecasts for consumption remain relatively unchanged from the previous *2017 IEPR* forecast. Managed sales are declining, but at a slower rate than the previous analysis, and managed net peak demand, driven up by a shifting peak hour, remains relatively flat over the forecast horizon.

Decarbonizing Buildings Is the Next Innovation

In California, building GHG emissions are second only to transportation, when accounting for electricity use, water use, and wastewater treatment. The focus over the past decade has been on advancing zero-net-*energy* buildings, and this must pivot to zero-*emission* buildings as the state mobilizes to meet its 2030 and 2050 climate goals. This change from zero-net energy to zero-emission buildings focuses squarely on reducing GHG emissions from the entire building, including from the use of electricity, natural gas, other fuels, as well as cooling systems that typically use highly potent GHGs.

Electrification of space and water heating using highly efficient technologies is a key strategy to reduce or eliminate GHG emissions from buildings. With electrification, achieving zero-emission buildings requires a recognition that emissions from the electricity system are not the same each hour of the day. For example, emissions are lowest midafternoon during peak solar production. Electrification needs to be coupled with strategies such as time-of-use rates and demand response to shift the timing of energy consumption to maximize the use of renewable energy and achieve zero-emission buildings. The future of zero-emission buildings is not only about energy efficiency and transitioning to zero-carbon performance, but about creating healthy and sustainable buildings sited in smart locations where people can travel via transit and active transportation modes. A lower carbon future will require higher-performing and healthier buildings and communities.

Investments in new construction, retrofitting existing buildings, and replacing appliances and other energy-consuming equipment essentially lock in energy system infrastructure for many years and can be longer-term commitments than even investments in transmission or power plants. As a result, each new opportunity for investment in energy efficiency is precious and has long-term implications on the state's ability to meet its climate goals. Increasingly integrating buildings with the grid to better take advantage of the growth in zero-emission energy sources is needed to achieve California's climate goals.

Doubling Energy Efficiency Remains Key

At sufficient scale, increases in energy efficiency can reduce the need for new power plants and new or upgraded transmission and distribution lines and will continue to create headroom for load growth associated with electrification of transportation and buildings. To meet its energy efficiency goals, the state will need to expand energy efficiency efforts and harness emerging technologies, progressive program designs, and innovative market solutions across all sectors of the economy.

For example, manufacturing and agriculture account for about a quarter of total state energy consumption, with about 85 percent of the energy consumed by the industrial sector and the remaining 15 percent by the agricultural sector. Additional savings in these sectors can help fill the gap in meeting SB 350 doubling targets. Energy infrastructure can also benefit from efficiency advancements, and conservation voltage reduction is a proven technology that reduces energy use and peak demand by optimizing voltages on the distribution system.

California Adopts First-in-Nation Standards Requiring Solar on New Homes

The Energy Commission took a bold step in 2018 toward reducing emissions from buildings and increasing efficiency. The new standards require high levels of wall and attic insulation to reduce heating and cooling needs, which is a continuation of the Energy Commission's four-decade long work establishing cost-effective efficiency requirements in statewide building design and construction standards. Moreover, the

Energy Commission adopted and the California Building Standards Commission in December approved the first in the nation building standards that require solar on new homes starting in 2020, following a rigorous assessment of homeowner financial benefits of rooftop PV systems. Six cities have already chosen to require solar in new construction.

Increasing Access to Clean Energy Benefits

While California's renewable and energy efficiency goals are ambitious, meeting them will not be truly successful unless the benefits from the clean energy economy reach all Californians. The state is committed to increasing the equitable distribution of clean energy benefits and creating an inclusive clean energy economy.

As directed by SB 350, the Energy Commission examined the barriers to energy efficiency and weatherization investments, renewable energy generation, and contracting opportunities for local small businesses in low-income and disadvantaged communities. Likewise, the California Air Resources Board (CARB) reported on barriers faced by low-income residents, including those in disadvantaged communities, to accessing zero-emission and near-zero-emission transportation and mobility options. The Energy Commission adopted its report in December 2016, and CARB released its study in February 2018 (termed the Barriers Study Part A and the Barriers Study Part B, respectively).

Multi-agency efforts to implement the recommendations in the two-part barriers study are underway. For example, in June 2018, the Energy Commission launched the Energy Equity Indicators to identify opportunities for improving clean energy access, investment, and resilience in California's low-income and disadvantaged communities. The report is paired with an interactive mapping tool to visualize different mapping layers and focus on different regions of the state.

Also, the Energy Commission developed the *Draft Clean Energy in Low-Income Multifamily Buildings Action Plan*. The report identifies existing programs and policies, remaining challenges, and actions the state can take to accelerate the use of distributed energy resources within California's multifamily housing stock.

CARB is leading efforts to increase access to, and awareness about, clean transportation and mobility options for low-income residents. CARB's efforts concentrate on expanding education and outreach and developing a One-Stop-Shop Pilot Project for CARB's Low-Carbon Transportation Equity Projects.

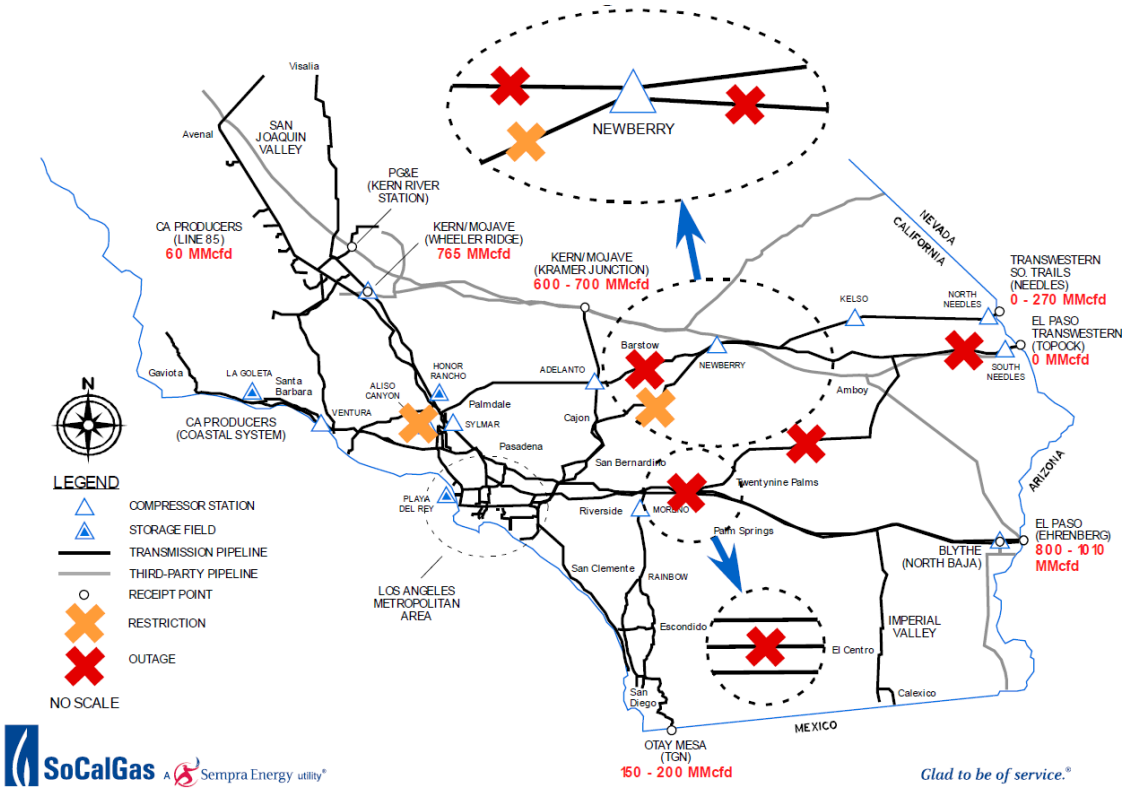
Continued Efforts Needed to Maintain Energy Reliability in Southern California

While pursuing a cleaner energy system with benefits for all Californians, the state continues to grapple with making sure energy supplies are reliable in the near term, particularly in Southern California. This region has been the focus of electric reliability concerns beginning with the outage of the two San Onofre Nuclear Generating Station

units (San Onofre) in January 2012, followed by the decision to retire San Onofre in June 2013 and the massive gas leak discovered on October 23, 2015, at the Aliso Canyon natural gas storage facility. These events, coupled with the expected compliance-related closure of several Southern California coastal power plants that use ocean water for cooling, as well as long-term outages on major natural gas pipelines in the Southern California Gas (SoCalGas) system, place the regional energy supply in a tight situation.

The Energy Commission, CPUC, and the California ISO continue to work together to address reliability issues first with the closure of San Onofre and, with the additional partnership of the Los Angeles Department of Water and Power, to address reliability issues related to Aliso Canyon. This year marks the third year of analysis by the joint agency team of the natural gas and electricity systems, this time for summer 2018 (see Figure ES-5) and winter 2018–2019. For all scenarios studied, the analysis finds that pipeline capacity is more constrained in 2018 than in the previous year, meaning there is a greater risk of service interruptions than last year or solely due to restricted use of Aliso Canyon. The summer 2018 study identified five new mitigation measures, including steps to increase local gas and electricity supply, to help improve the short-term reliability concerns. Reliability risks remain the same in winter 2018–2019, with the possibility of multiple cold days late in winter posing the greatest risk to energy reliability in the region.

Figure ES-5: Southern California Gas System Outages (as of April 2018)



Source: SoCalGas presentation at the May 8, 2018, IEPR joint agency workshop on Southern California Energy Reliability, http://www.energy.ca.gov/2018_energypolicy/documents/#05082018.

Looking further ahead, planning is underway to phase out Aliso Canyon within 10 years, as former Governor Brown has directed Energy Commission Chair Robert B. Weisenmiller. Chair Weisenmiller and CPUC President Michael Picker requested that California ISO President and Chief Executive Officer Stephen Berberich evaluate expanded transmission capability of low-carbon supplies to and from the Northwest to support phasing out Aliso Canyon. The study is underway.

For reliability issues related to San Onofre and the closure of coastal power plants, the agencies are periodically reviewing progress on preferred resources (local energy efficiency, demand response, renewable generation, storage, and combined heat and power), conventional generation, and transmission projects to determine whether further actions are needed. Delays of a large transmission project to increase capability to import electricity into the region, the Mesa Loop-in project, bear watching. The joint agencies will continue to evaluate actions to take in 2019, as needed.

California's Leadership to Address Climate Change Remains Strong

The effects of climate change pose serious risks to the state, and the level of risk is contingent upon global emission trends. California leads by example, demonstrating strategies to reduce emissions while stimulating economic growth.

Under the leadership of former Governor Brown, the state has forged partnerships with nations and subnational governments worldwide to help limit the rise in global average temperature to below 2 degrees Celsius to avoid catastrophic climate change. Former Governor Brown's achievements include spearheading the Subnational Global Climate Leadership Memorandum of Understanding (the "Under-2 MOU"), being a leader in achieving the Paris Agreement at the 2015 United Nations Climate Change Conference, and being appointed the special advisor for States and Regions ahead of the 2017 conference. In September 2018, California hosted the Global Climate Action Summit in San Francisco to strengthen the push for greater emissions reductions internationally.

In signing California's goal for 100 percent clean energy by 2045 into law, former Governor Brown stated, "To truly stop global warming, cleaning up our electricity grid is not enough. We must transition to carbon neutrality and that will not be easy. It will require large investments across all sectors — energy, transportation, industrial, commercial and residential buildings, agriculture, and various forms of sequestration, including natural and working lands. California is committed to doing whatever is necessary to meet the existential threat of climate change." Former Governor Brown also signed an executive order setting a new statewide goal to achieve carbon neutrality "as soon as possible, and no later than 2045, and achieve and maintain net negative emissions thereafter." The executive order notes that "scientists agree that worldwide carbon pollution must start trending downward by 2020, and carbon neutrality — the point at which the removal of carbon pollution from the atmosphere meets or exceeds emissions — must be achieved by midcentury."

CHAPTER 1: Decarbonizing Buildings

Introduction

California must make sharp shifts in building energy use to achieve the greenhouse gas (GHG) emissions reductions necessary to meet the state's long-term climate goals. Doubling energy efficiency savings in electricity and natural gas end uses by 2030, as discussed in Chapter 2, will reduce building-related energy consumption and help move toward these goals. However, the state will need additional efforts to decarbonize homes and businesses to meet California's goals for 2030 and 2050.

Throughout the economy, builders, building occupants, and home and commercial property owners must have the tools and clear options to make low- and zero-carbon choices. This will require decisive actions to implement the necessary policies, including:

- More strategic use of data on energy consumption and usage patterns.
- Revisions to building and equipment codes and standards.
- Continued research and development of efficient and renewable electric and gas technologies.
- Development of programs, rates, and practices that will lead systematically to actions and investments that reduce the carbon footprint of California's buildings.

Electrification is one highly salient strategy to reduce or eliminate GHG emissions from buildings, including the methane emissions associated with natural gas use. Carbon dioxide (CO_2) reductions will accelerate as the electricity system becomes cleaner with large increases in renewable resources. (See Chapter 3.) In particular, electrification of space and water heating with highly efficient technologies, coupled with strategies to intelligently shift energy consumption in time, will be key to reducing emissions from buildings. Strategies employed must also encourage the use of refrigerants with low global warming potentials and otherwise reduce GHG emissions associated with refrigerants. Addressing refrigerant emissions will become increasingly important as building energy systems rely more on heat pump technologies rather than fossil fuels to meet heating demands.

Because buildings have long lives, opportunities to make major investments in new equipment and infrastructure are limited. It is essential that when constructing new buildings, retrofitting existing buildings, or replacing appliances and equipment that zero-emission technologies, designs, and measures be readily available and easy to implement. Considerable market transformation must occur to reach that end.

This chapter discusses:

- The policy goals that are driving the state to decarbonize buildings.
- The sources of GHG emissions in buildings.
- The reasons for pursuing electrification strategies.
- Challenges to building decarbonization.
- Utility and California Public Utilities Commission (CPUC) efforts in electrification.
- Research and development to support decarbonizing buildings.

Policy Goals for Decarbonizing Buildings

Over the last decade, California has adopted key state policies and statutes that are driving GHG emissions reductions, starting with enactment of Assembly Bill 32, the California Global Warming Solutions Act of 2006 (Núñez, Chapter 488, Statues of 2006). AB 32 established an economywide goal of reducing GHG emissions to 1990 levels by 2020 and charged the state with adopting policies and regulations to achieve the maximum technologically feasible and cost-effective GHG reduction strategies. Since that time, the state has increasingly moved to organize energy policies and programs around achieving GHG emissions reduction goals.

In his January 2015 inaugural address, then-Governor Edmund G. Brown Jr. set the following energy and climate goals:

- Increase from one-third to 50 percent the state's electricity supplied by renewable sources.
- Reduce petroleum use in cars and trucks by up to 50 percent.
- Double the efficiency of existing buildings while making heating fuels cleaner.
- Reduce the relentless release of methane, black carbon, and other potent pollutants across industries.
- Manage farm and rangelands, forests, and wetlands so they can store carbon.

Senate Bill 350 (De León, Chapter 547, Statutes of 2015), enacted in 2015, requires California to achieve 50 percent renewable electricity by 2030. It also calls for the doubling of energy efficiency savings in electricity and natural gas through efficiency and conservation. California's energy efficiency and renewables targets support the state's GHG reduction goals. Senate Bill 32 (Pavley, Chapter 249, Statues of 2016) established a GHG emissions reduction goal of 40 percent below 1990 levels by 2030, building on the 2006 landmark legislation (Assembly Bill 32, Núñez, Chapter 488, Statutes of 2006) requiring GHG emissions be reduced to 1990 levels by 2020. In addition, Senate Bill 1383 (Lara, Chapter 395, Statutes of 2016) set a goal that California reduce methane and hydrofluorocarbon (HFC) refrigerants to 40 percent below 2013 levels by 2030.

Senate Bill 1440 (Hueso, Chapter 739, Statutes of 2018) requires the CPUC, in consultation with CARB, to consider adopting "specific biomethane procurement targets or goals for each gas corporation."[1] In its filed comments on the *Draft 2018 IEPR Update*, SoCalGas notes that it believes this market stability will "increase production, drive down costs over time … and provide the volumes of renewable gas necessary to move it into the core market to decarbonize the building sector."[2] SoCalGas also suggests that Senate Bill 1369 (Skinner, Chapter 567, Statutes of 2018) may help with "increasing the volumes of renewable hydrogen gas available to assist in decarbonizing the building sector."[3]

Former Governor Brown's capstone climate policy was issued September 10, 2018, with Executive Order B-55-18, which establishes a new statewide goal to achieve carbon neutrality by 2045 then achieve and maintain net negative carbon emissions thereafter.[4] On the same day, then-Governor Brown signed Senate Bill 100 (De León, Chapter 312, Statutes of 2018) that sets a planning target of having renewable resources and zero-carbon electricity resources serve 100 percent of California's electricity use by 2045. It also increases the 2030 Renewables Portfolio Standard target from 50 percent to 60 percent. (See Chapter 3 for further discussion.) On September 13, 2018, former Governor Brown signed Assembly Bill 3232 (Friedman, Chapter 373, Statutes of 2018), directing the Energy Commission to develop a statewide plan by 2021 to reduce GHG emissions from buildings 40 percent below 1990 levels by 2030.[5] Senate Bill 1477 (Stern, Chapter 378, Statutes of 2018) requires the CPUC, in consultation with the Energy Commission, to create an upstream and downstream incentive program that would use $50 million of gas corporation cap-and-trade revenues annually to ease installation of GHG emissions reducing technologies in buildings.

California's 2017 Climate Change Scoping Plan recommends establishing target dates and pathways for a state policy on zero-carbon buildings to help achieve the deep reductions needed across all sectors to meet the state's long-term 2050 climate goals. Outside of energy use, there are additional opportunities to reduce GHG emissions associated with buildings (such as low-GHG potential refrigerants).

California, as part of the Pacific Coast Collaborative (PCC), also shares the ambitious goal of reducing Pacific Coast GHG emissions by at least 80 percent by 2050.[6] The PCC is a group of cities, states, and provinces on the West Coast of North America that collectively represent a population of 54 million and a gross domestic product of $3

1 https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180SB1440.

2 https://efiling.energy.ca.gov/GetDocument.aspx?tn=225796&DocumentContentId=56469.

3 Ibid.

4 https://www.gov.ca.gov/wp-content/uploads/2018/09/9.10.18-Executive-Order.pdf.

5 https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180AB3232.

6 PCC, "How Will the West Coast Reduce Greenhouse Gases From Building Heating and Cooling?"

trillion.[7] The PCC, established in 2008, promotes regional action to transform power grids, transportation systems, buildings, and economies to address climate change. The state of California, as well as the cities of San Francisco, Oakland, and Los Angeles, are PCC members.

In 2016, the PCC committed to lower the carbon intensity of heating fuels in buildings. It has also established three primary pathways for large reductions in GHG emissions in buildings: increasing energy efficiency, electrification, and renewable natural gas. To achieve deep decarbonization goals, PCC has targeted the need to significantly reduce GHG emissions from heating and cooling in buildings. This target includes avoiding near-term steps that lock in fossil-based fuels and technologies that may prevent the region from meeting its long-term climate goals.

In 2018, California joined the Net Zero Carbon Buildings Commitment, administered by the World Green Building Council for the Global Climate Action Summit. The commitment calls on signatories to enact regulations and planning policies to ensure that all new buildings operate at net zero carbon emissions by 2030 and for all buildings to do so by 2050.

Reducing GHG Emissions From Buildings

Electricity and natural gas each account for about half of the total energy used in California's buildings, as shown in Figure 1. Residential buildings use about two-thirds of the natural gas, 90 percent of which is for space heating and water heating. In commercial buildings, space heating represents a similarly large portion of the gas use. Water heating, on the other hand, accounts for just over one-tenth of commercial natural gas use. Commercial cooking, laundry, and process loads account for the remaining gas use in this sector.[8]

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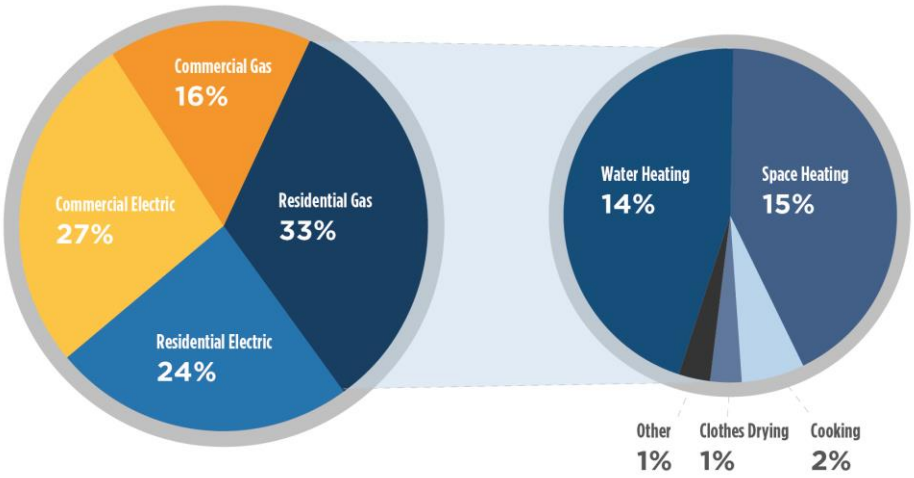
7 Member of the PCC include Alaska. British Columbia, Oregon, Washington, and California. http://pacificcoastcollaborative.org/.

8 Kavalec, Chris, Asish Gautam, Mike Jaske, Lynn Marshall, Nahid Movassagh, and Ravinderpal Vaid. 2018. *California Energy Demand 2018 — 2030 Revised Forecast. California Energy Commission*, Energy Assessments Division. Publication Number: CEC-200-2018-002-CMF. https://efiling.energy.ca.gov/getdocument.aspx?tn=223244.

Figure 1: Energy Use in California Buildings

2016 Energy Use in California Buildings (MMBtu)



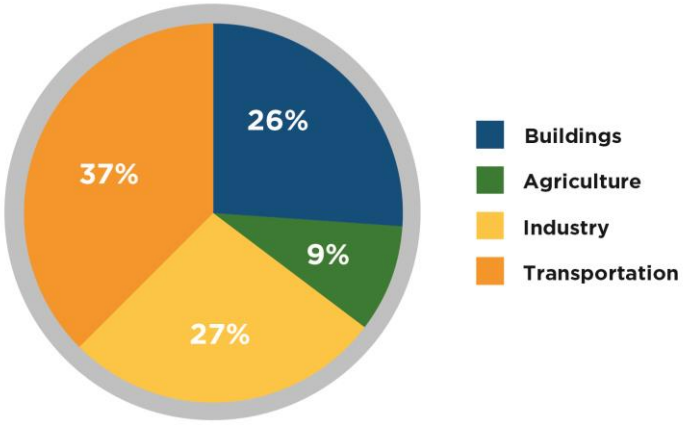
Source: California Energy Commission

Direct GHG emissions from fossil fuels used in buildings account for about 10 percent of the state's total GHG emissions. Energy infrastructure, such as generation, transmission, and distribution assets, generally last 30 to 40 years or longer, while most structures in California's built environment will remain for 50 to 100 years.[9]

New construction projects, retrofitting existing buildings, and replacing appliances and other energy-consuming equipment essentially lock in energy system infrastructure for many years. As a result, each new opportunity for truly impactful investment in energy efficiency and fuel choice is precious. If the decisions made for new buildings result in new and continued fossil fuel use, it will be that much more difficult for California to meet its GHG emission reduction goals. Parties planning new construction have the opportunity instead to lock in a zero- or low-carbon emission outcome that will persist for decades. Similarly, renovations of existing buildings and replacement of appliances and equipment at the end of life can also move California closer to meeting GHG reduction goals. The opportunity to put in place lower-cost, lower-GHG-emission buildings and equipment may be lost unless consumers are positioned to make, and investors to explicitly support, informed decisions at the pivotal moments of choice around infrastructure replacement.

9 In this report, the term *built environment* refers to the buildings in which people live and work and conduct the activities that make up their daily lives. There are broader definitions that include the infrastructure people rely on.

Figure 2: GHG Emissions by Sector (Percentage of Carbon Dioxide Equivalent)



Source: California Energy Commission using data from the California Air Resources Board 2018 GHG Inventory and the *2017 IEPR Electricity Demand Forecast*

In California, building GHG emissions are second only to transportation, when accounting for electricity use, water use, and wastewater treatment (Figure 2).[10] Due to cross-sector interactions, buildings also affect waste disposal and recycling systems, as well as land-use and transportation patterns. The future of zero-emission buildings is not only about energy efficiency and transitioning to zero-carbon performance, but about creating healthy and sustainable buildings sited in smart locations where people can travel via transit and active transportation modes. A lower carbon future will require higher-performing and healthier buildings and communities.

In addition to GHG emissions, nitrogen oxides (NO_x), carbon monoxide, and other pollutants that are products of fossil fuel combustion can harm human health. Increasing concentrations of NO_x contribute to ground-level ozone, another chemical that can be detrimental to human health. Ozone is also a major component in smog. In metropolitan areas of California, ozone concentrations frequently exceed existing health-protective standards in the summertime.[11] An estimated 93 percent of Californians live in ozone nonattainment areas. Additional ventilation requirements are needed in buildings that use gas equipment and appliances to minimize the indoor air pollutants caused by incomplete combustion. By decarbonizing buildings, California is striving to make changes that reduce smog and support human health.

Two potent short-lived climate pollutants also contribute significantly to GHG emissions from buildings: hydrofluorocarbons (HFC), from use as refrigerants in buildings, and

10 Does not add to 100 percent due to rounding.

11 CARB, Common Air Pollutants, https://ww2.arb.ca.gov/resources/common-air-pollutants.

methane emissions associated with the natural gas system, discussed in the following section.

The Case for Building Electrification

There is a growing consensus that building electrification is the most viable and predictable path to zero-emission buildings. This consensus is due to the availability of off-the-shelf, highly efficient electric technologies (such as heat pumps) and the continued reduction of emission intensities in the electricity sector. With former Governor Brown's signing of Senate Bill 100, the electricity grid will produce fewer GHG emissions throughout the useful lives of California's buildings. Renewable gas can be a part of the solution to reducing GHG emissions from buildings, but the role is likely to be constrained by limitations on renewable gas availability, cost, and ongoing methane leakage concerns. The Environmental Defense Fund considers building electrification a critical strategy for California to attain its GHG emission reduction goals, in light of new findings of methane leakage throughout the natural gas supply chain.[12] Many private citizens added their support for building electrification in the Energy Commission docket for this policy topic.

Heat pump technology is central to the concept of electrification to achieve decarbonization. Electric heat pump appliances are able to consume three to five times less energy than conventional electric and gas heating versions. That increased efficiency allows significant decarbonization today and even more benefits as the GHG levels of the electricity sector continue to decrease with higher levels of renewable generation.

Homes in moderate and cold inland climates in the state, such as Sacramento, have a substantial opportunity to reduce GHG emissions by powering high-efficiency space-heating devices with electricity rather than natural gas. Similarly, homes in mild coastal climates, such as Los Angeles, have the opportunity to reduce GHG emissions by powering high-efficiency water-heating devices with electricity instead of gas. All-electric homes, as well as commercial buildings, particularly for new construction, have great promise in reducing GHG emissions.

Policy Studies on Decarbonization

Several recent studies identify building electrification as a low-cost strategy to decarbonize buildings and, if properly integrated and optimized, complement energy efficiency, renewables, and energy storage. One study analyzed long-term options and costs of different pathways to achieve the 2030 and 2050 GHG reduction goals.[13] A second study examined how low-carbon energy policies, including building

12 https://efiling.energy.ca.gov/Lists/DocketLog.aspx?docketnumber=18-IEPR-09, TN# 223957.

13 Energy and Environmental Economics. June 2018. *Deep Decarbonization in a High Renewables Future: Updated Results from the California PATHWAYS Model.* https://efiling.energy.ca.gov/GetDocument.aspx?tn=223785.

electrification, would affect incomes and employment across the state, with a focus on disadvantaged communities.[14] A third study assessed the economics of electrifying buildings, specifically examining how electrification of space and water heating supports decarbonizing homes.[15] The Natural Resources Defense Council (NRDC) commissioned an additional study on the topic of decarbonizing building heating energy use that was released by Synapse Energy Economics in October 2018.[16] This report is not summarized here, but is referenced later in this chapter.

Pathways Study

As part of the research funded by the Energy Commission, Energy and Environmental Economics (E3) developed long-term energy scenarios to examine the amount of GHG reductions possible with a variety of technologies and mitigation strategies. E3 developed a reference case to determine how far current policy will take the state toward its climate goals. The study also developed scenarios to identify additional measures needed in terms of deployment, market transformation, and "reach" technologies.[17] All the GHG mitigation scenarios are characterized by high levels of energy efficiency and conservation, renewable electricity generation, and transportation electrification. In addition to conventional energy efficiency, the study suggested deep decarbonization in buildings with extensive building electrification, featuring heat pumps for space conditioning and water heating, or replacing fossil natural gas use with carbon-neutral renewable gas.

The study found that achieving California's climate goals would fundamentally transform the state's energy economy, but that the net cost of converting to a low-carbon system is relatively small. The estimated 2030 direct costs (excluding health and climate benefits) for the different scenarios range from a savings of $2 billion per year to a net cost of $17 billion per year, with a base case net cost of $9 billion per year. To put this in context, the $2 billion in projected savings equate to roughly 0.1 percent of California's gross state product, while the $17 billion in projected costs amount to roughly 0.5 percent of gross state product. Other studies estimate the health benefits alone of GHG reductions are likely to outweigh these costs.

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14 Mahone, Amber, Zachary Subin, Jenya Kahn-Lang, Douglas Allen, Vivian Li, Gerrit De Moor, Nancy Ryan, and Snuller Price. 2018. *Deep Decarbonization in a High Renewables Future: Updated Results from the California PATHWAYS Model.* California Energy Commission. Publication Number: CEC-500-2018-012. https://www.ethree.com/wp-content/uploads/2018/06/Deep_Decarbonization_in_a_High_Renewables_Future_CEC-500-2018-012-1.pdf.

15 Billimoria, Sherry, Leia Guccione, Mike Henchen, and Leah Louis Prescott. 2018. *The Economics of Electrifying Buildings: How Electric Space and Water Heating Supports Decarbonization of Residential Buildings.* Rocky Mountain Institute. https://www.rmi.org/insight/the-economics-of-electrifying-buildings/.

16 Hopkins, Asa S., Kenji Takahashi, Devi Glick, and Melissa Whited. 2018. *Decarbonization of Heating Energy Use in California Buildings: Technology, Markets, Impacts and Policy Solutions.* Synapse Energy Economics. http://www.synapse-energy.com/sites/default/files/Decarbonization-Heating-CA-Buildings-17-092-1.pdf.

17 A *reach technology* is not widely commercialized today but has been demonstrated outside laboratory conditions and has the potential to lower emissions from sectors that are difficult to address.

Overall, the study concluded that a high electrification scenario offers the most promising path to achieving GHG reduction targets in the least costly manner. The high electrification scenario described a transition of the state's buildings from using natural gas to low-carbon electricity for heating. Potential costs from the early retirement of end-use equipment and any cost equity effects for natural gas customers were not included in this study. The high electrification scenario showed moving to high-efficiency heat pumps for heating, ventilation, and air conditioning (HVAC) and water heating achieved the largest reductions in total building demand for electricity and natural gas.

The study noted that this electrification presents a suite of implementation challenges, including uncertain feasibility and costs of retrofitting the state's existing building stock, equity and distributional cost impacts; and consumer acceptance. To decarbonize heating demands in buildings through a transition to electric heat pumps (without requiring early retirements of functional equipment), the study suggests that the transition to electrification must start by 2020 and achieve significant market share by 2030. The study concluded that to achieve high levels of consumer adoption of zero-carbon technologies, particularly of energy efficiency and electric heat in buildings, market transformation is needed to bring down the capital cost and increase the range of options available. The study further noted that many contractors in California do not have experience sizing and installing heat pump equipment, and customers do not have experience using it.

Berkeley Economic Advising and Research Study

In 2016, the Energy Commission initiated a companion research study with Berkeley Economic Advising and Research LLC to assess the implications of accelerating GHG emission reductions.[18] The study examined a combination of expanded renewable electricity, electrification of vehicles and heating, and a wide array of technology-driven energy efficiency improvements. There were four general insights from the study:

- Energy system investments are a potent catalyst for income and job growth.
- Technology adoption benefits can far exceed the related direct costs.
- Energy savings from implementing policies are substantial and induce broad-based job creation.
- Statewide savings from averted mortality and morbidity are likely to be comparable to the direct costs of the energy system buildout.

The study estimates the investment in low-carbon energy infrastructure would increase California's real gross state product by 2 percent by 2030 and 9 percent by 2050. It would promote job growth with 500,000 additional full-time jobs, mostly in

18 Roland-Holst, David, Samuel Evans, Samuel Heft-Neal, Drew Behnke, and Myung Lucy Shim. 2018. *Exploring Economic Impacts in Long-Term California Energy Scenarios.* California Energy Commission. Publication Number: CEC-500-2018-013.

construction, by 2030 and 3.3 million jobs by 2050. The average economic benefits are relatively greater in disadvantaged communities than in nondisadvantaged communities from the primary job stimulus in the construction and services sectors. Jobs from California's climate policies in disadvantaged communities could increase by nearly one million by 2050.

In addition to the economic benefits, reducing GHG emissions could yield substantial health benefits because reducing GHG emissions would also reduce air pollutants that have known health effects. The health effects, like the economic impacts, are greater for disadvantaged communities, as they are exposed to more pollutants and have higher rates of pollution-associated diseases like asthma. While disadvantaged communities have 25 percent of the population, they could see 30 percent of the total economic benefits from averted health costs, bringing $1.7 billion in health benefits to these communities.

Rocky Mountain Institute Study

The Rocky Mountain Institute's study examined the economics of electrifying buildings with electric heat pump space and water heating to meet a deep decarbonization target of a 75 percent reduction in GHG emissions. The study compared electric space and water heating to fossil fuel-based heating for new construction and home retrofits under various electric rate structures in four locations: Oakland, California; Houston, Texas; Providence, Rhode Island; and Chicago, Illinois. The study found that with an increasingly low-carbon electricity grid, there is an opportunity to meet nearly all energy use in buildings with electricity. The study concluded that this change could eliminate direct fossil fuel use in buildings and make the gas distribution system, along with the associated costs and safety challenges, nearly obsolete. In addition, the study found that electric space and water heating could aid in cost-effectively integrating renewables into the grid through intelligent management to shift energy consumption in time.

The study notes that achieving GHG reductions will require massive market transformation, including discontinuing the expansion of the gas distribution system, widespread adoption of new appliances in homes and businesses, and new markets for intelligent devices to provide flexible demand to the grid. The study concluded that the most efficient space- and water-heating devices have small market share today. It found that many homes would need additional electrical work to accommodate heat pumps and that consumer awareness of this technology is low. The study focused primarily on electrification of the residential sector but pointed out commercial building electrification would require similar market transformation to achieve deep decarbonization. It assumed that cooking, clothes drying, and other end uses in homes would be electric.

The study results showed that for most new home construction, electrification reduces costs over the lifetime of the appliances when compared with fossil fuels. However, it found that for many existing homes heated with natural gas, electrification would increase costs at today's prices compared to replacing gas furnaces and water heaters

with new natural gas devices. The study concluded that electrification is cost-effective for those customers who would otherwise need to replace a furnace and an air conditioner simultaneously or for customers who bundle rooftop solar with electrification.

The study also found electrification cost-effective for most new homes, especially when considering the avoided cost of natural gas mains, services, and meters not needed in all-electric neighborhoods. Customers with existing gas service face higher upfront costs to retrofit to electric space- and water-heating compared with new natural gas devices. In the case studied for Oakland, electric space and water heating would save too little to make up the additional capital costs. The study makes recommendations to capture near-term benefits from cost-effective electrification.

Benefits of Building Electrification

Building electrification is essential to California's strategy to meet its GHG reduction goals for 2030 and 2050. To set effective policies to guide electrification strategies, a recent paper by the Regulatory Assistance Project frames the case for what it calls *beneficial electrification*.[19] The fundamental premise is that to be beneficial, electrification must meet one or more of the following conditions without adversely affecting the other two:

- Saves consumers money over the long run.
- Enables better grid management.
- Reduces negative environmental impacts.
- Provides building occupant health benefits.

In many cases, building electrification meets these criteria. Using heat pumps for space and water heating, as well as other uses, is cost-effective in the long run simply because electrification technologies can be significantly more efficient than natural gas technologies. In addition, all electricity ratepayers could benefit from electrification because of associated system benefits if electrification of space and water heating is coupled with communication and control technologies to ease and increase grid flexibility by shifting electricity use across the hours of the day, while delivering the same end-use service at the same or better quality and lower cost. The benefits of electrification are contingent on actions beyond the simple installation of appliances — rates that support load shifting, contracts that allow and support automation at scale, and the networks and systems that implement it. It is also appropriate to couple envelope efficiency measures, such as additional attic insulation, with high-efficiency

19 Farnsworth, David, Jessica Shipley, Jim Lazar, and Nancy Seidman. June 2018. *Beneficial Electrification: Ensuring Electrification in the Public Interest*. Regulatory Assistance Project. https://www.raponline.org/knowledge-center/beneficial-electrification-ensuring-electrification-public-interest/.

electric equipment installations to deliver the best outcomes and maximize consumer benefits.[20]

Automatic controls and rate structures can encourage customers to reshape their demand profiles in ways that are either invisible or minimally affect their level of service.[21] For example, for water heating and space conditioning, flexible devices preheat or precool during periods of low-cost, low-GHG emitting electricity so customers can use less electricity when supplies have higher costs and GHG emissions, thus using buildings as thermal storage. As noted earlier, the shift to electrification, in addition to lowering GHG emissions, reduces criteria pollutants and methane leakage, providing additional health and environmental benefits.

A survey of mechanical engineering firms in California finds that most of the time, all-electric, low-carbon buildings are cost-competitive with the natural gas-dependent counterparts.[22] The architectural and engineering industry has already completed a significant number of these buildings and anticipates increases in the proportion of projects that are either all-electric or lower in carbon. The practical benefits of all-electric design include the following:

- Eliminating gas service from mains to buildings provides substantial cost savings for new construction projects.
- Eliminating gas service to equipment saves space, cost, and design complications.
- Eliminating combustion venting saves space and installation costs.
- All-electric buildings can more fully leverage onsite electricity generation and storage, reducing electricity distribution costs.
- Using air-source cooling with heat pumps instead of water-based cooling with cooling towers saves water and maintenance.

An additional benefit of building electrification is that the fuel used in California buildings will be supplied, over time, by more in-state renewable energy resources. Roughly 90 percent of natural gas used in California is imported, while most renewable electricity is generated in state. The expectation that energy supply industries will provide additional good jobs for Californians is included in the benefits cited by the Berkeley Economic Advising and Research study, summarized above.

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20 Hopkins, Asa S., Kenji Takahashi, Devi Glick, and Melissa Whited. 2018. *Decarbonization of Heating Energy Use in California Buildings: Technology, Markets, Impacts and Policy Solutions*. Synapse Energy Economics. Pg. 2-3. http://www.synapse-energy.com/sites/default/files/Decarbonization-Heating-CA-Buildings-17-092-1.pdf.

21 Billimoria, Sherry, Leia Guccione, Mike Henchen, and Leah Louis Prescott. 2018. *The Economics of Electrifying Buildings: How Electric Space and Water Heating Supports Decarbonization of Residential Buildings*. Rocky Mountain Institute. https://www.rmi.org/insight/the-economics-of-electrifying-buildings/.

22 Shell, Scott. "Are We Ready for All-Electric Buildings?" March 14, 2018. https://efiling.energy.ca.gov/GetDocument.aspx?tn=223763.

Challenges for Building Electrification

At the June 14, 2018, *IEPR* workshop on Achieving Zero-Emission Buildings, participants discussed several challenges to building electrification. The following discusses issues and barriers, including inadequate efficiency ratings for heat pump technologies, changes to building standards, infrastructure impacts, multifamily energy equity barriers, and cost and rate impacts.

Equipment Replacements

To successfully decarbonize buildings, gas equipment will likely need to be replaced with electric equipment. Existing buildings that use gas for water heating, for example, may not have the electrical infrastructure capacity to install heat pump water heaters (HPWHs), since these require 240-volt electrical service. Electrical upgrades that may include a new receptacle outlet, wiring, circuit breaker, and the service panel would add significant costs to these equipment replacements. These infrastructure upgrade costs are raised in the California Building Industry Association's March 2018 study on costs associated with residential electrification.[23]

Technology developments are needed to provide highly efficient electric equipment that is designed to cost-effectively replace gas equipment without additional infrastructure upgrades. As noted by the NRDC, the most recent HPWHs on the market allow many customers to install an HPWH without a panel upgrade.[24] There is also a great need for workforce training to support the installation of new technologies that are unfamiliar to trade professionals. Senate Bill 1477 is aimed at helping address some of these issues.

Installed Performance of Heat Pump Technologies

While heat pumps have seen significant technological improvements in recent years, the current U.S. Department of Energy (U.S. DOE) test procedures and performance metrics do not adequately capture the real-world performance for heat pump space heaters and heat pump water heaters. If heat pumps do not perform as expected from the associated efficiency ratings, then energy use will be larger than necessary, and GHG emission reductions will be small or nonexistent. Installation of heat pumps that fail to provide heat effectively in buildings could jeopardize consumer acceptance of the technology.

Several regional organizations have taken initiatives to better characterize heat pump performance to measure energy efficiency over the full range of expected equipment operation. The initiatives have resulted in significant advancement in availability of products that are not only energy-efficient, but provide improved consumer comfort. The following briefly discusses equipment ratings issues and how they are being addressed.

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23 https://efiling.energy.ca.gov/GetDocument.aspx?tn=224498.

24 https://efiling.energy.ca.gov/GetDocument.aspx?tn=224592.

The DOE heating efficiency metric for air-source electric heat pumps used for space heating is the *heating season performance factor* (HSPF).[25] HSPF does not provide adequate information on heating performance of heat pumps at low temperatures. Supplement data provided by manufacturers are not standardized or consistent, making it difficult for the building industry to compare products and make appropriate recommendations to consumers.

The Northeast Energy Efficiency Partnership has developed a voluntary Cold Climate Air-Source Heat Pump Specification to better characterize heat pump performance and transform markets to accelerate adoption of air-source heat pumps.[26] The specification was designed to identify air-source heat pumps that are best suited to heat efficiently in cold climates. The partnership also maintains a product listing that shows standardized performance parameters to provide better performance information on heat pumps.

The Central Valley Research Homes project in Stockton demonstrated that variable-capacity heat pumps have Seasonal Energy Efficiency Ratio (SEER) and HSPF ratings that do not correlate with field performance.[27] The project showed that the performance of variable-capacity heat pumps is heavily influenced by how they are controlled, which cannot be properly addressed by current test procedures for SEER and HSPF ratings. To address this issue, the Canadian Standards Association is developing a voluntary test standard for variable capacity heat pumps, referred to as EXP-07, which it plans to publish in the first few weeks of 2019.

Further Work on California Building Efficiency Standards

Significant progress has been made in the *2019 Building Energy Efficiency Standards* to support building decarbonization. These efforts are summarized in Appendix A.

In future Building Energy Efficiency Standards updates, the Energy Commission will strive to adopt an energy performance metric that aligns more fully with GHG emissions while preserving the consideration of time-differentiated energy impacts. In the past, the Energy Commission has used either an annual source energy metric or an hourly energy cost metric in its standards development and compliance processes. The Energy Commission will consider the use of an hourly source energy metric, which should reflect changes in the emission intensities of electricity across hours of the day and seasons of the year. This type of energy metric would also compare gas use and electricity use in buildings in a way that places the appropriate import on the carbon

25 The *heating season performance* metric measures the total space heating required during the heating season, expressed in British thermal units (Btu), divided by the total electrical energy consumed by the heat pump system during the same season, expressed in watt-hours.

26 The Northeast Energy Efficiency Partnership is one of six regional energy efficiency organizations partly funded by U.S. DOE to support state efficiency policies and programs.

27 *SEER* is a metric used to measure how much cooling a system puts out for each unit of energy it consumes. In theory, the higher the SEER rating, the more efficiently the air conditioner operates.

emissions expected from each fuel type, while encouraging buildings to be designed and operated to use electricity when the associated emission intensity is relatively low.

Sacramento Municipal Utility District's (SMUD) written comments note that gas measures in building standards do not include the additional cost of the required installation of gas infrastructure.[28] It argues that providing electricity to a building is a given, but the gas service line from the street to the house, the gas meter, and the gas piping inside the house are all discretionary costs. SMUD believes these costs are real societal costs that should be assessed for all natural gas measures in the next cycle of the building standards.

Utility Infrastructure Impacts

The utility infrastructure in California was designed to deliver two forms of energy to buildings: natural gas and electricity. As California moves toward electrification for new and existing buildings, several infrastructure issues will need to be addressed.

Natural gas demand in California has remained relatively flat over the last several years. (See Chapter 7.) Most of this can be explained by climate changes, where many California locations have lower heating demands now than a decade or more ago. Policies are also driving an increasing trend to reduce natural gas use, including additional energy efficiency and reduced reliance on natural gas for electricity generation as renewable mandates increase. As identified in the *2017 IEPR*, natural gas is a large and important energy source in California to heat homes, cook, and generate electricity.

As the state moves away from natural gas, investor-owned utilities (IOUs) have made large investments in their gas infrastructure over the last several years to improve safety, primarily in response to the natural gas explosion in San Bruno in 2010. These large investments in safety improvements have increased natural gas transmission rates, driving up gas rates paid by utility customers. With increased costs and declining use, the gas utilities have lower volume over which to spread their revenue requirements.

Several recent actions point to the prospect of declining gas demand and the possibility of utilities shrinking some of their natural gas infrastructure assets. For example, PG&E proposed divesting two natural gas storage facilities.[29] In addition, then-Governor Brown has called for SoCalGas to phase out its Aliso Canyon Gas Storage Facility by 2027.[30] The CPUC also rejected an application for a new pipeline project proposed by San Diego Gas & Electric Company (SDG&E) and SoCalGas because the companies had not shown why

28 Comments of the Sacramento Municipal Utility District on IEPR Commissioner Workshop on Achieving Zero-Emission buildings. June 28, 2018. https://efiling.energy.ca.gov/GetDocument.aspx?tn=223994.

29 http://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M198/K890/198890109.PDF.

30 July 19, 2017, letter from Energy Commission Chair Robert B. Weisenmiller to CPUC President Michael Picker, TN 220299 in https://efiling.energy.ca.gov/Lists/DocketLog.aspx?docketnumber=17-IEPR-11.

they needed to increase gas pipeline capacity in an era of declining demand and the state moving away from fossil fuels.[31]

As discussed later, methane is a potent GHG emission from the natural gas system. While use of renewable natural gas may help offset declines in fossil natural gas, concerns about methane leakage remain regardless of whether the gas is renewable or fossil. Addressing climate change, especially the 2050 goals, may be the biggest force behind the declining use of natural gas, and the state will need to develop a plan to address changes in natural gas use.

Consumer Acceptance

While consumers are unlikely to express a preference regarding fuels used for space and water heating, consumers may have fuel preferences for cooking. "Because cooking is not simply utilitarian but also part of one's lifestyle, bias, perceptions and preference should not be discounted."[32] The Sierra Club and NRDC argue that consumers will embrace induction cooking, which has a higher consumer regard, as the market develops.[33] This is just one example of the challenge of electrification from the consumer perspective — the need for consumers to experience and eventually adopt highly efficient and effective electric equipment for uses typically served by gas equipment.

Switching from gas equipment to highly efficient electric equipment, such as HPWHs, can reduce consumers' energy bills, even when electricity is more expensive than gas. However, some local governments have expressed the concern that a shift toward all-electric homes may contribute to housing unaffordability.[34] The relative cost paths between natural gas and electricity equipment in buildings need further study.

Retail Rates to Support Decarbonization

Both natural gas and electricity rates faced by consumers should include the costs of associated carbon emissions. Because the electric generation and natural gas distribution sectors are covered by CARB's Cap-and-Trade Program, carbon allowance costs are part of the costs used to set rates. For IOUs, natural gas and electric rates now include a carbon allowance cost component. However, utilities and policy makers should consider whether there are additional carbon costs not reflected in rates.

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31 http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M217/K013/217013446.pdf.

32 Hopkins, Asa S., Kenji Takahashi, Devi Glick, and Melissa Whited. 2018. *Decarbonization of Heating Energy Use in California Buildings: Technology, Markets, Impacts and Policy Solutions.* Synapse Energy Economics. Pg. 29. http://www.synapse-energy.com/sites/default/files/Decarbonization-Heating-CA-Buildings-17-092-1.pdf.

33 NRDC comments on the *Draft 2018 IEPR Update*, submitted to Docket 18-IEPR-01, https://efiling.energy.ca.gov/GetDocument.aspx?tn=225794.

Sierra Club comments on the *Draft 2018 IEPR Update*, submitted to Docket 18-IEPR-01, https://efiling.energy.ca.gov/GetDocument.aspx?tn=225791.

34 For example, Kern County - Board of Supervisors Comments on Achieving Zero-Emission Buildings, dated June 26, 2018, TN 224029, https://efiling.energy.ca.gov/Lists/DocketLog.aspx?docketnumber=18-IEPR-09.

By 2020, an increasing share of residential consumers in California will be on time-of-use (TOU) electricity rates that vary by time of day. (See Chapter 3 for more information on TOU rates.)

The cost and the carbon content of electricity vary over time. (For more on hourly changes in the GHG content of electricity, see "GHG Emission Intensity Projections" in Chapter 2.) Hourly, daily, and seasonal variations are significant, but the retail price that consumers see often does not directly reflect those variations. In addition, the real cost is not necessarily correlated to the carbon content, which may lead to increases in one when policies attempt to reduce the other. Wholesale prices of electricity in California are lowest midday, when renewable resources with zero emissions and fuel costs set the prices, but simple two-period TOU rates with mild price differentials do not fully signal the benefits of shifting load to specific times of day. As customers become more familiar with time-varying rates, rate designs that more clearly signal low carbon periods could help make electrification measures more attractive and reduce emissions.

Reducing Methane Emission From Natural Gas Use

Natural gas is composed primarily of methane, a potent short-lived climate pollutant.[35] Methane emissions associated with the natural gas system come from intentional and unintentional releases of natural gas. Unintentional releases of methane, or *fugitive emissions*, can come from multiple sources and phases of the natural gas system, such as from leaking pipelines, storage facilities, abandoned wells, or inefficient combustion.[36] In 2015, methane emissions contributed about 9 percent of total GHG emissions in California, with methane emissions from the natural gas system comprising about 10 percent of the state's total methane emissions.[37]

In California, legislation and regulatory decisions are focusing attention on methane leakage from the natural gas system. In March 2017, as called for by SB 1383, CARB adopted a comprehensive short-lived climate pollution plan that includes strategies necessary to reduce methane emissions 40 percent below 2013 levels by 2030.

The Energy Commission, CPUC, and CARB have all taken actions to better detect and reduce methane leakage. In general, these efforts will result in greater mandatory monitoring on a wider assortment of gas system components than considered previously. In addition, new laws and regulations are pushing for better mitigation strategies for emissions from pipelines and oil and gas production. Recent research has found that 0.5 percent of gas used in homes is released to the atmosphere as

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35 Methane is estimated to have a global warming potential of 28 to 36 over 100 years. https://www.epa.gov/ghgemissions/understanding-global-warming-potentials.

36 Intentional releases are purposeful and known emissions that occur in the normal operations of the natural gas system. For example, safety dictates the venting of natural gas when pressures reach levels where there could be a safety risk.

37 California Energy Commission staff. 2017. *2017 Integrated Energy Policy Report*. California Energy Commission. Publication Number: CEC-100-2017-001-CMF. http://www.energy.ca.gov/2017_energypolicy/index.html.

uncombusted methane.[38] California has ongoing research aimed at identifying, quantifying, and reducing this leakage.

New homes built to the *2019 Building Energy Efficiency Standards* will have different emission profiles than existing buildings, depending on the fuel used for space and water heating, as well as for cooking and laundry. CARB estimates that removing the dependence of a home on natural gas and powering it entirely with electricity could reduce annual GHG emissions by 1 ton of CO_2 equivalent (CO_2e) per home.[39] The magnitude of this reduction will vary based on home size, occupant behavior, climate zone, vintage, and other factors. Electrifying buildings entails harnessing heat pumps, solar thermal, and other high-efficiency technologies.[40]

Role of Renewable Gas in Decarbonizing Buildings

Another potential method of decarbonizing buildings is the use of renewable gas to displace fossil natural gas use. As defined in the *2017 IEPR*, renewable gas includes, but is not limited to, biogas; biomethane (also known as renewable natural gas); synthetic natural gas generated from organic waste, or electricity generated by an eligible renewable energy resource or at a renewable electric generating facility; renewable hydrogen; and gaseous products composed of the aforementioned, such as renewable dimethyl ether. Renewable gas is similar in chemical composition to fossil natural gas, and renewable gas that complies with utility pipeline specifications can be injected into natural gas pipelines. However, unlike fossil natural gas, renewable gas derives from contemporary, renewable resources such as organic waste material (such as food waste, grass clippings, animal manure, or wastewater) or electrolytic hydrogen from renewable electricity. In the *2017 IEPR* (Chapter 7), the Energy Commission assessed and made recommendations for developing and using renewable gas, as required by Senate Bill 1383 (Lara, Chapter 395, Statutes of 2016).[41]

Navigant prepared a study titled *Analysis of the Role of Gas for a Low-Carbon California Future* for SoCal Gas.[42] The premise of the study is that renewable gas can be used to decarbonize buildings in SoCal Gas' service territory to an emission level comparable to building electrification by 2030. The study also attempts to compare the costs of providing renewable gas and more efficient gas appliances with the costs of electrifying

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38 Fischer, Marc L., Wanyu Rengie Chan, Woody Delp, Seongeun Jeong, Vi H. Rapp, and Zhimin Zhu. "An Estimate of Natural Gas Methane Emissions From California Homes." *Environ. Sci. Technol.* Just Accepted Manuscript · DOI: 10.1021/acs.est.8b03217. Publication Date (Web): August 2, 2018.

39 Presentation on Carbon Footprint Cooling Sector, by Aanchal Kohli, CARB. June 14, 2018, IEPR Workshop on Achieving Zero-Emission Buildings. https://efiling.energy.ca.gov/GetDocument.aspx?tn=223802.

40 Energy Commission staff presentation on Building Decarbonization, June 14, 2018, pgs. 17–18; https://efiling.energy.ca.gov/Lists/DocketLog.aspx?docketnumber=18-IEPR-09.

41 California Energy Commission staff. 2017. *2017 Integrated Energy Policy Report*. California Energy Commission. Publication Number: CEC-100-2017-001-CMF.

42 Navigant. July 24, 2018. *Analysis of the Role of Gas for a Low-Carbon California Future, Final Report, Prepared for SoCal Gas*. https://www.socalgas.com/1443741887279/SoCalGas_Renewable_Gas_Final-Report.pdf.

buildings. The study concludes, "Based on [renewable gas (RG)] supply availability at the costs assumed in this study, RG delivered to residential and commercial buildings could reach similar GHG emissions reduction targets in 2030 as appliance electrification." The study offers three recommendations:

- Further explore renewable gas as an option for GHG emission reductions.
- Conduct further research on how appliance electrification could affect electric utilities and consumers with better data than were available for the Navigant study to fairly compare renewable gas to electrification.
- Evaluate opportunities to foster greater in-state and out-of-state renewable gas supplies, particularly for transportation and electricity generation.

The *2017 IEPR* assessed the potential supply of renewable gas based on studies by the University of California, Davis (UC Davis) Biomass Collaborative,[43] the Institute of Transportation Studies at UC Davis,[44] and ICF International.[45] The studies conclude that from 60 million to 100 million British Thermal units (MMBTU) of renewable gas can be derived annually from organic waste resources in California using conventional production methods. This amount could range up to roughly 100 to 340 MMBtu per year if lignocellulosic waste, such as agricultural residue and woody biomass, were included, but that requires alternative, early stage conversion technologies not currently available.

According to E3's study of long-term GHG reduction scenarios, discussed in the previous section, California's total potential renewable gas supply from waste biomass, including woody resources, is insufficient to meet the state's natural gas demand from buildings and industry.[46] Other approaches, such as building electrification, energy efficiency breakthroughs, natural gas heat pumps, power-to-gas, or purpose-grown biomass or a combination thereof, are needed to bridge the gap between supply and demand.

As discussed, E3 concluded that the high electrification scenario with high levels of building and transportation electrification, high levels of energy efficiency, and limited biofuels would have a lower cost than a scenario that relies solely on renewable gas and biofuels. Renewable gas can be used to help decarbonize systems that are not easily

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43 Williams, R. B., B. M. Jenkins, and S. Kaffka (California Biomass Collaborative). 2015. *An Assessment of Biomass Resources in California, 2013 – DRAFT*. Contractor report to the California Energy Commission. Contract 500-11-020. https://biomass.ucdavis.edu/wp-content/uploads/CA_Biomass_Resource_2013Data_CBC_Task3_DRAFT.pdf.

44 Jaffe, Amy Myers, Rosa Dominguez-Faus, Nathan C. Parker, Daniel Scheitrum, Justin Wilcock, and Marshall Miller. 2016. *The Feasibility of Renewable Natural Gas as a Large-Scale, Low Carbon Substitute*. Institute of Transportation Studies, University of California, Davis, Research Report UCD-ITS-RR-16-20. https://steps.ucdavis.edu/wp-content/uploads/2017/05/2016-UCD-ITS-RR-16-20.pdf.

45 Sheehy, Phil. 2017. *Design Principles for a Renewable Gas Standard*. ICF International. https://www.icf.com/resources/white-papers/2017/design-principles-for-renewable-gas.

46 Subin, Zach. Long-Term Energy Scenarios in California Implications for Building Decarbonization. Presentation at the June 14, 2018, IEPR Workshop on Achieving Zero-Emission Buildings. https://efiling.energy.ca.gov/GetDocument.aspx?tn=223756.

electrified or until natural gas-powered systems reach the end of life. However, the *2017 IEPR* concluded that renewable gas could likely play a more significant role in reducing GHG emissions in other energy sectors, such as transportation.

Over the past several years, the state has provided significant grant funding and other incentives to renewable gas projects for electricity generation and transportation fuel production. The state expects to increase its investment in these areas to support the goals of reducing short-lived climate pollutants and diverting organic waste from landfills. California's Low Carbon Fuel Standard (LCFS) and the federal Renewable Fuel Standard (RFS2) programs enable transportation fuel projects to earn monetized environmental credits that offer even greater revenue potential than electricity generation. In many cases, the value of these credits can constitute the majority of the revenue stream of a project. Financial incentives specific to renewable gas use in buildings do not exist in California.

Current renewable gas project developers throughout the state are focusing largely on the transportation fuel market. This primary focus on transportation is anticipated to continue due to factors including the expected continuation of the LCFS and RFS2 programs, multiple near- and long-term options for using renewable gas as a vehicle fuel, and the greatest reduction in GHG and criteria pollutant emissions being achieved when renewable gas is used as a transportation fuel to displace diesel. As a result, renewable gas is not expected to play a large role in decarbonizing buildings given these other priority areas.

SoCalGas encourages the Energy Commission to examine more fully the role renewable gas can play in thermal decarbonization. It asserts that if the goal is to make significant strides to combat climate change, a multifaceted approach that considers all pathways to lower the carbon intensity of homes and businesses should be undertaken. While the primary emphasis for decarbonization will be on electrification, other cost-effective measures such as natural gas decarbonization strategies that reduce GHG emissions and solar thermal applications can also play a role.[47] PG&E also commented on its support for decarbonizing "the natural gas stream through renewable and low-carbon gas alternatives."[48]

As California implements the *2017 IEPR* recommendations on renewable gas, the state will gain additional information and experience with the most appropriate uses, benefits, and costs of renewable gas. This can help inform policy makers on the long-term role for renewable gas in the state. SoCalGas' comments note that it has commissioned an analysis of how the use of more efficient natural gas appliances and renewable gas can achieve GHG emission reductions in buildings. SoCalGas believes this

47 SoCalGas comments on June 7, 2018, IEPR Workshop on Achieving Zero-Emission Buildings, TN 224017, Submitted June 29, 2018, https://efiling.energy.ca.gov/GetDocument.aspx?tn=224017.

48 PG&E's comments on June 7, 2018, IEPR Workshop on Achieving Zero-Emission Buildings, TN 223988, Submitted June 28, 2018, http://www.energy.ca.gov/2018_energypolicy/documents/2018-06-14_workshop/2018-06-14_comments.php.

study will provide another viewpoint on reaching the 2030 targets. The Energy Commission intends to follow up on the recommendation from the *2017 IEPR* that the status of renewable gas be revisited as part of the *IEPR* in four years. Further, the Energy Commission's plan to decarbonize buildings mandated by AB 3232 will include a long-term perspective on the industry and infrastructure changes needed and will require discussions with all stakeholders on how best to reach a desired end point at or close to zero-carbon emissions from buildings.

As discussed, SoCalGas' written comments advocate for renewable gas as an alternative to electrification to decarbonize buildings. The Sierra Club and NRDC argue instead that renewable gas, such as biomethane, is not a viable alternative to electrification.[49] SoCalGas refers to numerous studies that indicate that renewable gas supply from waste in California is limited and at best could meet only 0.6 percent to 4.1 percent of California's total gas consumption. While SoCalGas adds that out-of-state supplies of renewable gas could supplement supplies, Sierra Club cites several studies that indicate limited supply of out-of-state renewable gas.

SMUD's written comments suggest that the Energy Commission, with the CPUC, should begin developing a gas distribution resource planning structure, similar to what the CPUC is developing for the electricity distribution system.[50] SMUD notes that as new homes and businesses are built, there is a significant risk of stranded assets if the infrastructure is abandoned before the end of useful life. The replacement of existing, aging infrastructure faces the same issue. SMUD advocates that changes the state needs to meet its carbon reduction goals require careful planning on the gas side as well as the electricity side.

Reducing the GHG Emissions of Cooling Equipment in Buildings

California cannot realize its goal of zero emissions in the built environment without addressing refrigerant emissions. Most buildings contain cooling equipment, such as refrigeration and HVAC systems. Cooling equipment is a significant source of GHG emissions through two routes: indirectly through electricity usage associated with operating the equipment, and directly through the release of heat transfer fluids, such as refrigerants contained in the equipment. Historically, the former has received more attention as consumers can save money from improvements that reduce electricity usage. However, refrigerant leakage during HVAC operation is a large portion of the GHG emissions associated with the equipment over the lifetime and a significant portion of total building emissions.

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49 Sierra Club and NRDC comments on Achieving Zero-Emission Buildings workshop on June 14, 2018, and Building Decarbonization docket (19-IEPR—09). June 29, 2018. http://www.energy.ca.gov/2018_energypolicy/documents/2018-06-14_workshop/2018-06-14_comments.php.

50 Comments of the Sacramento Municipal Utility District on IEPR Commissioner Workshop on Achieving Zero-Emission buildings. June 28, 2018. https://efiling.energy.ca.gov/GetDocument.aspx?tn=223994.

HFCs, a common class of refrigerants, make up 17 percent and 6 percent of all commercial and residential building GHG emissions (in CO_2 equivalent), respectively.[51] These percentages are expected to increase with the transition to electrification. Refrigerants are typically very potent GHGs, with global warming potentials (GWP) per molecule that can be hundreds to thousands of times greater than CO_2.[52] HFC refrigerants are a fast-growing source of GHGs in California and nationally; without action to curtail them, the emissions from these refrigerants could more than double by 2030.[53]

Alternative technologies that use climate-friendly low-GWP refrigerants and improve energy efficiency are already commercially available for many types of cooling equipment. On a global scale, switching to low-GWP technologies can have a huge positive impact on the climate, avoiding as much as 0.5 degrees Celsius of warming by the end of this century.[54] Senate Bill 1383 (Lara, Chapter 395, Statutes of 2016), along with the state's Short-Lived Climate Pollutant Strategy,[55] mandates a 40 percent reduction of 2013 HFC levels by 2030. To meet this challenge, agencies and industry stakeholders need to adopt a holistic approach for evaluating refrigerant technologies — for example, considering indirect and direct emissions when replacing or installing cooling equipment in buildings.

A large emission reduction potential exists for cooling equipment in various building types. Supermarkets, which are among the most energy-intensive buildings in the United States, are one example.[56] A typical supermarket refrigeration system using a common refrigerant (for example, R-404A with a GWP of 3,922) can emit more than 20,000 metric tons (MT) of CO_2e over a 15-year lifetime. About 85 percent of these emissions are from direct release of the refrigerant, and only 15 percent are from electricity-related emissions. Switching to a CO_2 refrigerant can eliminate almost 100 percent of the direct

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51 Presentation by Aanchal Kohli from CARB at the June 14, 2018, IEPR Commissioner Workshop on Achieving Zero-Emission buildings. TN 223802. http://www.energy.ca.gov/2018_energypolicy/documents/2018-06-14_workshop/2018-06-14_presentations.php.

52 *Global warming potential* (GWP) is a common measure of how much energy the emissions of 1 ton of greenhouse gas will absorb over a given period, relative to the emissions of 1 ton of CO_2. The larger the GWP, the more that a given gas warms the Earth compared to CO_2 over a period, usually 100 years.

53 President Obama's Climate Action Plan. 2013. https://obamawhitehouse.archives.gov/sites/default/files/image/president27sclimateactionplan.pdf.

54 Xu Y., D. Zaelke, G. J. M. Velders, and V. Ramanathan. 2013. "The role of HFCs in mitigating 21st century climate change," *Atmospheric Chemistry and Physics* 13, 6083-6089, doi: 10.5194/acp-13-6083-2013. https://www.atmos-chem-phys.net/13/6083/2013/acp-13-6083-2013.html.

55 CARB. *Short-Lived Climate Pollutant Reduction Strategy.* March 2017. https://www.arb.ca.gov/cc/shortlived/meetings/03142017/final_slcp_report.pdf.

56 Perez-Lombard, L., José Ortiz, and Christine Pout. 2008. "A review of buildings energy consumption information," *Energy and Buildings,* 40, 394-398. doi: 10.1016/j.enbuild.2007.03.007. http://scholar.google.com/scholar_url?url=https%3A%2F%2Fwww.sciencedirect.com%2Fscience%2Farticle%2Fpii%2FS0378778807001016&hl=en&sa=T&ct=res&cd=0&d=13579531421116877832&ei=kkuQW6baIoLMyQSi56yIAw&scisig=AAGBfm2xOmrgDJjWN6arohNKqC1S8pItpg&nossl=1&ws=1280x855.

emissions and a portion of the indirect emissions, while gaining energy efficiency (a total savings of more than 18,000 MT CO_2e).[57]

While homes and apartments are less energy intensive than supermarkets, they also have a large untapped potential to reduce refrigerant emissions because of sheer numbers. More than 13 million dwellings in California are typically equipped with an HVAC system and a refrigerator. By switching to low-GWP alternatives, it is possible to slash direct and indirect emissions associated with the equipment over the lifetime of these appliances by 40 percent.[58]

In written comments, the UC Berkeley Energy and Resources Group notes that as heat pump water heaters become more prevalent, the issue of refrigerant leakage becomes more significant.[59] However, group members indicate that initial testing of a new refrigerant, R-1234yf, suggests it might be able to achieve very similar performance to the conventional refrigerant R-134. This result is promising because it has a GWP of 4, as opposed to R-134 with a GWP of 1,430.

Utility-Sector Efforts to Decarbonize Buildings

Policy studies reviewed earlier in this chapter, as well as numerous other reports and studies, call out the need for incentives and market transformation efforts to support building decarbonization. The state is in the early stage of identifying the appropriate programs to ease building decarbonization. To the extent that energy efficiency programs can bring about market transformation, some of the program designs discussed in Chapter 2 on SB 350 energy efficiency doubling are likely to work for electrification and other decarbonization strategies. The state's publicly owned utilities (POUs), as well as the IOUs and energy efficiency providers overseen by the CPUC, are undertaking efforts to promote decarbonizing buildings. Local governments are collaborating with utilities and energy efficiency providers in leading decarbonization efforts, as discussed in the next sections.

CPUC Efforts to Decarbonize Buildings

The CPUC has ongoing activities related to building electrification and is contemplating additional activities. Several CPUC and IOU programs provide incentives for customers to install solar, such as net energy metering, in which they receive a credit for excess generation compensated at the full retail rate. The Self-Generation Incentive Program provides rebates for behind-the-meter technologies such as wind, waste heat-to-power technologies, pressure-reduction turbines, internal combustion engines, microturbines, gas turbines, fuel cells, and advanced energy storage systems. The CPUC also oversees

57 Presentation on Carbon Footprint Cooling Sector, by Aanchal Kohli, CARB. June 14, 2018, IEPR Workshop on Achieving Zero-Emission Buildings. https://efiling.energy.ca.gov/GetDocument.aspx?tn=223802.

58 Ibid.

59 Shuba V Raghavan, Energy and Resources Group. 2018. Comments Energy Consumption and Emission of Residential Heat Pump Water Heaters. https://efiling.energy.ca.gov/GetDocument.aspx?tn=223989.

the California Solar Initiative (CSI) Single-family Affordable Solar Homes program that provides incentives for single-family, low-income homes. In addition, the CPUC oversees the CSI Multifamily Affordable Housing Program that provides incentives to multifamily low-income housing. Due to the popularity of the program, which is fully subscribed, the virtual net energy metering tariffs that allow a building owner to share bill credits for solar production with the tenants of a building have been expanded.

The CPUC is examining three additional approaches to advance building electrification that include:

- *Increased Availability of Favorable All-Electric Rates*: Customers could be encouraged to move away from natural gas by reducing the current residential all-electric tariff rates and offering an all-electric tariff to commercial or industrial customers. Since utilities would still need to collect their electricity revenue requirements, utilities could offset lower rates for all-electric customers by increased rates for dual-fuel customers. However, the increased consumption for all-electric customers could partially offset the need for rate increases.
- *Resource Acquisition Programs*: This approach encourages entities at various points along the supply chain to adopt specific equipment by offering them incentives, providing or promoting low-cost financing, or supporting the development of new technologies. This approach could include the following:
    - A new program focused on incentives and rebates targeted at GHG reduction, rather than reductions in energy consumption, could commit to a schedule of financial incentives across a long time horizon, similar to the CSI. This program might encourage manufacturers, distributors, and retailers to promote electric heat pump HVAC systems, heat pump and electric water heating systems, electric cooking appliances, and electric industrial equipment. Incentives would begin at significant levels, accompanied by substantial marketing and outreach support, and decline over time.
    - On-bill or other financing programs could provide low- or no-interest loans and incentives for electric appliances to make all-electric appliances affordable to households and businesses. It might be possible to develop a dedicated financing program for customers to have all-electric homes, as well as for small businesses, larger commercial, or industrial enterprises interested in having all-electric buildings.
    - The energy efficiency portfolio Emerging Technology Program has developed technology priority maps used to prioritize promising emerging efficiency technologies. Using a similar approach to identify and prioritize electrification-focused technologies could encourage electrification of buildings.

- *Market Transformation Programs*: Market transformation programs are often not cost-effective in the early stages, but successful programs are highly cost-effective over the associated lifespans. Allowing program administrators to follow a set of new rules for building electrification, such as exempting buildings from year-on-year cost-effectiveness in exchange for meeting life-cycle cost-effectiveness, could open new possibilities for capturing energy and emissions savings. CPUC staff is developing a market transformation proposal for energy efficiency programs to recognize quantifiable energy and GHG savings from market-level activities.

CPUC Three-Prong Test for Fuel Substitution

The *three-prong test* is a CPUC requirement to determine if a measure, program, or project incentive can be offered to ease fuel substitution, such as the change from one regulated fuel to a different regulated fuel. For example, the test is used to evaluate whether customers who replace a natural gas furnace with an electric heat pump should receive incentives. The three-prongs require that a program, measure, or project must not increase source-Btu consumption, must be cost-effective, and must not adversely impact the environment.

In developing the SB 350 energy efficiency doubling targets, several parties raised the three-prong test as a significant barrier to electrification. The SB 350 report recommended developing a comprehensive framework to implement fuel substitution programs that maximize efficiency savings and GHG emission reductions, including a joint effort with the CPUC to coordinate SB 350 fuel substitution requirements.

In June 2017, the NRDC, Sierra Club, and the California Efficiency and Demand Management Council filed a motion with the CPUC seeking review and modification of the three-prong test. They requested the following:

- Review the clarity, utility, and alignment of the test with CPUC policies and California's climate goals, modify as needed, and provide guidance on method and baseline.
- Clarify under what conditions the test must be passed, for example, for substitution from one regulated fuel to another, and consider modifying to allow fuel switching between regulated and unregulated fuels.
- Provide guidance, with example cases, on how fuel substitution projects or programs will be evaluated under the CPUC's standard cost-effectiveness test for efficiency programs.

In April 2018, the CPUC issued a scoping memo in its energy efficiency proceeding to identify possible revisions to the three-prong test, including asking questions about how the test should be clarified or modified and whether existing analytical tools were adequate.

IOU and CCA Building Decarbonization Programs

Some IOUs, community choice aggregators (CCAs), and regional energy networks overseen by the CPUC offer incentives for electrification. Under the business plan framework for energy efficiency, described in Chapter 2 on doubling energy efficiency targets, they expect to include building electrification as part of their efficiency portfolios and implementation plans.

Pacific Gas and Electric

Pacific Gas and Electric Company (PG&E) is collaborating with Sonoma Clean Power (SCP) and the Bay Area Air Quality Management District (BAAQMD) on the Advance Energy Rebuild Program that offers incentives to fire victims in Sonoma and Mendocino Counties. For customers who choose to rebuild their homes as all-electric, combined incentives can amount to $12,500. PG&E is providing building design assistance to build beyond the building standards, while SCP and BAAQMD are providing incentives for electric appliances, solar panels, and EV charging stations. This program launched in May 2018. PG&E is using its existing California Advanced Home Program funds to support the above code design assistance offered to Sonoma and Mendocino Counties for fire rebuild efforts.

Southern California Edison

Southern California Edison (SCE) released its Clean Power and Electrification Pathway in October 2017.[60] This is a proposal for a cost-effective path to reducing California's GHG emissions and improving the state's air quality. By 2030, the pathway calls for an electric grid that is supplied by 80 percent carbon-free energy and accommodates more than 7 million electric vehicles and electrification of up to a third of space and water heating in buildings. SCE estimates that electrifying space and water heating in homes and businesses can reduce GHG emission statewide by about 12 metric tons. SCE supports an increase in the availability of mature clean technologies and supports fuel neutrality in the building standards. SCE is designing incentive programs to help customers decarbonize in the most affordable and practical way.

SoCalGas

SoCalGas programs focus on building decarbonization from a natural gas use and efficiency perspective. SoCal Gas's Emerging Technologies Program identifies, assesses, and demonstrates new, efficient technologies for buildings to transform the market as part of an energy efficiency portfolio. Some of these technologies include drain water heat recovery, advance solar water heating, advanced boiler controls, and a combination of water- and space-heating systems. SoCalGas is decarbonizing the electricity supply while focusing on renewable gas to decarbonize the gas supply. SoCal Gas is approaching decarbonization on the supply side aimed at producing a lower-cost and

60 https://www.edison.com/content/dam/eix/documents/our-perspective/g17-pathway-to-2030-white-paper.pdf.

more consumer-friendly approach to GHG emission reductions that also enables consumer choice.

SCP

SCP is participating in the Advance Energy Rebuild program, previously discussed, to provide $7,500 for mixed-fuel homes participating under the flexible performance path, which requires buildings to be 20 percent more efficient than the current building standards. The flexible performance pathway for all-electric homes offers incentives of $12,500 and requires electric end uses to be 20 percent more efficient than the current building standards. Roof design to accommodate solar panels (and conduit to allow future solar) and electric vehicle charging station using equipment are provided free by SCP. A solar panel system designed to offset annual electric usage can obtain an additional $5,000 incentive if combined with either a 7.5 kilowatt-hour (kWh) battery storage system or prepurchase of a 20-year premium on 100 percent local renewable power. SCP customers can leverage PG&E's existing California Advanced Homes Program.

POU Electrification Efforts

Several POUs are also promoting building decarbonization, including the Los Angeles Department of Water and Power (LADWP), Sacramento Municipal Utility District (SMUD), the City and County of San Francisco, the City of Palo Alto, and Southern California Public Power Authority.

LADWP

The City of Los Angeles has efforts underway to decarbonize buildings in Los Angeles, as well as LADWP's utility system. The city already has a goal of reaching 80 percent carbon reduction from 1990 levels by 2050, and the mayor wants to expand that goal in the city's next Sustainable Study Plan to net-zero-carbon emissions by 2050. In September 2016, the Los Angeles City Council directed the LADWP to determine how to move the city to 100 percent renewables. LADWP is convening a collaborative working group of experts to identify the investments and priorities needed to run the city entirely and equitably on renewable energy.

The City of Los Angeles has a high priority on reducing energy consumption by buildings, which are the source of about 70 percent of the city's emissions, especially commercial and industrial occupancies. The City of Los Angeles completed its Building Forward Design Initiative that considered how buildings could be more resilient and sustainable. The study examined electrification measures such as electric heat pumps and self-generation with rooftop PV panels, and the city will publish the study later this year.

SMUD

SMUD has electrification incentive programs for new and existing homes. The All-Electric Smart Homes Program provides incentives up to $5,000 per new home. For

existing homes, SMUD has integrated its existing energy efficiency program, the Home Performance Program, with electrification measures to allow customers to simultaneously electrify and make their homes more efficient. As much as $13,750 in incentives per home are available, which include $2,500 for wiring and panel upgrades, $2,500 for heat pump space heating, $3,000 for heat pump water heating, $250 for an induction cooktop, and $3,000 for insulation and sealing. SMUD is developing a midstream heat pump water heater program that will provide incentives to the distributor, rather than directly to the customer, and a direct install heat pump water heater program for emergency water heat replacement of gas equipment.[61]

SMUD hopes to assist local governments in adopting mandatory electrification ordinances by offering incentives, making them cost-effective over the life of the measure. Since local ordinances expire at the end of each three-year building standard cycle, utilities like SMUD are making a three-year commitment to provide the incentives to consumers that would make an ordinance feasible. SMUD indicates that local energy ordinances are necessary to spur market transformation in time to meet statewide goals, as there are still many market barriers to overcome.

SMUD is investigating the impact of electrifying existing homes to reduce building GHG emissions. It has seen a 36-40 percent reduction in HVAC energy use in a home that replaces its natural gas furnace with an electric heat pump space heater. SMUD estimates this would translate into a savings of $150–$280 annually, depending on home vintage, in operating costs.[62] SMUD is also examining the impacts of electrifying residential water heating by comparing gas storage tank heaters, gas tankless heaters, and electric heat pump water heaters.[63]

The City and County of San Francisco

The City and County of San Francisco has the ambitious goal of reaching carbon neutrality for the public and private sectors by 2050. It found that the only path toward 100 percent emissions reduction from 1990 levels is the widespread transition of thermal appliances serving primarily domestic hot water and space heating from fossil fuel to renewable electricity. The city estimates that using on-the-shelf technology, such as efficient heat pumps, can reduce overall GHG emissions by 13 percent or more. To support the transition, the city is engaged in education and is collaborating with other cities through the Bay Area Regional Energy Network (BayREN).

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61 Owen Howlett, SMUD, presentation at the June 14, 2018, IEPR workshop on Achieving Zero-Emission Buildings.

62 The study has not yet included the current roughly $2,000 premium on the cost of a heat pump over a natural gas furnace, as well as the possibility that an electrical panel upgrade or additional wiring may be needed.

63 It estimates $2,800 as a base cost to have a heat pump water heater installed, of which the water heater itself is about $1,300 and the remainder is labor for installation, whereas a gas tankless would run $2,000 and a gas storage water heater would be $1,400.

The City of Palo Alto

The City of Palo Alto, which is a POU providing natural gas and electricity, has ambitious goals of reducing GHG emissions by 80 percent below 1990 level by 2030, which it intends to meet through gas efficiency and decarbonization. Palo Alto is purchasing all of its electricity from carbon-free, hydroelectric, and renewable sources under long-term contracts. In addition to CO_2 reductions, Palo Alto is targeting all sources of GHG emissions from electricity and natural gas in determining its total GHG emissions, including methane leakage from natural gas distribution, emissions from waste to landfills, wastewater process emissions, landfill fugitive emissions, and emissions from road travel.

In 2017, Palo Alto adopted its Sustainability and Climate Action Plan,[64] which provides clear community direction to work on building electrification. There is a core group of community advocates generating innovative program ideas such as the Heat Pump Water Heater rebate pilot program. To promote electrification, Palo Alto plans to improve its permitting process in the next year, explore a regional midstream incentive program with BayREN, and enhance assistance to customers in evaluating electrification readiness. In the longer term, the city will evaluate electric-ready mandates in its 2019 local green building code update, consider heat pump space heating in multifamily buildings, and evaluate on-bill financing and direct installation of efficient electric appliances.

Southern California Public Power Authority

Southern California Public Power Authority (SCPPA) members are decarbonizing their electricity systems, including the addition of renewables to meet the Renewables Portfolio Standard (RPS) and early divestiture from out-of-state coal facilities. Efforts to date have focused on transportation electrification. The City of Anaheim designed its new Public Access EV Charging Station Rebate Program with multiunit dwelling customers and disadvantaged communities in mind. It provides a rebate of up to $5,000 per charging station for actual equipment and installation costs for stations that provide public access at a workplace, school, or multiunit dwelling. The City of Burbank has installed a public charging network, including curbside chargers. It also provides electric vehicle (EV) rebates for residents (up to $500) and businesses (up to $2,000), time-of-use rates for EVs, and EV Ride and Drive events for residents. It also has a workplace charging pilot program for small employers and a managed charging pilot program for large employers, and it is studying transportation electrification impacts. Several SCPPA members are looking at developing building electrification programs.

Research to Reduce Carbon Intensity of Buildings

Energy research, development, and demonstration (RD&D) that supports and advances technologies to improve reliability, affordability, and public health and safety is vital to

64 https://www.cityofpaloalto.org/services/sustainability/sustainability_and_climate_action_plan/default.asp.

achieving California's energy and climate goals. The E3 study discussed earlier identified several actions to encourage building decarbonization. In addition to changing consumer behavior as a key to realizing decarbonization goals, the following areas need additional research and development to help advance:

- Energy efficiency to reduce consumption.
- Electrification of services in buildings.
- Electrification of end uses that have been hard to electrify.
- Renewable power generation to about 70 percent.
- Diversity in renewable energy systems and integrated solutions.
- EV deployment.

To meet these and other challenges, the Energy Commission's research and development programs, Electric Program Investment Charge (EPIC) and Natural Gas Research and Development, have focused on research to reduce energy use across end-use sectors and prioritized technologies to optimize low-carbon generation. Table 1 highlights the specific research areas (indicated by check marks) with a focus on reducing the carbon intensity of end-use technologies.

Table 1: Program Areas for Research

Electric Program Investment Charge (~$125 million per year)	Natural Gas R&D (~$24 million per year)
✓ Energy Efficiency & Demand Response ✓ Renewable Energy & Advanced Generation o Smart Communities ✓ Smart Grid, Storage, Distributed Energy Resources o Environmental o Climate Adaptation and Infrastructure Risk Reduction ✓ Electric Vehicle Grid Integration o Market Facilitation	✓ Energy Efficiency ✓ Renewable Energy & Advanced Generation o Pipeline Safety o Environmental ✓ Methane Leakage o Climate Adaptation o Infrastructure Risk Reduction ✓ Natural Gas Transportation

Source: California Energy Commission

Achieving Zero Carbon in Buildings

The Energy Commission is researching low- and no-carbon alternatives for space heating, water heating, and cooking. As the E3 study pointed out, there are implementation challenges such as the cost of equipment and installation, consumer acceptance, and concern about future bill increases. Installing and demonstrating commercially available high-efficiency units or emerging technologies under real operating conditions address some of these challenges. The goal is to obtain technical and economic data needed to verify installation, capital costs, and operating costs, as well as real-world feedback from consumers on the use of these technologies. The following projects focus on retrofitting or constructing new buildings that are zero-net-energy or zero-carbon and using technologies to increase energy efficiency:

- Replacing current natural gas heating system with high-efficiency (Seasonal Energy Efficiency Ratio [SEER] 16) heat pumps at a low-income senior housing complex unit in Ontario (San Bernardino County). Other upgrades include lighting, controls, and water-heating systems.[65]
- Coupling an innovative central water heating system with air conditioning in two new low-income multifamily properties in Northern California.[66]
- Incorporating electric heat pump water heaters and providing incentives for other measures including induction cook tops, heat pump dryers, HVAC heat pumps, and other high-efficiency electric measures in all single-family homes a developer is building near Fresno.[67]
- Testing of gas-fired heat pumps in homes and businesses. For commercial buildings, the technology has the potential of providing hot water and air conditioning.
- Evaluating the use of low GWP refrigerants, such as hydrocarbons, carbon dioxide, and ammonia and hydrofluoroolefins[68] for space conditioning and refrigeration.[69]

CARB Zero-Carbon Building Research

Research is underway to evaluate the technical feasibility and cost-effectiveness of achieving zero-carbon building performance for new and existing buildings. The zero-carbon building research study CARB is conducting with the University of California, Berkeley, is focused on all building end uses with potential to reduce energy, water, waste, and transportation emissions.[70] Overall, the results of the study will be used to assess the practicality and appropriate time frame for a zero-carbon building state policy. The research is being done to:

- Determine how best to reduce any remaining GHG emissions from the operation of zero-net-energy buildings.

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65 Customer-Centric Approach to Scaling IDSM Retrofits, http://innovation.energy.ca.gov/SearchResultProject.aspx?p=30924&tks=636692660966018714.

66 Achieving Zero-Net Energy in Multifamily Buildings, http://innovation.energy.ca.gov/SearchResultProject.aspx?p=31078&tks=636692663883724120.

67 Zero-Energy Residential Optimization – Community Achievement, http://innovation.energy.ca.gov/SearchResultProject.aspx?p=30923&tks=636692665324246588.

68 *Hydrofluoroolefins* are unsaturated organic compounds composed of hydrogen, fluorine, and carbon.

69 Climate appropriate HVAC Systems for Commercial Buildings to Reduce Energy Use and Demand, http://innovation.energy.ca.gov/SearchResultProject.aspx?p=30114&tks=636692667748673670, Development and Testing of an Energy-Efficient Ultra-Low Charge Ammonia Refrigeration System in a Food Processing Plant, http://innovation.energy.ca.gov/SearchResultProject.aspx?p=31312&tks=636692668389685888.

70 *Zero-Carbon buildings in California: A Feasibility Study*, https://www.arb.ca.gov/board/books/2018/032218/prores1811.pdf.

- Evaluate time-of-use and energy storage options to match the renewable supply with dynamic end uses.
- Evaluate which strategies are best implemented at a municipal or neighborhood scale.
- Leverage a low-income zero-net-energy housing project in Richmond (Contra Costa County) to create a benchmarking and GHG emission reduction framework for zero-carbon communities.

In addition to energy end uses, CARB incorporates EV charging infrastructure and water end uses into the zero-emission building framework. CARB's research is refining estimates for electricity intensity of water pumping, which varies by region throughout California. In many parts of California, large reductions in outdoor irrigation and indoor water use are still possible and cost-effective. However, total electricity consumption for supplying water will increase in spite of decreasing per-capita water consumption.

Increasing Renewable Energy Use in Buildings

Research is underway that focuses on improving the energy efficiency and cost-effectiveness of renewable energy alternatives, integrating renewables and energy efficiency, and evaluating the potential for increasing conversion efficiency through use of direct current infrastructure.

Integrating renewable energy production, such as solar photovoltaics, could enable direct current (DC) use and increase the efficiency of onsite generated electricity. As the DC loads are increased through increasing availability of electrical appliances and equipment, more efficient DC or hybrid alternating current (AC)/DC systems could become more viable. Integrating direct EV charging and DC battery storage could eliminate AC-to-DC conversion losses, increasing the efficient use of electricity generated onsite. A recently completed research project indicates that DC power can save significant energy in buildings, especially commercial buildings with battery storage.[71] DC can be the integrating platform for distributed energy resources, and no technology breakthroughs are needed to make it viable. Market development in the form of standards, codes, design practices, trade familiarity, and more DC-ready products are needed. Product availability and cost are the major barriers today, but with sufficient scale, DC products should cost the same or less than AC equivalents.

In addition, a recent research project demonstrated the feasibility and benefits of a commercial-scale DC building grid that integrates generation resources to operate lighting, ventilation fans, and forklift charging at an automobile manufacturing distribution center. Performance data will be collected to validate the cost savings,

71 Energy Commission agreement: EPC-14-015. Direct Current as an Integrating and Enabling Platform. http://innovation.energy.ca.gov/SearchResultProject.aspx?p=30016&tks=636728708968315130. Final report pending.

energy efficiency gains, and the capabilities of the advanced DC microgrid energy management system.

Integrating Building Energy Demand, Distributed Energy Resources, and Grid Needs

Research is underway on increasing the penetration of renewable energy resources, such as solar and wind, to benefit customers and the electric grid. This research includes:

- Testing demand response with various end uses.
- Developing and field testing smart inverters with communications capability to ensure proper operation with the electric grid.
- Testing new energy storage technologies.
- Demonstrating the integration of distributed energy resources (such as solar and wind), building energy system controls, optimal designs, and best practices in microgrids.

The research also involves integration of smart, managed plug-in electric vehicle (PEV) charging strategies into building management systems. These systems can optimize building and PEV charging load profiles while maintaining driver mobility needs and building occupant comfort. PEVs could also act as energy storage to enable renewable integration. Two projects are underway to:

- Assess the benefits of integrating renewables and storage using PEVs as distributed energy resources, performing vehicle-to-grid services integrated with buildings or microgrid controllers.
- Manage PEV charging and renewable energy generation using an all-in-one inverter smart power integrated node, which can provide real and reactive power simultaneously to the grid.

Increasing Customer Connectivity and Empowerment

Customer engagement with, and acceptance of, the next generation of technologies is vital to reducing carbon in the state's energy system and buildings. The Energy Commission supports a portfolio of projects designed to empower customers to adjust their energy use with information about their usage and potential cost savings. The following research projects are underway:

- Testing an intelligent energy management system that optimizes and controls demand-side resources such as solar PV and energy storage in 100 San Diego homes.
- Using social media to engage homeowners and renters in demand response wholesale market participation by notifying them of impending demand response events, such as "Flex Alerts," in real time and rewarding performance with points that can be redeemed for cash, donated to charity, or used to buy

automated thermostats, smart plugs, and other devices. In turn, those devices respond automatically to enable larger and more reliable future load reductions.

- Improving commercial customer participation in demand response programs by providing a cost-effective energy management system that allows a wide range of service offerings, as well as effective and automated price-based management. This approach allows customers to adapt to demand response with individual preferences, as well as tracking, evaluating, and controlling multiple devices.
- Providing demand response using an automated, cloud-based optimizing building energy management system that continuously and automatically assesses and adjusts the critical energy systems in buildings at Pomona College.

Understanding Fugitive Methane Emissions

Previous research results suggest some fugitive methane emissions in the natural gas system take place behind meters, meaning in the building in which natural gas is combusted. Measurements from more than 70 homes in California suggest that average methane emissions are relatively high and equivalent to about 0.5 percent of the natural gas consumed in the residential sector.[72]

Commercial buildings and industrial plants consuming natural gas may also leak methane. The Energy Commission is funding research testing of 60 to 80 commercial buildings (PIR-15-003 and PIR-15-017) and a handful of industrial plants (PIR-16-014). The testing of commercial buildings focuses on food service and health care centers — two of the largest natural gas users in the commercial sector.

Finally, the Energy Commission will support a large field study in the southern San Joaquin Valley using different methane measurement technologies. This area includes urban sources, such as homes, businesses, and factories, and natural gas production and processing units.[73]

Recommendations

The following actions will help decarbonize new and existing buildings in the state.

- **Establish *zero-emission building* goals for California**. The state should replace its zero-net-energy policy goals with appropriate goals for low-carbon buildings. Zero-emission building goals, while ambitious, are a necessary component of the state's aggressive greenhouse gas (GHG) emission reduction policy initiatives.
- **Align energy metrics with hourly GHG intensities.** The energy metrics used for the state's building, appliance, and load management standards should align

72 Fischer. M. L., W. R. Chan, W. Delp, S. Jeong, V. Rapp, and Z. Zhu. 2018. "An Estimate of Natural Gas Methane Emissions From California Homes." *Environmental Science and Technology*. 52 (17), pp 10205–10213. DOI: 10.1021/acs.est.8b03217.

73 Large field study: PIR-17-015 with LBNL Super Emitters of Methane Detection Using Aircraft, Towers, and Intensive Observational Network.

with hourly GHG intensities on the electricity grid. Annual GHG emission reductions are not sufficient to capture the temporal variation of GHG emissions from the electricity system.

- **Develop a plan to reduce GHG emissions from buildings.** The Energy Commission, in consultation with the California Public Utilities Commission (CPUC), California Air Resources Board (CARB), and the California Independent System Operator (California ISO), should develop a plan for the state to reduce the GHG emissions from residential and commercial buildings, consistent with Assembly Bill 3232. This plan should include 2019 updates to the *Existing Buildings Energy Efficiency Action Plan* and the *Doubling Energy Efficiency Savings by 2030* report and assessments of:
    - The feasibility of reducing GHG emissions from buildings 40 percent below 1990 levels by 2030.
    - The 1990 GHG emission baseline for building emissions that includes methane and refrigerants.
    - The cost per metric ton of carbon dioxide equivalent of the potential reduction from residential and commercial building stock relative to other statewide GHG emission reduction strategies.
    - The cost-effectiveness of strategies to reduce GHG emissions from space heating and water heating in new and existing homes and businesses.
    - Challenges associated with reducing GHG emissions from low-income housing, multifamily housing, and high-rise buildings; and proposed solutions.
    - Load management strategies, such as rate designs, to optimize building energy use in a manner that reduces GHG emissions and considers infrastructure impacts. The Energy Commission should consider opening a load management standard proceeding to achieve this.
    - Potential impacts — positive and negative — of GHG emission reduction strategies on ratepayers, construction costs, and grid reliability. The impact on grid reliability should include the requirements for solar energy systems on all new single-family and low-rise multifamily dwellings and the increased load and impact on electrical infrastructure due to electrification of transportation and heating end uses.
    - The future of natural gas use in buildings, including the potential for stranded gas technology assets, the GHG emission impacts of methane leakage, and how decisions to decarbonize buildings may change gas system infrastructure investments.

    - The feasibility of a decarbonization of the natural gas system equivalent to the expected decarbonization of the electricity grid.

- **Convene a market development collaborative.** The state should convene a market development collaborative consisting of state and local governments, industry, and utilities to bring higher-performance and lower-cost clean space and water heating technologies to all buildings in California.
- **Establish separate funding mechanisms.** The state should establish a separate funding mechanism for building electrification strategies. Potential sources of funding could include cap-and-trade revenues and private sector partnerships.
- **Encourage electrification in buildings.** State programs should encourage electrification in buildings that can provide the flexible assets needed for renewable power integration of California's relatively clean electricity system, including demand response and load shifting. State building codes should include cost-effective electric-ready infrastructure requirements and consider the relative costs of mixed fuel and all-electric construction, where appropriate.
- **Address refrigerant leakage.** State programs should address GHG emissions in buildings from refrigerant leakage in HVAC and water heating systems by:
    - Providing incentives for strategies that use low-global-warming-potential refrigerants, improve energy efficiency, and use fewer refrigerants.
    - Using better design, installation, and maintenance practices, as well as improved refrigerant recovery and reclaim programs that reduce end-of-life loss.
    - Developing a workforce that is trained and certified to handle alternative heating and cooling technologies and the associated refrigerants.

CHAPTER 2: Doubling Energy Efficiency Savings

In 2017, as called for in Senate Bill 350, the Clean Energy and Pollution Reduction Act (De León, Chapter 547, Statutes of 2015), the California Energy Commission established ambitious annual targets to achieve a statewide doubling of cumulative energy efficiency savings in electricity and natural gas end uses by 2030.[74] The Energy Commission developed the doubling targets in collaboration with the California Public Utilities Commission (CPUC), investor-owned utilities (IOUs), publicly owned utilities (POUs), and other stakeholders through a public process. Achieving these efficiency targets is one of the primary ways the electricity sector can help achieve the state's climate goal of reducing greenhouse gas (GHG) emissions to 40 percent below 1990 levels by 2030. Reaching these efficiency targets calls for a shift in focus from solely achieving energy savings, to maximizing GHG reductions from energy efficiency efforts, as discussed further in Chapter 1.

The state will need to harness emerging technologies, progressive program designs, and innovative market solutions as part of this effort. Getting projects on the ground will require better alignment of the energy efficiency supply and implementation chains. The state can assist through efficiency policies, regulations, and codes. However, it is also increasingly important to encourage and work with the marketplace to avoid hindering the transformation underway. Leveraging private capital will be especially important to meeting the doubling targets.

Achieving the ambitious efficiency targets will require the collective efforts of many entities, including state and local governments, utilities, program administrators and implementers, private lenders, market participants, builders, equipment manufacturers, suppliers, and installers, as well as end-use customers. Transforming the energy efficiency marketplace will require the formation of partnerships and cooperation among these diverse stakeholders. In addition, it will be necessary to better track efficiency savings and further define the metrics for measuring progress in achieving efficiency savings to include GHG metrics.

On June 7, 2018, the Energy Commission held an Integrated Energy Policy Report (IEPR) Commissioner Workshop on Doubling Energy Efficiency Savings. The workshop covered topics including combining and updating the *Existing Buildings Energy Efficiency Action Plan* and *SB 350 Doubling Energy Efficiency Savings by 2030* reports to be completed in

74 Jones, Melissa, Michael Jaske, Michael Kenney, Brian Samuelson, Cynthia Rogers, Elena Giyenko, and Manjit Ahuja. 2017. *Senate Bill 350: Doubling Energy Efficiency Savings by 2030*. California Energy Commission. Publication Number: CEC-400-2017-010-CMF.

2019.[75] In addition, representatives from utilities, government, and industry addressed topics such as energy efficiency programs and business plans; agricultural and industrial program barriers and opportunities, behavior, and market transformation; conservation voltage reduction (CVR) technology; and accounting for GHG savings from efficiency programs. Topics related to SB 350 are discussed below.

The Changing Landscape of Energy Efficiency

As the energy system evolves, state policy makers must carefully orchestrate actions on the demand side to more closely align energy efficiency and demand response efforts with an evolving distribution system. This orchestration will be particularly important as the state moves to widespread electrification of buildings and transportation. New and emerging energy efficiency technologies can be integrated into the distribution system through energy management systems and smart control technology so they can respond to the needs of the distribution system. In fact, with proper telemetry and controls, buildings themselves can become demand response resources. In this way, energy efficiency and demand flexibility can become an integral part of the ongoing decarbonization of the energy system.

Changes to California's Electricity Market Structure

California's market structure for electricity is fundamentally changing as consumers are increasingly choosing to procure from providers other than their utility. At the same time, regulators in California are trying to achieve the ambitious goal of doubling energy efficiency savings by 2030, in tandem with achieving the state's climate goals. California's long history of advancing energy efficiency, which has helped keep California's energy consumption relatively flat over the last 40 years while that of the United States has grown, has been achieved largely by the establishment of statewide codes and standards on appliances and buildings by the Energy Commission, and by energy efficiency programs implemented by utilities. A substantial portion of utility-program energy efficiency savings has come from programs designed and administered by IOUs and overseen by the CPUC.

With these changes to the retail electricity landscape in California, there are questions about how energy efficiency programs will be used in the future. As a result of legislation and recent CPUC decisions, energy efficiency program administration and design have been opened up to regional energy networks (RENs) and community choice aggregators (CCAs) while maintaining CPUC oversight. Marin Clean Energy is the only CCA that administers energy efficiency programs. The question of how to continue to advance energy efficiency given the shifting landscape of providing energy services was raised at the June 22, 2018, joint en banc on the *Draft Green Book: An Evaluation of Regulatory Framework Options for an Evolving Electricity Market*.[1] The Green Book notes that, due to the policy of decoupling, California's investor-owned utilities are not paid for selling electricity, but for costs incurred for providing services that customers need. While CCAs reported on their efforts to advance energy efficiency, CCAs are not decoupled. Energy Commissioner Andrew McAllister stated, "I think if you don't have that incentive to really push for efficiency and you're [not] impartial to the actual revenue impact of that, then that is a potential concern."

1 http://www.energy.ca.gov/2018_energypolicy/documents/#06222018.

In addition, changes on the bulk electricity grid with the emergence of large amounts of renewable energy resources, primarily solar photovoltaic (PV), are highlighting an important time-related

75 Notice of IEPR Commissioner Workshop on Doubling Energy Efficiency Savings, https://efiling.energy.ca.gov/getdocument.aspx?tn=223468.

element to energy efficiency. (See Chapter 3 for information on integrating renewables.) To capture the highest value energy efficiency potential and maximize GHG reductions, the timing of energy savings matters. During the middle of the day, solar energy is abundant, and power prices are low and, in some cases, negative. Energy efficiency programs and measures that deliver savings during periods of high renewable generation are less cost-effective and have less impact on GHG reductions. Efficiency savings are more beneficial if delivered in the late afternoon and evening, when solar energy is coming off the system and natural gas plants must quickly ramp up to meet demand. This means leveraging advanced metering infrastructure (AMI) data, control technologies, and rate structures that allow customers to make better decisions about the timing and amount of their energy use.

The energy efficiency market is also changing as the focus of efficiency programs shifts from capturing low-hanging fruit to achieving and sustaining long-term energy savings. Achieving the doubling of energy efficiency savings requires a partnership between efficiency programs and markets.[76] Private sector energy efficiency retailers and providers are already dominant players in energy efficiency markets. Yet, on their own, markets cannot overcome key barriers that result in underusing energy efficiency. Energy efficiency programs play a vital role in addressing impediments to fully harnessing energy efficiency potential. Some of these barriers include lack of information, scarcity of high-efficiency options in local markets, inexperience or lack of training in the latest high efficiency techniques for local suppliers or contractors, customer payback requirements that differ from those of the utility system, and the inconvenience or hassle of arranging audits or energy efficiency retrofits, among others. Private market actors can provide their services more effectively with well-designed programs that can help overcome these barriers.

The introduction of nonutility program deliverers and administrators is also changing the energy efficiency landscape. A series of CPUC decisions established a rolling portfolio process for funding energy efficiency portfolios for the next several years and beyond, and requirements for energy efficiency programs and administration.[77] These decisions introduce a new paradigm in which third-party efficiency deliverers, in addition to the IOUs, community choice aggregators (CCAs), and regional energy networks (REN), will play a more prominent role in achieving deep energy efficiency savings. By the end of 2020, IOUs will be required to have at least 60 percent of their energy efficiency portfolio budgets designed and implemented by third parties. The strong emergence of CCAs is further changing the energy industry as they roll out efficiency programs for customers previously served by the IOUs.

76 ACEEE. "Why We Don't Have To Choose Between Energy Efficiency Programs And Market-Driven Solutions." February 10, 2015. https://aceee.org/blog/2015/02/why-we-don%E2%80%99t-have-choose-between-ener.

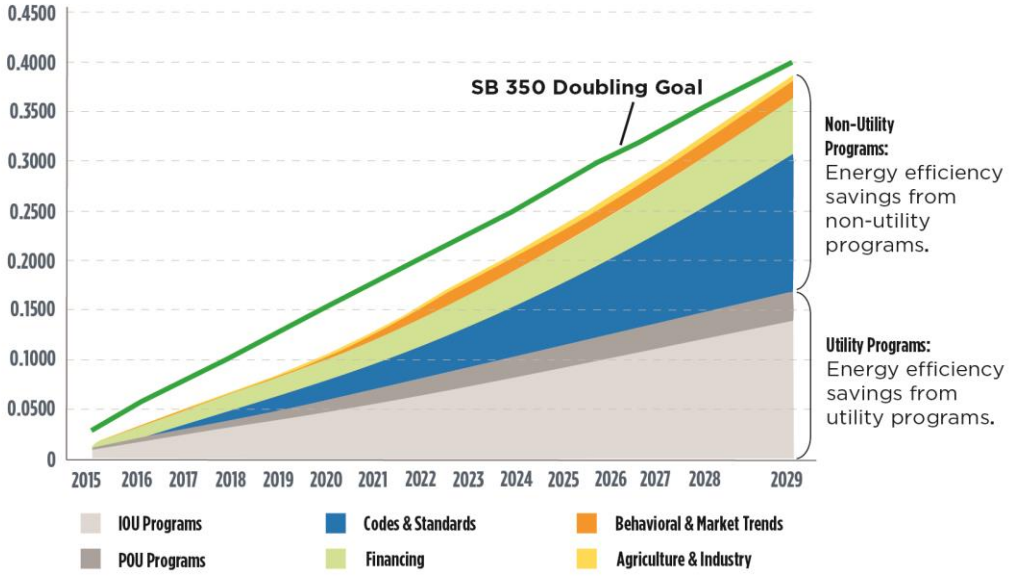
77 CPUC Decision 15-10-028, Decision 16-08-019, and Decision 18-01-004.

Energy Efficiency Targets and Action Plans

SB 350 Energy Efficiency Doubling Targets

Doubling energy efficiency savings by 2030 requires early action in implementing effective programs and measures, as well as vigilance in refining methods for projecting and tracking progress in achieving targets. The doubling targets established by the Energy Commission consist of energy savings projections from utility and nonutility programs summarized in Figure 3.[78] Utility-funded efficiency activities range from incentives aimed at directly influencing consumer choices to programs that target efficiency improvements in the supply chains, including manufacturers, contractors, and builders. Nonutility-funded activities include advancing building and appliance codes, financing programs, behavioral and market transformation, as well as increased public awareness and targeted marketing efforts. While utility programs have been available for the industrial and agricultural sectors, they have not been sufficient to achieve deeper efficiency savings. These additional savings are needed to achieve SB 350 targets.

Figure 3: Projected Combined Electricity and Natural Gas Savings (Quadrillion British Thermal Units, or Quad BTUs)



Source: *Senate Bill 350: Doubling Energy Efficiency Savings by 2030*. California Energy Commission. Publication Number: CEC-400-2017-010-CMF. Based on work in Appendix B by NORESCO. August 2017.

78 Jones, Melissa, Michael Jaske, Michael Kenney, Brian Samuelson, Cynthia Rogers, Elena Giyenko, and Manjit Ahuja. 2017. *Senate Bill 350: Doubling Energy Efficiency Savings by 2030*. California Energy Commission. Publication Number: CEC-400-2017-010-CMF. https://efiling.energy.ca.gov/Lists/DocketLog.aspx?docketnumber=17-IEPR-06.

In addition to traditional energy efficiency programs and measures, there is tremendous potential for fuel substitution savings, which the SB 350 framework defines as equipment installations and replacements that provide both savings in electricity or natural gas and GHG emission reductions. For example, the vast majority of buildings in California use natural gas for water and space heating.[79] As discussed in Chapter 1, advances in heat pump technology make substituting electricity for natural gas in heating systems more viable and, especially when integrated with renewable generation, can both reduce energy consumption and GHG emissions. In comments, POUs recommended that the Energy Commission consider expanding the definition of fuel substitution to align with their definition, which includes diesel, propane, heating oil, and wood-burning uses, in addition to natural gas.[80] However, the Energy Commission believes SB 350 was clear that energy efficiency savings are reduced electricity and natural gas usage, and fuel substitution applies to utility-supplied or -connected electricity or natural gas.[81]

SB 350 also allows CVR, which is a proven technology to reduce energy use and peak demand. By controlling voltage on a distribution circuit to the lower end of the tolerance bands, end users and the distribution utility can realize efficiency benefits.

Building Energy Efficiency

Improving the energy efficiency of existing buildings, in addition to the appliances and other devices used in them, is a key source of potential energy efficiency savings to meet SB 350 doubling targets. In 2015, the Energy Commission developed the *Existing Buildings Energy Efficiency Action Plan* to improve the energy efficiency of existing residential, commercial, and government buildings.[82] The *Existing Building Energy Efficiency Action Plan*, required by Assembly Bill 758 (Skinner, Chapter 470, Statutes of 2009), relies on measures and programs to increase energy efficiency markets, enable more effective targeting and delivery of energy efficiency upgrade services, improve the decision-making of occupants and investors, and advance improvements to the performance of California's buildings. Regulatory solutions alone will not accomplish these. Chapter 1 discusses strategies to decarbonize buildings, a central focus of energy efficiency efforts for both new and existing buildings.

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79 Almost 90 percent of all residential water heaters in California are fueled by natural gas. *2009 California Residential Appliance Saturation Study, Executive Summary*, http://www.energy.ca.gov/2010publications/CEC-200-2010-004/CEC-200-2010-004-ES.PDF, p. 11.

80 Joint Publicly Owned Utilities' Comments on the *Draft Outline 2019 Statewide Energy Efficiency Savings Action Plan*. Docket Number 18-IEPR-07. June 21, 2018. https://efiling.energy.ca.gov/GetDocument.aspx?tn=223907.

81 SB 350 defines *fuel substitution* as "programs that save energy in final end uses by using cleaner fuels to reduce greenhouse gases as measured on a lifecycle basis." It defines energy efficiency as "a measure or reduced electricity or natural gas usage produced either by the installation of an energy efficiency measure or the adoption of an energy efficiency practice."

82 The Energy Commission developed the *Existing Buildings Energy Efficiency Action Plan – Final* in 2015, followed by the *2016 Existing Buildings Energy Efficiency Action Plan Update*. http://www.energy.ca.gov/ab758/.

New Combined Energy Efficiency Reporting

SB 350 requires the Energy Commission to revisit the statewide doubling targets and report biennially to the Legislature on progress achieved toward them and the impacts on disadvantaged communities, starting with the *2019 IEPR*. In addition, the next update of the *Existing Building Energy Efficiency Action Plan* is due by January 1, 2020.[83] Because of the close connection between the activities necessary to meet SB 350 doubling targets and AB 758 requirements for new and updated action plans, the Energy Commission intends to combine these efforts. This includes bringing together content from similar reports, such as the *Low Income Barriers Study* and the *Clean Energy in Low-Income Multifamily Building Action Plan*.[84, 85] A holistic approach to energy efficiency targets and action plans will help improve and expand energy efficiency adoption across the state.

The Energy Commission plans to update the new combined energy efficiency report biennially and address intermediate progress or significant new information in the *Integrated Energy Policy Report*. For example, this format is similar to the update of *2015 Existing Buildings Energy Efficiency Action Plan*, which addressed new regulations and policies and provided an overview of the energy efficiency status of a sector. New topics will include conservation voltage reduction, agricultural and industrial energy efficiency, fuel substitution, avoided greenhouse gas emissions metrics, and decarbonizing buildings. As directed by Assembly Bill 3232 (Friedman, Chapter 373, Statutes of 2018), signed into law by former Governor Brown in August 2018, building decarbonization will increasingly be the central organizing principle for California's demand-side energy policies, and the new combined energy efficiency report will begin in earnest to incorporate and reflect this shift.

The Energy Commission intends to develop a draft of the first combined energy efficiency report in early 2019, which will be the basis for a series of workshops across the state in the first half of 2019. The Energy Commission expects to visit several areas in the state, including Southern California, the Central Coast, the Central Valley, the San Francisco Bay Area, and Northern California. The feedback received from these workshops will inform the final draft, expected for released in the fall of 2019, with the final report available in late 2019. Stakeholders will have additional opportunities to provide feedback after the release of the final draft report.

In their filed comments, stakeholders generally support combining these reports and plans. The POUs recommended convening a separate IEPR workshop to allow

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83 Scavo, Jordan, Suzanne Korosec, Esteban Guerrero, Bill Pennington, and Pamela Doughman. 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. Publication Number: CEC-300-2016-009-CMF. https://efiling.energy.ca.gov/getdocument.aspx?tn=214830.

84 Ibid.

85 *Clean Energy in Low-Income Multifamily Buildings Action Plan*. California Energy Commission. Publication Number: CEC-300-2018-005-SD. https://efiling.energy.ca.gov/GetDocument.aspx?tn=223600.

representatives from across building and market sectors to share their perspectives on the support and programs that would be most helpful in spurring demand.[86] The Energy Commission is considering holding such a workshop as part of the *2019 IEPR*.

Utility Energy Efficiency Programs

Utility efficiency programs will continue to play an essential role in meeting SB 350 energy efficiency targets. The Energy Commission used the potential and goals studies developed by the CPUC and POUs as the basis for projecting energy efficiency savings and setting statewide and utility doubling targets.[87] New potential and goals studies underway are likely to identify additional energy efficiency potential; however, the coordinated actions and cooperation of program administrators across the state will be necessary to meet these targets. These program administrators include not only the IOUs and POUs, but also RENs, CCAs, government agencies, third-party administrators, and others. Existing and proposed energy efficiency efforts are summarized below.

CPUC Energy Efficiency Rolling Portfolio Business Plans

The CPUC recently adopted the energy efficiency business plans submitted by the IOUs, RENs, and CCAs under its jurisdiction.[88, 89] The business plans are based on energy efficiency goals established by the CPUC in 2015 and include budgets for 2018 through 2025. While based on the earlier goals, the business plans are considered flexible enough to address future goal updates and SB 350 targets, as well as other policy guidance.

These plans focus more on strategies and metrics than on specific programs, which will be included in implementation plans developed by program administrators. The decision gives policy guidance for designing incentives for customers and implementers, prohibiting incentives for compact fluorescent lighting in favor of light-emitting diodes (LEDs), requiring continuation of incentives for street-lighting bulk conversions, and addressing workforce issues. The intent of these changes is to increase realization rates, reduce overhead costs, streamline delivery, and encourage innovative portfolios.

Under the decision, the utility program administrators can undertake certain limited integration activities to realize ancillary demand response benefits when funding energy efficiency projects. These projects can include residential heating, ventilation, and air

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86 Joint Publicly Owned Utilities' Comments on the *Draft Outline 2019 Statewide Energy Efficiency Savings Action Plan*. Docket Number 18-IEPR-07. June 21, 2018. https://efiling.energy.ca.gov/GetDocument.aspx?tn=223907.

87 *Energy Efficiency Potential and Goals Study for 2018 and Beyond*. ftp://ftp.cpuc.ca.gov/gopher-data/energy_division/EnergyEfficiency/DAWG/2018_Potential%20and%20Goals%20Study%20Final%20Report_092517.pdf.

88 CPUC D.18-05-041. http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M215/K706/215706139.pdf.

89 CPUC approved business plans for eight program administrators in California: Pacific Gas and Electric Company (PG&E), San Diego Gas & Electric Company (SDG&E), Southern California Gas Company (SoCalGas), Southern California Edison Company (SCE), BayREN, the Southern California REN, the Tri-County REN, and Marin Clean Energy.

conditioning (HVAC) controls, non-residential HVAC, and lighting controls. In addition, administrators can conduct studies on the potential for integrating demand response and energy efficiency as part of their integrated resource planning (IRP) analysis. The purpose is to take advantage of opportunities for adding demand response functionality for little incremental cost (when an efficiency investment has already occurred) and assist customers in preparing for the roll-out of time-varying rates over the next several years.

For the first business plan cycle, program administrators must use a rolling portfolio framework, which allows the CPUC to regularly review and revise program administrators' portfolios. Furthermore, third parties must administer 60 percent of energy efficiency programs through a solicitation by 2020. Program administrators must post program implementation plans for new programs within 120 days of issuance of the decision or 60 days after the execution of third-party contracts. Program implementation plans must undergo a stakeholder process and should contain net life-cycle savings for the program, tiered incentives to promote various degrees of efficiency above code, strategic targeting of products, discussion of customer barriers, and, for performance-based programs, independently verified savings performance.[90] The program administrators must track metrics and indicators demonstrating progress toward CPUC-adopted energy efficiency goals.

Focus of Energy Efficiency Portfolios

Program administrators anticipate challenges and changes to their energy efficiency programs. Many customers have already installed energy efficiency technologies that have low installation costs and short paybacks, such as interior lighting and controls. As a result, program administrators are looking to increase their energy efficiency program budgets to invest in technologies with longer paybacks, such as HVAC replacement. Program administrators are also planning to use a single point of contact model to make customer communication easier and energy efficiency recommendations tailored to unique customer needs.[91]

The approved business plans include strategies such as more demand response, water-energy nexus activities, data analytics, workforce education and training, and code compliance. Program administrators are also looking to implement strategic partnerships with the agricultural sector to install measures that save energy and water, as discussed later in this chapter.

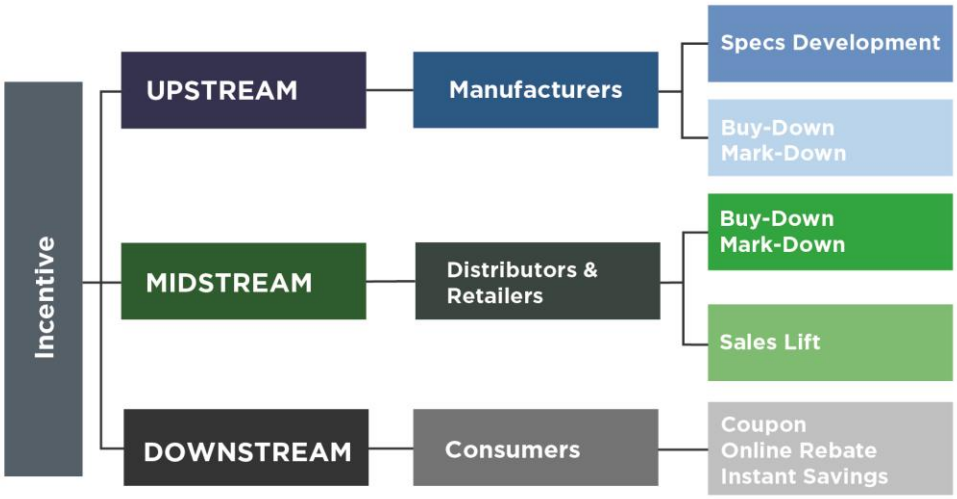
At the June 7, 2018, workshop, utilities including Southern California Edison (SCE) and Southern California Gas Company (SoCalGas) listed midstream and upstream programs as an important portion of their energy efficiency portfolio. Upstream programs provide incentives directly to the manufacturer of a product and midstream programs offer an

90 CPUC D.15-10-028. http://docs.cpuc.ca.gov/publisheddocs/published/g000/m155/k511/155511942.pdf.

91 IEPR Workshop on Doubling Energy Efficiency Savings, http://www.energy.ca.gov/2018_energypolicy/documents/#06072018.

incentive to the distributor or retailer of a certain good, as shown in Figure 4. These programs eliminate some of the decision-making barriers consumers face when they have to submit rebates after a purchase. Access to midstream and upstream programs depend on a utility's ability to work with manufacturers, distributors, and retailers.

Figure 4: Energy Efficiency Incentive Structure



Source: Vincent, Julie-Ann and Mariangiola Fabbri, Dunsky Energy Consulting, "Influencing Smaller Markets: Can Residential Midstream and Upstream Incentive Models Succeed?" 2016, ACEEE Summer Study on Energy Efficiency in Buildings.

Building energy codes and standards are advancing, but many existing buildings are still operating below code. Program administrators are working to target "stranded potential" energy savings opportunities by bringing these existing buildings up to code. A CPUC-funded study identified residential and commercial HVAC equipment, commercial lighting, and residential and commercial water heating equipment as sectors with below-code savings potential.[92] Further analysis to identify possible below-code savings in industrial and agricultural measures, commercial and residential envelope measures, and commercial refrigeration equipment is needed.

Public sector buildings in California are aging and serve specific needs, such as education. In addition, investment in these buildings typically involves a public decision-making and budgeting process. Although they are small, public sector buildings can be a visible part of a local government's climate action plans, providing an opportunity for deep energy efficiency retrofits and public education on energy efficiency. One commenter raised a concern about lumping all public buildings together in one sector, recommending that from a scale standpoint, it might be more effective to focus

92 CPUC. *AB 802 Technical Analysis.* http://dawg.energy.ca.gov/sites/default/files/meetings/3.DAWG%20July%2019%20-%20AB802%20Technical%20Analysis%20Summary.pdf. p.2.

efficiency programs on the public education sector.[93] Program needs to meet SB 350 doubling goals will be considered as part of the *2019 IEPR*.

HVAC Workforce and Compliance

Workforce training and code compliance are key to achieving real energy savings from installed equipment. At the June 7, 2018, workshop on Doubling Energy Efficiency Savings, numerous HVAC parties commented on the need to improve the workforce installing HVAC measures and increasing compliance with the energy standards. The California Sheet Metal and Air Conditioning Contractors' National Association and Joint Committee on Energy and Environmental Policy provided written comments that advocate for an HVAC registry to improve compliance with Title 24 Building Standards. They also advocate for policies that encourage hiring a trained and qualified workforce, especially workers who have gone through apprenticeship programs.[94, 95] According to the Joint Committee for Energy Efficiency and Policy, poor quality installation and widespread permit avoidance are undermining the state's energy efficiency goals. They suggest that to address this issue, workforce standards be attached to energy efficiency subsidy programs to increase permit and code compliance.[96]

The Energy Commission recognizes this issue and is developing a plan in consultation with the Contractors State License Board, local governments, building officials, and other stakeholders that promotes compliance with the energy standards in the installation of central air-conditioning and heat pump systems. Senate Bill 1414 (Wolk, Chapter 768, Statutes of 2016), which mandates this plan, also gives the Energy Commission authority to adopt regulations designed to increase compliance with permitting and inspection requirements. The Energy Commission held a series of workshops in 2018 to collect stakeholder insight on the path forward.[97] Compliance with the standards is important, not just for achieving the doubling of energy efficiency, but for myriad other reasons, beginning with consumer protection and safeguarding public health and safety. The Energy Commission will continue stakeholder engagement with the goal to publish a final plan in 2019.

Leveraging Customer Information

Increasing access to information by customers and program deliverers will be important for driving future investments in energy-related performance improvements. Program administrators use home energy reports as the main driver to target customer behavior.

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93 Comment in Support of Doubling Energy Efficiency to Deep Energy Retrofit of CA Public-K-12 Sector. Docket Number 18-IEPR-07. June 20, 2018. https://efiling.energy.ca.gov/GetDocument.aspx?tn=223906.

94 CAL SMACNA Comments, California Association of Sheet Metal and Air Conditioning Contractor's National Association, Docket 18-IEPR-07, June 20, 2018, https://efiling.energy.ca.gov/GetDocument.aspx?tn=223891.

95 JCEEP Comments on SB 350 Doubling of Energy Efficiency Workshop, Joint Committee for Energy Efficiency and Policy, Docket 18-IEPR-07, https://efiling.energy.ca.gov/GetDocument.aspx?tn=223896.

96 Ibid.

97 http://www.energy.ca.gov/title24/enforcement/.

Home energy reports compare a customer's energy usage to that of their neighbors, with the expectation of motivating changes by high-usage consumers.[98] This purely behavioral approach produces savings ranging, on average, from less than 1 percent up to 3 percent per household,[99] which is laudable, but in practice only scratches the surface of the potential savings in the residential sector.

A positive and potentially transformative shift in efficiency program design is underway, enabled by the widespread installation of smart meters. Interval meter data can help determine the energy consumption profiles of different customers and sectors, across climate zones, and enable facile quantification of the effects of energy efficiency programs through what is termed *normalized metered energy consumption* (NMEC).[100]

There are generally two types of NMEC-based incentive programs. One type aggregates, or groups, buildings with similar energy characteristics (for example, all single-family homes in a given climate zone), sets an overall goal of energy savings from that portfolio of buildings, and pays based on the savings the portfolio achieves. The other focuses on single buildings and pays the implementer based on the performance of that project. These approaches promise to enable high-quality solutions tailored to each customer at low cost. Various behavioral and market transformation approaches that rely on better access to customer usage information, including NMEC-based programs, hold great potential for enabling targeted, flexible program approaches that improve the performance of California's building stock at a scale that could achieve the doubling goal.

Utility pilot programs are underway to better understand the program applications of interval meter data. Pacific Gas and Electric Company (PG&E) is launching a trial pay-for-performance program that pays incentives based on the actual savings captured, as opposed to deemed savings, which are estimated through engineering calculations or laboratory tests and are unreliable. Interval meter data also allow researchers and utilities to identify the measures that save energy at the most valuable times of the day. A recent report from Lawrence Berkeley National Laboratory showed that residential air conditioning is a major energy-consuming measure that aligns with high value for avoided energy.[101] It is possible to use interval meter data to identify homes that could benefit most from an air-conditioning retrofit.

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98 *Interval meters* record energy use in 15-minute intervals, which one can aggregate into hourly, daily, or monthly consumption.

99 CPUC. (May 2018). *Energy Efficiency Portfolio Report*. Pg. 28. Retrieved from http://www.cpuc.ca.gov/uploadedFiles/CPUCWebsite/Content/About_Us/Organization/Divisions/Office_of_Governmental_Affairs/Legislation/2018/13-15%20Energy%20Efficiency%20Report_Final.pdf.

100 NMEC leverages meter data to establish a comparison baseline using historical data and the associated correlation to weather. Once an energy efficiency project is complete, meter readings are compared to the baseline to compute energy savings.

101 Mims, Natalie, Tom Eckman, and Charles Goldman. June 2017. *Time-Varying Value of Electric Energy Efficiency.* Pg. 34. Lawrence Berkeley National Laboratory. https://emp.lbl.gov/publications/time-varying-value-electric-energy

The CPUC is drafting guidelines for interval meter data-based programs.[102] The CalTRACK working group, composed of the Energy Commission, CPUC, energy service companies, utilities, and out-of-state energy agencies, is developing open-source methods to analyze interval meter data for portfolio-style energy efficiency programs.[103] The goal is to develop consistency among entities when determining energy efficiency savings, especially when it comes to weather-normalization techniques, data-cleaning choices, gathering of interval data, and choosing buildings for analysis.

Stakeholder comments from the June 7, 2018, workshop further advocate for an independent, statewide organization to develop and maintain an NMEC tool to measure energy savings from projects. They also recommend establishing an open process to improve NMEC techniques at the project level, leveraging interval meter data, and defining a standard process for submitting projects for savings verification.[104]

The Energy Commission will continue to work with the various utilities and stakeholders to ensure that sufficient information about energy consumption and energy usage patterns is available to customers, program deliverers, and system planners to help target the most energy-efficient measures and programs. To plan for energy efficiency as a resource, robust time and locational savings estimates will be needed. As PV generation, battery storage, and electric vehicles become more prevalent as large energy-consuming or -generating systems in buildings, it will be important for customers and their agents to have ready access to detailed energy information.

In addition, the marketplace needs good information to unlock the innovation needed to meet the SB 350 targets. With the collection of customer-metered data, under revised data collection regulations that went into effect on July 1, 2018, the Energy Commission expects to play a pivotal role in ensuring access to energy usage information.

POU Energy Efficiency Programs

California's POUs, governed by locally elected boards such as city councils, develop energy efficiency programs based on the diverse range of customers and communities they serve. As such, they respond primarily to local concerns and needs in developing energy efficiency programs. POUs in California cover 13 of the state's 16 climate zones and a range of urban, rural, coastal, and inland customers.[105] The Los Angeles Department of Water and Power (LADWP) serves more than 4 million customers, while

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102 CPUC, *Draft Rulebook for Custom Program and Projects Based on Normalized Metered Energy Consumption (NMEC)*, March 2018. http://www.cpuc.ca.gov/General.aspx?id=6442456320.

103 *CalTRACK* is a set of methods for calculating site-based, weather-normalized, metered energy savings from an existing baseline and applied to single-family home retrofits using data from utility meters. http://www.caltrack.org/.

104 Home Energy Analytics, HEA Comments on 6/7/18 Workshop, 18-IEPR-07 https://efiling.energy.ca.gov/GetDocument.aspx?tn=223900.

105 CMUA, *Energy Efficiency in California's Public Power Sector, 12th Edition* March 2018 http://ncpasharepointservice20161117100057.azurewebsites.net/api/document?uri=https://ncpapwr.sharepoint.com/sites/publicdocs/Compliance/2018_Energy_Efficiency_Report2.pdf, p. 4.

the smallest POUs have fewer than 1,000 customers.[106] These differences between POUs presents challenges in looking at energy efficiency potential for POUs as a whole.

Among the initiatives that POUs are pursuing to achieve the SB 350 doubling targets are building electrification programs, residential LED distribution programs, and commercial lighting incentive programs. For example, LADWP offers residential rebates for the purchase of energy-efficient products, certified pool pump replacement, an HVAC optimization program (via direct install service), and free Wi-Fi-enabled smart thermostats.[107]

Sacramento Municipal Utility District (SMUD) is transitioning residential customers to time-of-use rates, which it hopes will place more focus on measures and load management strategies that reduce peak demand. SMUD has also switched its retail lighting program product mix from 90 percent LEDs and 10 percent compact fluorescents in 2016 to 100 percent LEDs in 2017. It also debuted an online marketplace, the SMUD Energy Store, which provides ready access to energy-saving equipment.[108]

Reporting Requirements for Disadvantaged Communities

CPUC Reporting on Disadvantaged Communities

Beginning in July 2019, and every four years thereafter, Senate Bill 350 directs the CPUC to report to the Legislature progress toward increasing and maximizing the contribution of energy efficiency savings in disadvantaged communities. The term "disadvantaged communities" refers to the areas throughout California that suffer most from a combination of economic, health, and environmental burdens. These burdens include poverty, high unemployment, health conditions like asthma or heart disease, air pollution, water pollution, and hazardous waste.[109] New strategies to increase participation of disadvantaged communities are needed, along with new reporting requirements to separate the energy efficiency savings of disadvantaged customers from the energy efficiency savings of other customers.

The CPUC's recent decision on business plans included high-level strategies that program administrators intend to employ to increase participation in disadvantaged

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106 CMUA, *Energy Efficiency in California's Public Power Sector, 12th Edition* March 2018 http://ncpasharepointservice20161117100057.azurewebsites.net/api/document?uri=https://ncpapwr.sharepoint.com/sites/publicdocs/Compliance/2018_Energy_Efficiency_Report2.pdf, p. A-53.

107 As of March 2018, LADWP reported that the AC Optimization Program served more than 3,400 customers.

108 In 2017, almost 10,000 items were purchased, including 4,600 ENERGY STAR® smart thermostats (One thousand six hundred ENERGY STAR® smart thermostats received rebates through traditional SMUD rebate channels.) CMUA, *Energy Efficiency in California's Public Power Sector, 12th Edition* March 2018 http://ncpasharepointservice20161117100057.azurewebsites.net/api/document?uri=https://ncpapwr.sharepoint.com/sites/publicdocs/Compliance/2018_Energy_Efficiency_Report2.pdf, p. A-108.

109 http://www.cpuc.ca.gov/discom/.

communities.[110] Some of the strategies to reach more disadvantaged customers include improving opportunities for energy efficiency, renewable energy, demand response, energy storage, and electric vehicle infrastructure for multifamily housing rental properties. Program administrators are considering conducting market studies of targeted disadvantaged communities to identify unique market characteristics, market barriers, and customer preferences and energy habits. In addition, program administrators are developing strategies that leverage customer data to target core program coordination and outreach to rural and disadvantaged communities, and that relax certain parameters that hinder rural and disadvantaged community participation.[111]

This decision also included a required set of metrics and indicators to track progress toward meeting energy efficiency goals at the portfolio and sector levels for disadvantaged communities. First-year annual and life-cycle energy efficiency savings for gas and electric, as well as peak demand savings, have always been reported. Beginning in 2018, the program administrators will report these savings metrics separately for disadvantaged customers. By separating the energy efficiency savings of disadvantaged customers from non-disadvantaged customers, the program administrators can make sure they are addressing the needs of disadvantaged populations. Program administrators will also need to provide a new metric that captures the percentage of participation in energy efficiency programs in disadvantaged communities.

These new savings metrics for disadvantaged communities will be used as more detailed metrics are being developed. The Energy Commission has begun working with the CPUC on using geographic information system data to help identify disadvantaged customers who are eligible to participate in energy efficiency programs but are not participating. By using these and other metrics being developed, program administrators can maximize energy efficiency savings in disadvantaged communities and do more targeted marketing to reach eligible but nonparticipating customers.

POU Reporting on Disadvantaged Communities

Beginning with the March 2018 annual POU energy efficiency report, the POUs are separately reporting energy efficiency savings for customers living in multifamily buildings and disadvantaged customers.[112] In addition, the POUs are expanding the programs they offer to low-income and disadvantaged customers. Some of these new programs include deep energy retrofits such as heating and cooling upgrades, attic insulation, refrigerator replacement, weather-stripping, and LED lighting. Some POUs are

110 CPUC D.18-05-041. http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M215/K706/215706139.pdf.

111 IEPR Commissioner Workshop on Doubling Energy Efficiency Savings. http://www.energy.ca.gov/2018_energypolicy/documents/#06072018.

112 For example, see http://ncpasharepointservice20161117100057.azurewebsites.net/api/document?uri=https://ncpapwr.sharepoint.com/sites/publicdocs/Compliance/2018_Energy_Efficiency_Report2.pdf.

also partnering with IOUs to offer joint energy efficiency programs to disadvantaged customers. LADWP and SoCalGas have started a single point of contact approach for gas, electric, and water efficiency programs that should simplify the process for accessing these programs. The Imperial Irrigation District is using another approach to reach disadvantaged customers by working with churches and other faith-based groups to help inform its disadvantaged customers of programs that are available to them.

Behavioral and Market Transformation

Experience with behavioral and market transformation programs is demonstrating that they do, in practice, achieve energy efficiency savings. Behavioral programs recognize that energy efficiency not only depends on the equipment and appliances that customers purchase, but in the way these energy-consuming devices are used. The energy efficiency industry is identifying the most effective ways to encourage and sustain behaviors that modulate energy consumption in homes, workplaces, and industrial buildings.

Market transformation can play a central role in bringing new and emerging products and technologies into the mainstream through targeted programs, as well as inclusion in voluntary standards such as ENERGY STAR® or mandatory codes and standards for buildings and appliances. There is also an important behavioral element in market transformation that goes beyond the customer to include how the behavior of vendors, manufacturers, builders, and other market players can be considered in the complex energy efficiency marketplace.

The Energy Commission's SB 350 targets for behavioral and market transformation programs account for about 2 percent of the total projected electricity savings and 7 percent of natural gas savings in 2030.[113] In establishing the SB 350 targets, the Energy Commission used the best available data and methods to project savings from behavior and market transformation while recognizing that these programs and measures are still being designed and developed for widespread implementation.

The SB 350 doubling targets considered the following measures for behavioral and market transformation: benchmarking, fuel substitution,[114] energy asset rating, smart meters and controls, and behavioral, retrocommissioning, and operational changes. Because many of these are nascent programs, uncertainty remains about whether the Energy Commission's projections capture all possible behavioral-based strategies and the amount of confidence to place in current methods to count potential savings.

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113 Jones, Melissa, Michael Jaske, Michael Kenney, Brian Samuelson, Cynthia Rogers, Elena Giyenko, and Manjit Ahuja. 2017. *Senate Bill 350: Doubling Energy Efficiency Savings by 2030*. California Energy Commission. Publication Number: CEC-400-2017-010-CMF. p. 19.

114 See Chapter 1 on "Decarbonizing Buildings" for a discussion of fuel substitution focused primarily on electrification.

Shoring Up Behavioral and Market Transformation Efforts

The Energy Commission believes that experimentation is essential to evaluating behavioral-based programs, helping inform policy, and guiding future program designs that can confidently generate efficiency savings. Some of the methodological challenges and uncertainties with behavioral and market transformation programs center around the inherent difficulty in determining what would have happened in the absence of intervention. In conducting reliable evaluation of behavioral and market transformation interventions, there are several factors to consider, including:

- Properly identifying behavioral and market effects, such as the expected size of the net and gross savings.
- Appropriately attributing savings, for example, avoiding double-counting.
- Accurately anticipating behavioral and market impacts.
- Accounting for the permanence and persistence of program effects such as savings decay and replacement.

Much of the savings anticipated for existing buildings will rely on behavioral and market transformation programs and measures. Several central challenges for achieving savings in existing buildings discussed at the June 7, 2018, workshop include ways to influence timely retrofitting of existing buildings, the wide variations in energy consumption characteristics in buildings, a relatively poor track record of predicting energy consumption, and limited data availability. Despite uncertainties in capturing and tracking savings from behavior and market interventions, these potential behavioral and market programs are an important resource in meeting the SB 350 doubling goals.

In comments, San Diego Gas & Electric Company (SDG&E) and SoCalGas disagreed with the CPUC's decision to limit behavior-based energy efficiency program savings claims in the business plans to those evaluated using experimental designs.[115] They recommended that greater energy efficiency savings could be realized if proven behavior-based programs (such as home energy reports) were not limited to using experimental design methods. Evaluation uncertainties remain, however, for behavior-based programs including home energy reports. A recent review of the performance of home energy reports concludes that the magnitude and persistence of such programs are uncertain and recommend that utilities continue to evaluate home energy reports program treatment and control group customers after a program ends.[116]

SDG&E and SoCalGas also advocated that all eligible customers should be allowed to participate in behavioral interventions instead of having to evaluate the program using a

115 SoCalGas Comments on the June 7, 2018, joint agency workshop on Doubling Energy Efficiency Savings, 18-IEPR-07. https://efiling.energy.ca.gov/GetDocument.aspx?tn=223894.

116 Khawaja, M. S. and James Stewart. 2014. *Long-Run Savings and Cost-Effectiveness of Home Energy Reports Programs*. Cadmus Group Inc. Pp 17-18. https://cdn2.hubspot.net/hubfs/472557/Publications/Cadmus-%20HERs%20Program%20White%20Paper-2017.pdf?submissionGuid=8da66767-e700-4f1e-9089-2925f38f6fa5.

control group — customers who do not receive the intervention. They also recommended discontinuing the use of randomized control trials for behavior programs.[117]

The Energy Commission supports the CPUC's decision in its proposed treatment of behavioral interventions. Discontinuing the use of experimental methods, particularly randomized controlled trials for evaluating behavioral-based programs, creates problems in identifying and verifying energy savings. Energy efficiency evaluators have argued that if the uncertainties about program effects are to be resolved, program administrators and regulators must support the use of experiments in evaluating programs where large effects of attribution and spillover are expected.[118] Randomized controlled trials for behavior-based efficiency programs provide robust, unbiased estimates of program savings.[119]

At the same time, as a rule California ought not wait for definitive conclusions from expensive, multiyear evaluations to act boldly in the scale-up of program approaches that seem to be achieving results. The greatest rewards come with some risk. Climate change is not waiting; policy and program interventions must respond in a relevant, rapid time frame. Achieving a balance of informed program development and proactive innovation is the responsibility of the energy agencies, in concert with the variety of market actors and advocacy stakeholders that California is fortunate to have.

Industrial and Agricultural Sector Energy Efficiency

California, now the world's fifth largest economy, leads the nation in electronics and computer manufacturing. In addition, the state leads the nation in cash farm receipts, with California producing more than one-third of the vegetables and two-thirds of the fruits and nuts for the nation.[120] These two sectors consume about a quarter of total energy consumed in the state, with about 85 percent of the energy consumed by the industrial sector and the remaining 15 percent by the agricultural sector.[121] In addition, about 70 percent of the energy consumed in the industrial sector is in the form of natural gas. The SB 350 targets for the industrial and agricultural sectors are preliminary savings estimates and not based on the most aggressive assumptions. As a

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117 In a program evaluation design, households in a given population are randomly assigned into two groups: a treatment group and a control group. The outcomes for these two groups are compared, resulting in unbiased program energy savings estimates.

118 Vine, E., M. Sullivan, L. Lutzenhiser, C. Blumstein, and B. Miller. 2014. "Experimentation and the Evaluation of Energy Efficiency Programs." *Energy Efficiency*, 7(4), 627–640. https://doi.org/10.1007/s12053-013-9244-4.

119 Todd, A., E. Stuart, S. R. Schiller, and C. A. Goldman. 2012. *Evaluation, Measurement, and Verification (EM&V) of Residential Behavior-Based Energy Efficiency Programs: Issues and Recommendations* (No. 1219686). Lawrence Berkeley National Laboratory. (p. x) https://doi.org/10.2172/1219686.

120 *California Agricultural Statistics Review 2016–2017*. https://www.cdfa.ca.gov/statistics/.

121 California Energy Commission. "*Electricity Consumption by Entity for 2016 and Natural Gas Consumption by Entity for 2016*." http://ecdms.energy.ca.gov/elecbyutil.aspx. The percentages include industrial, agricultural, mining, and construction energy use.

result, additional savings in these sectors can help fill the gap in meeting SB 350 doubling targets.

Efficiency Barriers and Opportunities for Agriculture and Industry

The IOUs' business plans outline their approach for reducing energy consumption in the industrial and agricultural sectors. At the June 7, 2018, workshop, IOUs highlighted several barriers for achieving energy efficiencies from these sectors.[122] These barriers include:

- Difficulties in offering standardized programs that fit the needs of industrial customers because of the diverse and customized production or manufacturing environments and proprietary processes.
- Competing priorities, such as maintaining production levels and quality control, that tend to overshadow energy efficiency considerations for industrial customers.
- Complex and time-consuming efficiency upgrades that involve retrofits and operational changes that can affect production levels.
- Decision-making processes that can be complicated.
- Difficulties and high costs to convince diverse customers to pursue energy efficiency, especially small customers.

Opportunities for energy savings in the industrial and agricultural sectors include using strategic energy management (SEM), which is a relatively new concept approved by CPUC on a two-year trial.[123] The IOU presentations at the June 7, 2018, workshop, along with their business plans, identified SEM as a key strategy to reduce energy consumption and increase efficiency savings.[124] SEM programs go beyond existing retrofit programs to focus on identifying and supporting customers to implement behavioral, retrocommissioning, energy efficiency, and operational savings measures on an ongoing basis.[125, 126]

For large customers, it is important to work one-on-one to take advantage of SEM strategies. SoCalGas noted in the workshop that it plans to work with large customers

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122 Transcript of June 7, 2018, IEPR Workshop on Doubling Energy Efficiency Savings, TN#224267, Testimony of Colleen Breitenstein (PG&E), Erin Brooks (So Cal Gas), Athena Besa (San Diego Gas & Electric) and questions, pages 145-168, and 178-185. https://efiling.energy.ca.gov/GetDocument.aspx?tn=224267.

123 CPUC D.18-05-041. http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M215/K706/215706139.pdf.

124 http://www.energy.ca.gov/2018_energypolicy/documents/2018-06-07_workshop/2018-06-07_presentations.php.

125 SEM engagements last from one to three years to realize the deepest levels of savings at participating customer facilities.

126 AESC and Cascade Energy Bring Strategic Energy Management to Southern California, http://www.aesc-inc.com/aesc-cascade-energy-bring-strategic-energy-management-southern-california/.

that represent 7 percent of its customers but consume 95 percent of the natural gas.[127] Even though large customers consume a significant amount of energy, it is important that utilities and efficiency program providers also work with medium and smaller customers to reduce their energy consumption. PG&E anticipates providing SEM program offerings that target small and medium customers through cohorts and trade associations.[128]

One aspect of SEM is conducting energy audits, which can be expensive — especially for many medium-sized and small companies. IOUs and program deliverers may be able to leverage government energy audit programs or provide subsidies or incentives for these audits.[129] Tracking energy usage for SEM programs can also be a challenge, especially for small and medium-sized customers. However, there are tools and models available to help companies analyze utility billing, weather, and production data to understand a company's energy consumption over time.

Other areas to increase energy efficiency in agriculture and industry include improved financing (including raising loan amounts), expanding and improving existing measures, developing relationships with customers, and providing education, technical assistance, knowledge-sharing, and training opportunities. Energy efficiency measures related to pumps and pumping requirements dominate the energy savings potential for agriculture. Energy efficiency opportunities include exploring enhancements to variable-frequency drive measures, relaunching process fan variable-frequency drives specifically for agricultural applications, and installing high efficiency motors and thermal curtains (to reduce heat loss).

A complementary state program that could help finance energy improvements is the California Alternative Energy and Advanced Transportation Financing Authority (CAEATFA). The Energy Commission serves as a board member for this program. CAEATFA provides California companies with clean energy financing options for energy efficiency upgrades, a sales tax exclusion program for qualified advanced manufacturing and transportation projects, and other opportunities to reduce GHG emissions by making industrial processes more efficient and sustainable.[130]

Agricultural and Industrial Efficiency Research

A recent area of focus for research on industrial and agricultural energy efficiency and the related ability to reduce GHG emissions is the Energy Commission's Food Production

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127 Brooks, Erin. June 7, 2018. "Agricultural and Industrial Energy Efficiency." Presented at the 2018 IEPR Commissioner Workshop on Doubling Energy Efficiency Savings. https://efiling.energy.ca.gov/GetDocument.aspx?tn=223678.

128 *Energy Efficiency Business Plan 2018-2025*. January 2017. Pacific Gas and Electric Company. https://docs.wixstatic.com/ugd/0c9650_cbeb1d9e14cf4575845e8d5cd6bce57f.pdf.

129 The U.S. Department of Energy's Industrial Assessment Centers at San Francisco State University and San Diego State University provide no-cost energy audits to medium-sized and small industrial plants.

130 https://www.treasurer.ca.gov/caeatfa/index.asp.

Investment Program.[131] IOUs have identified the food processing sector as a major energy user. At the June 7, 2018, workshop, SoCalGas identified food processing as one of the areas with a high potential for energy savings in its service area.[132] The Energy Commission's new food processing program provides grants to California's food processing industry to reduce GHG emissions by adopting and demonstrating the reliability and effectiveness of commercially available and advanced energy technologies.

In addition, the food processing program complements the Energy Commission's existing research and development efforts undertaken through the Electric Program Investment Charge (EPIC) and Natural Gas Research and Development programs.[133] Examples include testing and demonstrating technologies to reduce natural gas use for steaming, drying, and evaporation (such as rotary dryers and forward osmosis); energy management systems to enhance equipment operations; waste heat recovery systems; and water reuse and recycling operations. Potential areas of research under the EPIC program could include industrial refrigeration (compressor efficiency along with low global warming potential refrigerants), development of novel energy-efficient treatment methods for conventional and nonconventional sources of water supply, and development of strategies and tools to decarbonize the industrial sector. The Energy Commission recently completed a research roadmap to identify near- and midterm technology gaps in the industrial, agricultural, and water sectors and potential solutions to increase energy efficiency. This roadmap will be published and available later in 2018.

Conservation Voltage Reduction

CVR is a proven technology that reduces energy use and peak demand by optimizing voltages on the distribution system. It is included among the possible programmatic activities to meet the SB 350 doubling targets. The basic premise of this technology is that the standard voltage band between 114 and 126 volts can be compressed via regulation to the lower half (114–120 volts) instead of the upper half (120–126 volts). This compression results in substantial energy savings to the customer at low cost to the utility, with no adverse effects on consumer appliances. Distribution utilities implement CVR and gain savings from decreased losses on their systems. Although end users are not required to take any action, they benefit through reduced energy usage.

CVR technology has evolved from the traditional approach, which required control of system-side voltage equipment such as capacitor banks, line voltage regulators, and load tap changers. These older approaches cannot effectively manage unexpected secondary

131 http://www.energy.ca.gov/research/fpip/.

132 Transcript of June 7, 2018, IEPR Workshop on Doubling Energy Efficiency Savings, TN#224267, Testimony of Erin Brooks, SoCalGas, p. 166, https://efiling.energy.ca.gov/getdocument.aspx?tn=224267.

133 Both programs are testing and demonstrating precommercial and emerging technologies and strategies for reducing energy and greenhouse gas emissions in the industrial and agricultural sectors.

voltage drops, resulting in electricity provided with voltage levels below utility standards and equipment needs. Today's next generation volt/VAR optimization (VVO) and CVR technologies use power electronics devices installed on feeders to flatten and equalize voltages. Utilities can then reduce the voltage on the feeder lines that run from substations to homes and businesses. This capability allows utilities to operate their distribution grids at the low end of the acceptable voltage supply without exposing consumers to under-voltage conditions.[134]

An analysis conducted by Navigant Consulting, Inc. shows that CVR could result in a 2.18 percent reduction in electricity consumption.[135] This is about a quarter of the savings required from electric utilities by SB 350. Adding low (secondary) voltage control technologies can expand the number of circuits that can be cost-effectively upgraded with VVO and CVR capabilities by more than 20 percent, resulting in deeper savings. This could raise the maximum achievable savings potential from VVO and CVR to nearly one-third of the amount of energy reductions necessary from the utility sector to achieve the SB 350 statewide target of doubling energy efficiency by 2030.[136]

CVR Pilots and Deployment Activities

Several utilities nationwide have conducted field trials to demonstrate the effectiveness of CVR on their electric distribution systems. Published results have shown the CVR factors are typically between 0.6 and 0.8, which means that reducing the voltage by 1 percent results in an energy reduction of between 0.6 percent and 0.8 percent. Likewise, reducing the voltage by 3 percent during peak load conditions would reduce peak demand by 2.1 percent to 2.4 percent.[137]

A few California utilities have conducted CVR pilots to gain a better understanding of the cost-effectiveness, perceived barriers, and methods needed to verify the project savings of a CVR. PG&E conducted a pilot CVR program, the Voltage and Reactive Power Optimization pilot, which ran from 2013 through 2016. PG&E lab tested and conducted a field trial of VVO software on 14 distribution circuits in and around Fresno. According to PG&E, the CVR benefits are tangible enough to be economically valued at this time. The CVR-specific benefits of the pilot include reducing energy consumption, line losses, and peak demand.[138] PG&E's VVO pilot offered a benefit-to-cost ratio of 1.5 to 2.7, making it an attractive means of driving conservation and affordability.[139]

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134 http://varentec.com/applications/energysavings/.

135 Varentec, Inc. 2018. *Comments on the Energy Commission Docket No. 18-IEPR-07: Doubling Energy Efficiency Savings.* https://efiling.energy.ca.gov/GetDocument.aspx?tn=223901.

136 Ibid. p. 3.

137 Ardis, Rob and Robert Uluski. August 26, 2015. "CVR Is Here to Stay." *T&D World.* http://www.tdworld.com/grid-opt-smart-grid/cvr-here-stay.

138 PG&E Advice Letter 4990-E. December 30, 2016. pp. 198-199. https://www.pge.com/tariffs/assets/pdf/adviceletter/ELEC_4990-E.pdf.

139 Ibid., p. 212.

PG&E plans to improve the accuracy of the benefit-to-cost ratio forecast by collecting and analyzing additional SmartMeter™ voltage data. PG&E performed a benefits forecast on roughly 3 percent of its system (33 banks) and extrapolated this to a larger scale. If it expands SmartMeter voltage data collection, a larger sample size can be used to reduce the extrapolation assumptions, providing a better estimate of benefits.[140] PG&E also plans to replace distribution supervisory control and data acquisition and adopt an advanced distribution management strategy in 2018.[141] PG&E plans to continue to investigate the benefits and deploy CVR using its patented volt/VAR approach.[142]

Glendale Water and Power also conducted a CVR pilot project, which involved 19 transformers and feeders in its program. Within the next two years, it expects to have a full-scale program controlling 38 transformers and 54 feeders. Average savings per feeder was 2.2 percent.[143] Glendale Water and Power mentioned concerns from its electric service staff that the system might harm load tap changers and increase maintenance costs; however, these outcomes did not materialize, and the utility intends to have a full-scale program in place in two years.[144]

SCE successfully demonstrated its Distribution Voltage and VAR (volt ampere reactive) Control Algorithm and System in about 40 percent of its distribution substations, which resulted in more than 2 percent energy savings in test circuits.[145] Assuming no action is taken by the customer, SCE estimates that for every 1 percent reduction in voltage, there is a 1 percent actual savings in avoided costs of energy procurement and capacity to the customer.[146] SCE considers its CVR program part of its initiative to meet the SB 350 doubling targets, in addition to its business plan.

There were no technical or regulatory barriers cited by the utilities that presented at the June 7, 2018, workshop. While a few years ago utilities were looking only to pilot technology selection, moving forward, they are looking at deployment strategies. The utilities that rolled out CVR pilot programs all plan to pursue larger demonstrations and refine the methods used in forecasting the benefits and costs of CVR deployment.

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140 PG&E Advice Letter 4990-E, December 30, 2016, p. 208; https://www.pge.com/tariffs/assets/pdf/adviceletter/ELEC_4990-E.pdf.

141 Presentation by Russ Griffith with PG&E at the June 7, 2018, IEPR workshop on Doubling Energy Efficiency Savings, https://efiling.energy.ca.gov/GetDocument.aspx?tn=223679.

142 Southern California Edison. Comments on the Energy Commission Docket No. 18-IEPR-07: Doubling Energy Efficiency Savings. June 21, 2018. https://efiling.energy.ca.gov/GetDocument.aspx?tn=223902.

143 Presentation by Michelle Nall with Glendale Water and Power at the June 7, 2018, IEPR workshop on Doubling Energy Efficiency Savings, https://efiling.energy.ca.gov/GetDocument.aspx?tn=223680.

144 Ibid.

145 Presentation by Bryan Pham with Southern California Edison at the June 7, 2018, IEPR workshop on Doubling Energy Efficiency Savings, https://efiling.energy.ca.gov/GetDocument.aspx?tn=223682.

146 Southern California Edison. Comments on the Energy Commission Docket No. 18-IEPR-07: Doubling Energy Efficiency Savings. June 21, 2018. https://efiling.energy.ca.gov/GetDocument.aspx?tn=223902.

GHG Emission Intensity Projections

California electricity supply consists of a diverse portfolio of generation resources with specific operating profiles, GHG emissions, and response capabilities that result in an electricity grid that has significantly different GHG emission intensities from one hour to the next. Quantifying GHG emission savings due to changes in California's demand, such as through energy savings from energy efficiency and additional loads from electric vehicles, depend highly on the future composition of projected electricity supplies. The Energy Commission uses production cost modeling simulations to calculate hourly projections of system average GHG emission intensities (also referred to as *GHG emission factors*). These simulations, performed using PLEXOS simulation software, provide hourly projections of generation, imports, and fuel use for the Western Electric Coordinating Council (WECC) region.

Method for Estimating GHG Emission Intensities

The method used to calculate the emission intensity projections from the hourly generation, imports, and fuel use for each region uses the U.S. Environmental Protection Agency (U.S. EPA) fuel-specific emissions factor. The system average emission intensity is calculated by dividing projected total emissions (metric tons) by projected generation (megawatt-hours). Hourly average emissions intensities are determined in the same way. This simple calculation is sufficient for generation and fuel use within California; however, California imports about 30 percent of the electricity necessary to meet loads. To project statewide hourly emission intensities, the emissions associated with the imported electricity must be included.[147]

The GHG emission profile for imported power from California's ownership shares of generators located in other regions of the WECC and renewable resources located outside California can be identified. In simulations, these known ownership shares are allocated to existing import (transmission) paths into California, thereby accounting for California ownership shares of imported energy by fuel type. Using the California Air Resources Board (CARB) fuel-specific GHG emission factors and assumed heat rates identified in the PATHWAYS tool, staff converted energy imports by fuel type to a GHG emission intensity.[148] The appropriate emission factor to associate with Renewables Portfolio Standard (RPS) imports is uncertain at this time. For this analysis, RPS imports

147 Simulations results for imports are in terms of energy only, meaning no fuel use projections are available for imported power.

148 See Table 32.
https://www.arb.ca.gov/cc/scopingplan/california_pathways_model_framework_jan2017.pdf.

are assumed to be 80 percent GHG-free, with the remaining 20 percent assigned the CARB unspecified emission factor.[149, 150]

The remaining imported energy in the simulation results are unspecified imports, which are further classified as Pacific Northwest unspecified imports or Southwest unspecified imports. Pacific Northwest unspecified imports are assumed to be 80 percent GHG-free to reflect hydroelectric imports, while the remaining 20 percent of imports are assigned the CARB unspecified emission factor. All Southwest unspecified imports are assigned the CARB unspecified emission factor. Table 2 provides the specific emission factor applied to each type of import described in this section.

Table 2: GHG Emission Intensity Rates (Metric Tons Carbon Dioxide [CO_2]/Megawatt-Hour [MWh])

Imports to California	GHG Emission Intensity Rate (Metric Ton/MWh)
From Pacific Northwest Region	0.085
From RPS Renewables	0.085
From Specified Natural Gas	0.402
From Palo Verde, Southwest Hydro	0
From Specified Coal	0.956
From Unspecified Imports	0.427
Exports Out of California	**GHG Emission Intensity Rate (Metric Ton/MWh)**
Exports	0

Source: California Energy Commission, Supply Analysis Office

Simulation Assumptions

The production cost simulation results used to calculate the average emission intensities are based on the *2017 IEPR* adopted mid demand scenario.[151] Key assumptions for these projections are shown in Table 3.

149 California RPS guidelines allow LSEs to meet their RPS mandate with a maximum of 10 percent portfolio content category 3 (unbundled renewable energy certificates) contracts and a portion of portfolio content category 2 (firmed and shaped renewable contracts). The remaining 5 percent of RPS imports are assumed to be portfolio content category 0 renewables that are renewable resources procured before June 1, 2010.

150 See Table 32, https://www.arb.ca.gov/cc/scopingplan/california_pathways_model_framework_jan2017.pdf.

151 https://efiling.energy.ca.gov/getdocument.aspx?tn=223244.

Table 3: *2017 IEPR* Modeling Assumptions

Key Variables	IEPR 2017 Production Cost Modeling Assumptions
California RPS Portfolio	By 2030, nearly 7,800 megawatts (MW) in-state and 5,400 MW out-of-state renewables added to achieve a statewide 50 percent RPS
Thermal Resource Retirement	Retire uncontracted resources if 40 years of age during the forecast period
California Net Export Constraint	4,000 MW– California cannot export 4,000 MW more than it is importing in any hour
Out-of-State Renewables to Meet California RPS	Eighty percent of RPS imports are assumed GHG-free, with remaining 20 percent incurring the 0.427 metric ton/MWh default rate.

Source: California Energy Commission, Supply Analysis Office

System Average Hourly Emission Intensity Projections

Hourly system average emission intensity projections using the *2017 IEPR* adopted mid demand simulation results and the method described above are shown in Table 4 and Table 5. Table 4 provides projections for 2019, and Table 5 provides them for 2030. Comparing Table 3 and Table 4 shows that hourly average midday projected values are declining more than the late night and early morning hours. The fall period shows the highest emission factor projections late at night and or early in the morning. This result is attributed to the decline in hydroelectric generation during those months, as well as ancillary service obligations met by a combination of natural gas and battery storage resources.

Table 4: Average System Emission Factor by Month and Hour (Metric Tons CO_2/MWh)

2019	1	2	3	4	5	6	7	8	9	10	11	12
1	0.24	0.23	0.21	0.20	0.20	0.20	0.25	0.27	0.27	0.26	0.26	0.26
2	0.24	0.23	0.21	0.20	0.20	0.20	0.25	0.26	0.27	0.26	0.26	0.26
3	0.24	0.22	0.21	0.20	0.20	0.20	0.24	0.26	0.27	0.26	0.26	0.26
4	0.24	0.22	0.21	0.20	0.20	0.20	0.24	0.26	0.27	0.26	0.26	0.26
5	0.24	0.22	0.20	0.18	0.19	0.20	0.25	0.27	0.27	0.26	0.26	0.26
6	0.23	0.22	0.19	0.18	0.18	0.19	0.25	0.27	0.27	0.25	0.26	0.25
7	0.22	0.21	0.19	0.18	0.18	0.18	0.24	0.26	0.27	0.25	0.25	0.25
8	0.22	0.21	0.19	0.17	0.17	0.17	0.22	0.25	0.26	0.25	0.24	0.24
9	0.21	0.18	0.16	0.15	0.15	0.15	0.20	0.21	0.22	0.21	0.21	0.21
10	0.18	0.15	0.14	0.13	0.14	0.14	0.19	0.19	0.21	0.19	0.19	0.19
11	0.18	0.14	0.13	0.13	0.13	0.13	0.18	0.19	0.20	0.18	0.19	0.17
12	0.17	0.14	0.13	0.13	0.13	0.13	0.18	0.19	0.19	0.17	0.19	0.17
13	0.17	0.14	0.13	0.13	0.13	0.13	0.17	0.19	0.20	0.17	0.19	0.18
14	0.18	0.15	0.13	0.13	0.13	0.13	0.16	0.18	0.20	0.18	0.19	0.18
15	0.19	0.16	0.14	0.13	0.13	0.13	0.16	0.18	0.20	0.19	0.21	0.20
16	0.22	0.18	0.15	0.14	0.13	0.13	0.16	0.17	0.19	0.20	0.23	0.23
17	0.21	0.21	0.17	0.15	0.13	0.13	0.16	0.17	0.20	0.21	0.22	0.22
18	0.20	0.19	0.17	0.15	0.13	0.13	0.16	0.18	0.20	0.20	0.22	0.22
19	0.21	0.19	0.17	0.14	0.14	0.13	0.17	0.19	0.21	0.21	0.22	0.22
20	0.21	0.20	0.17	0.15	0.14	0.14	0.18	0.20	0.23	0.22	0.23	0.22
21	0.22	0.21	0.18	0.16	0.15	0.15	0.20	0.22	0.25	0.24	0.24	0.24
22	0.24	0.22	0.20	0.17	0.16	0.16	0.22	0.25	0.27	0.26	0.25	0.25
23	0.25	0.23	0.20	0.18	0.18	0.17	0.24	0.27	0.28	0.27	0.27	0.26
24	0.25	0.23	0.21	0.19	0.19	0.19	0.25	0.27	0.27	0.26	0.27	0.26

Source: California Energy Commission

Table 5: Hourly Average System Emission Factor by Hour (Ton CO_2/MWh)

2030	1	2	3	4	5	6	7	8	9	10	11	12
1	0.22	0.22	0.19	0.16	0.14	0.14	0.21	0.25	0.25	0.23	0.22	0.23
2	0.22	0.22	0.19	0.16	0.15	0.14	0.22	0.25	0.25	0.23	0.22	0.23
3	0.22	0.21	0.19	0.16	0.15	0.15	0.22	0.25	0.25	0.23	0.22	0.23
4	0.21	0.21	0.19	0.16	0.14	0.14	0.22	0.25	0.25	0.23	0.22	0.22
5	0.21	0.21	0.18	0.14	0.14	0.14	0.21	0.24	0.24	0.22	0.22	0.22
6	0.20	0.19	0.17	0.14	0.13	0.14	0.21	0.24	0.24	0.22	0.21	0.21
7	0.19	0.19	0.17	0.14	0.14	0.14	0.20	0.23	0.24	0.22	0.20	0.21
8	0.19	0.18	0.16	0.11	0.09	0.09	0.14	0.16	0.20	0.20	0.18	0.20
9	0.13	0.11	0.10	0.09	0.08	0.08	0.11	0.13	0.13	0.12	0.11	0.13
10	0.11	0.09	0.09	0.08	0.08	0.08	0.10	0.11	0.12	0.10	0.10	0.11
11	0.10	0.09	0.09	0.08	0.08	0.08	0.10	0.11	0.11	0.10	0.10	0.11
12	0.10	0.09	0.09	0.08	0.08	0.08	0.10	0.11	0.11	0.10	0.10	0.10
13	0.10	0.09	0.09	0.08	0.08	0.08	0.10	0.11	0.11	0.10	0.10	0.11
14	0.10	0.09	0.08	0.08	0.08	0.08	0.11	0.12	0.12	0.10	0.10	0.11
15	0.11	0.09	0.08	0.08	0.07	0.07	0.12	0.13	0.13	0.10	0.11	0.12
16	0.16	0.11	0.09	0.08	0.08	0.08	0.13	0.15	0.15	0.13	0.17	0.18
17	0.19	0.18	0.13	0.09	0.09	0.09	0.14	0.16	0.17	0.16	0.18	0.19
18	0.17	0.17	0.15	0.12	0.10	0.10	0.14	0.16	0.17	0.16	0.17	0.17
19	0.17	0.16	0.14	0.11	0.10	0.10	0.15	0.17	0.18	0.16	0.17	0.18
20	0.18	0.16	0.14	0.12	0.11	0.11	0.16	0.17	0.19	0.17	0.18	0.18
21	0.18	0.17	0.15	0.12	0.11	0.11	0.17	0.19	0.20	0.19	0.18	0.19
22	0.20	0.19	0.16	0.13	0.11	0.11	0.17	0.20	0.22	0.21	0.20	0.21
23	0.22	0.21	0.18	0.14	0.12	0.12	0.18	0.22	0.24	0.23	0.21	0.22
24	0.22	0.21	0.19	0.15	0.13	0.13	0.20	0.24	0.25	0.23	0.22	0.23

Source: California Energy Commission

SB 350 Avoided Emissions

An important component of doubling the state's energy efficiency by 2030 is the resulting avoided GHG emissions. To approximate avoided GHG emissions because of electricity savings, staff converted the hourly emissions factors described above to annual emission intensities as shown in Table 6.

Table 6: Average Annual GHG Emissions Intensity From 2019–2029

Annual GHG Emissions (Ton CO_2 per MWh)	
2019	0.199
2020	0.193
2021	0.190
2022	0.186
2023	0.182
2024	0.174
2025	0.173
2026	0.180
2027	0.177
2028	0.174
2029	0.171

Source: California Energy Commission

To determine the avoided GHG emissions from natural gas efficiency, staff used the natural gas conversion factor from the U.S. EPA (0.0053 million metric ton CO_2 per million therms).[152]

The NRDC suggested in its comments that the Energy Commission should develop long-run marginal estimates instead of average emission intensities for calculating avoided emissions from doubling of energy efficiency.[153] Energy Commission staff is establishing a working group with stakeholders to develop appropriate methods for calculating avoided GHG emissions from avoided energy use.

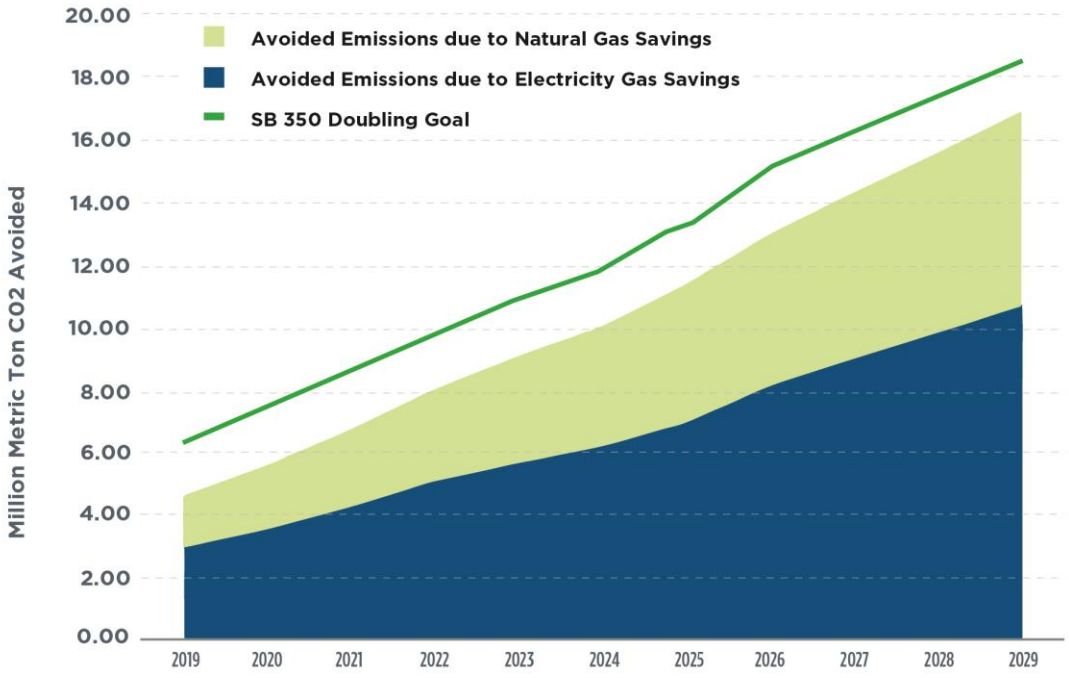
Converting Energy Efficiency Savings to Avoided GHG Emissions

Energy Commission staff converted the energy efficiency savings from the SB 350 Doubling Energy Efficiency by 2030 report to avoided GHG emissions using the emissions intensities described in the previous section. Figure 5 shows the SB 350 goals as avoided GHG emissions relative to the annual goal. This figure shows that additional savings are required for avoided GHG emissions projections to meet the 2030 goal.

152 United States Environmental Protection Agency, Energy and the Environment, https://www.epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references.

153 NRDC, June 22, 2018, Comments on the 2018 IEPR Commissioner Workshop on Doubling Energy Efficiency Savings, Docket Number 18-IEPR-07, June 7, 2018. https://efiling.energy.ca.gov/GetDocument.aspx?tn=223909.

Figure 5: Avoided GHG Emissions From Energy Efficiency Savings



Source: California Energy Commission

The Energy Commission will update energy efficiency estimates and the avoided GHG emissions in the *2019 IEPR*. As estimates of energy efficiency savings potential improve, the Energy Commission expects the gap between the projected avoided emissions and avoided emissions target will close. The Energy Commission will work to develop hourly energy efficiency estimates to match with hourly emission intensities described in this chapter.

Recommendations

- **Develop the Statewide Energy Efficiency Savings Action Plan.** The Energy Commission will develop and update biennially a new combined energy efficiency report called the Statewide Energy Efficiency Savings Action Plan. This report will combine the required updates under the overlapping energy efficiency targets that were established by Assembly Bill 758 (Skinner, Chapter 470, Statutes of 2009) and Senate Bill 350 (De León, Chapter 547, Statutes of 2015) and will begin the process of establishing explicit carbon reduction goals for buildings as called for by Assembly Bill 3232 (Friedman, Chapter 373, Statutes of 2018). (The full report for Assembly Bill 3232 is due January 1, 2021.) The new report is set to release by January 1, 2020, after a series of workshops across the state where staff will elicit feedback from stakeholders that will inform the final draft.

- **Track investor-owned and publicly owned utility energy efficiency program progress.** The Energy Commission will monitor and track the progress of investor-owned and publicly owned utility energy efficiency programs, which continue to target stranded potential energy savings opportunities. Any reported energy savings by program administrators must separate disadvantaged communities from nondisadvantaged communities using required and consistent metrics and indicators.
- **Develop a framework for measured energy savings.** The California Public Utilities Commission and the Energy Commission should develop best practices for evaluating and assessing behavior-related energy efficiency programs using interval meter data, where appropriate. In particular, develop a framework for using normalized metered energy consumption data when evaluating pay-for-performance and other programs that focus on measured energy and demand savings.
- **Track and expand program efforts in the industrial and agricultural sectors.** The Energy Commission will continue to track utility and nonutility program efforts to expand energy efficiency savings in the industrial and agricultural sectors. Acknowledge and remedy, to the extent possible, ratepayer program barriers to participation for these large, specialized utility customers.
- **Assist with outreach on conservation voltage reduction.** Conservation voltage reduction technology provides savings opportunities for energy efficiency gains within the distribution infrastructure. More effort is needed to create workforce alignment and other training and educational outreach to overcome the human-factor barriers perceived by the industry.
- **Update energy efficiency estimates.** Energy Commission staff will update energy efficiency estimates and the avoided greenhouse gas emissions in 2019. The hourly greenhouse gas emission intensities estimates suggest that energy efficiency programs can and should target the timing of energy efficiency savings.

CHAPTER 3: Increasing Flexibility in the Electricity System to Integrate More Renewable Energy

California's electricity sector has continued to make steady progress toward its energy and environmental goals. The electricity sector has achieved a 37.6 percent reduction in greenhouse gas (GHG) emissions *below* 1990 levels, driven largely by continued investment in and deployment of energy efficiency, increases in renewable generation, and reductions in imports of coal-fired electricity. Per-capita electricity consumption in California fell by more than 12 percent between 2008 and 2017 and is now 57 percent of the national level.[154] (See Chapter 2 for more information on energy efficiency.) In 2018, renewable generation such as wind, solar, geothermal, biomass, and small hydroelectric accounted for about 34 percent of the state's energy use.[155] In recent years, solar has been the fastest growing renewable resource and has represented the largest portion of renewable generation since 2017. Solar and wind generation together accounted for more than 69 percent of all renewable electricity generation in 2018, not including behind-the-meter or off-grid solar generation.[156]

Legislative initiatives have helped drive much of the growth of renewables in California's electricity sector. California's Renewables Portfolio Standard (RPS), enacted in 2002, has evolved to require increasing amounts of renewable resources in the state's electricity system. In 2015, Senate Bill 350 (De León, Chapter 547, Statutes of 2015) increased the RPS requirement from 33 percent to 50 percent by 2030. Senate Bill 100 (De León, Chapter 312, Statutes of 2018) sets a planning target of 100 percent renewable and zero-carbon electricity resources by 2045 and increases the 2030 RPS target from 50 percent to 60 percent.

The growth in renewable resources is a tremendous success story in California's efforts to reduce GHG emissions, but it is also fundamentally changing the electricity system and posing challenges for managing the grid. Grid operators need to manage the ramp-up of solar generation as it peaks at midday and then ramps down at sunset. At the end of the day, electricity demand remains high as Californians return home from work and continue to run their air conditioners, for example. Natural gas-fired generation that can quickly ramp up is the primary energy source to compensate for daily changes in solar and wind production. While many natural gas-fired power plants are retiring, and more

154 Energy Commission staff estimate based on Energy Information Administration data.

155 Energy Commission, Tracking Progress, Renewable Energy, updated December 2018, http://www.energy.ca.gov/renewables/tracking_progress/documents/renewable.pdf.

156 Ibid.

will need to retire for California to achieve deep reductions in GHG emissions, some continue to be needed to maintain grid reliability due to location, fast-ramping capabilities, and other characteristics.

As discussed in the *2017 Integrated Energy Policy Report* (*IEPR*), California must use a variety of tools to meet electricity demand when renewable energy is not available, and conversely, to use it when it is abundant. As then Governor Edmund G. Brown Jr. wrote in his signing statement for SB 100, "To get to 100 percent clean energy in a manner that ensures reliability and reduces cost, we must use a variety of strategies. Energy storage, increased efficiency, and adjusting energy use to the time of day when we have the most power will help with the transition. Additionally, we must join our neighbors in a power system that integrates utilities across the West."[157]

Senate Bill 100

Senate Bill 100, signed into law on September 10, 2018, codifies California's commitment to developing a near carbon-free electricity sector in support of reducing economy-wide GHG emissions by 80 percent from 1990 levels by 2050. The bill:

- Establishes 2045 targets for renewable energy procurement equal to 100 percent of retail sales to end users and 100 percent of electricity procured to serve state agencies and requires all state agencies to incorporate these targets into their relevant planning.
- Increases the state's RPS to an amount equal to 60 percent of retail sales to end-users by December 31, 2030, and raises interim procurement requirements by amounts consistent with this increase.
- Requires the California Public Utilities Commission (CPUC), Energy Commission, and the California Air Resources Board (CARB) to use programs authorized under existing statutes to achieve this policy and issue a joint report to the Legislature by January 1, 2021, and every four years thereafter, that includes specified information relating to the implementation of the policy.

The SB 100 reporting requirement requires analysis in upcoming *IEPRs*. A near-zero-carbon electricity sector will require continued integration of mature renewable generation technologies, very likely under higher-than-current load conditions, but also the development of resources such as renewable gas, including power-to-gas and renewable hydrogen. Staff discussed these resources and presented estimates of the related future costs in the *2017 IEPR* and will do so again in the *2021 IEPR* in support of the joint agency report to the Legislature.

This chapter focuses on updates to the *2017 IEPR* discussion on enhancing the resiliency of the grid while integrating increasing amounts of renewable energy.

California Continues to Dramatically Reduce GHG Emissions From the Electricity Sector

As discussed in Chapter 1, Senate Bill 32 (Pavley, Chapter 249, Statutes of 2016) sets a statewide goal to reduce California's GHG emissions 40 percent below 1990 levels by 2030, building on the Assembly Bill 32 (Núñez, Chapter 488, Statues of 2006) requirement to reduce GHG emissions to 1990 levels by 2020. While this is an economywide goal, in 2016 the electricity sector exceeded the 2020 goal and nearly met

157 Edmund G. Brown Jr., September 10, 2018, https://www.gov.ca.gov/wp-content/uploads/2018/09/SB-100-Signing-Message.pdf.

the 2030 goal. No other sector has made this much progress in reducing GHG emissions. In signing California's goal for 100 percent clean energy by 2045 into law, then-Governor Brown stated, "To truly stop global warming, cleaning up our electricity grid is not enough. We must transition to carbon neutrality and that will not be easy. It will require large investments across all sectors — energy, transportation, industrial, commercial and residential buildings, agriculture, and various forms of sequestration, including natural and working lands. California is committed to doing whatever is necessary to meet the existential threat of climate change."[158]

Changing Market for Renewable Energy

California's electricity market structure is fundamentally changing with the rapid growth of consumer choice. As more Californians make choices about where they get their electricity, such as installing rooftop solar and choosing to buy energy from community choice aggregators rather than their utility, California's framework for advancing renewable resources needs to be reexamined. The CPUC's *Draft Green Book: An Evaluation of Regulatory Framework Options for an Evolving Electricity Market*[1] states, "California was able to achieve rapid transformation in renewable technologies because of the requirements for utility contracting and incentives, which leveraged the incumbent utilities' ability to conduct competitive procurements for resources and their ability to borrow large sums of money cheaply from lenders. Investors were assured repayment over time by the CPUC's authority to grant cost recovery through transparent rate-setting procedures and a large universe of customers."

At the June 22, 2018, joint en banc on the Draft California Customer Choice, Pat Wood, former head of the Texas Public Utility Commission and former chair of the Federal Energy Regulatory Commission, described a changing model for renewable procurement. He stated that whereas 20-year contracts were a regular part of the RPS, they are now "a pipe dream of the past." Three- to five-year contracts are becoming the norm. Also, rather than contracting with utilities, renewable generators are contracting with customers such as WalMart, Target, military bases, and school districts.[1] Thus, instead of negotiating with one or two utilities, renewable generators must now work with a much larger number of potential entities — including various community choice aggregators and individual parties — to sell their power for a shorter time frame. This adds a new level of complexity and uncertainty to the renewables market.

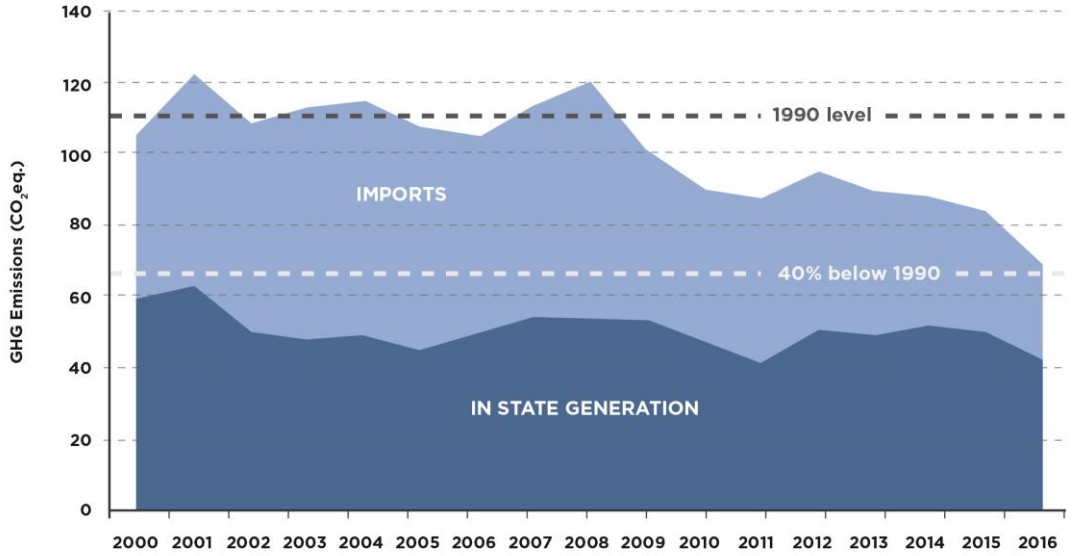
1 CPUC, *California Customer Choice – An Evaluation of Regulatory Framework Options for an Evolving Electricity Market, Draft Green Book*, May 2018, http://www.energy.ca.gov/2018_energypolicy/documents/2018-06-22_workshop/2018-06-22_documents.php.

Emissions from the electricity sector have decreased from 110.6 million metric tons in 1990 to 69.0 million metric tons in 2016, the most recent data available.[159] (See Figure 6.) As noted above, these reductions are due in large part to the development of renewable energy sources, which totaled almost 30,800 megawatts (MW) in California in 2018. (See Figure 7.) In the past five years, solar generation has increased by nearly 490 percent and behind-the-meter solar resources by approximately 310 percent. These generation estimates do not include 74 GWh from behind-the-meter wind resources. (See the sidebar for information about how the renewables market is changing.) A second contributing factor is reductions in coal-fired generation, which provided more than 37,200 GWh of energy in 2000 (15.7 percent of the state's needs) but only 12,000 GWh (4.1 percent) in 2017 and is expected to be essentially zero by 2026.

158 Edmund G. Brown Jr., September 10, 2018, https://www.gov.ca.gov/wp-content/uploads/2018/09/SB-100-Signing-Message.pdf.

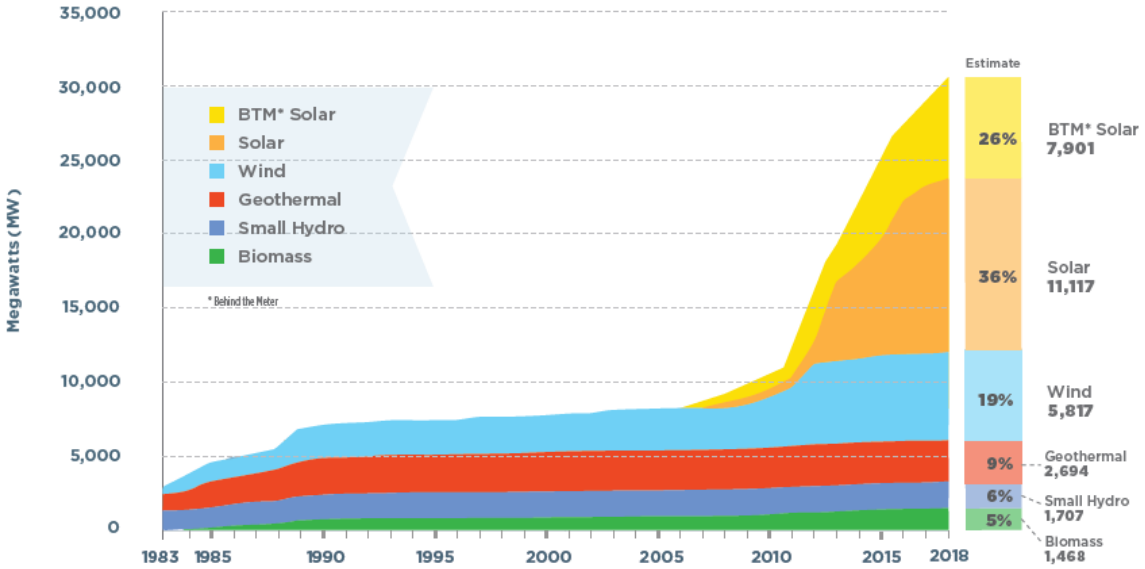
159 The hydropower generation was fairly typical in 2016, producing 28,977 GWh, which is the equivalent of about 93 percent of the average from 2001–2017.

Figure 6: GHG Emissions, California Electricity Sector, 2000–2016 (Million Metric Tons)



Source: California Energy Commission using data from CARB

Figure 7: Annual Cumulative Installed Renewable Capacity Since 1983 (Including Behind-the-Meter Solar)



Source: California Energy Commission, Tracking Progress, Renewable Energy, updated December 2018

As the cost of solar energy production has fallen, with utility-scale solar falling 78 percent since 2010[160] and similar cost reductions in behind-the-meter, California has increasingly relied on utility-scale and distributed solar energy to cost-effectively meet

160 U.S. Solar Photovoltaic System Cost Benchmark: Q1 2017 National Renewable Energy Laboratory, https://www.nrel.gov/docs/fy17osti/68925.pdf.

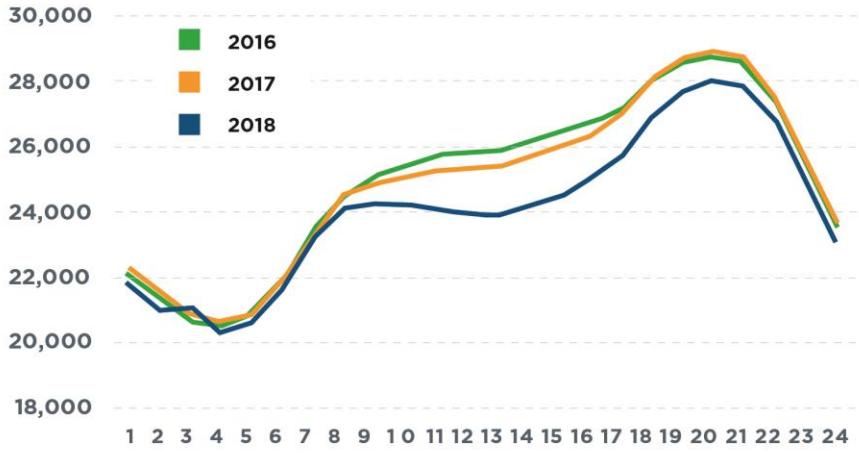
its RPS and GHG emissions reduction.[161] As discussed in Chapter 2, energy efficiency improvements have also played a critical role in reducing GHG emissions.

While reducing GHG emissions, California's economy continues to grow. Since 2010, California's gross domestic product has grown by 46 percent, while the rest of the country has experienced a 35 percent increase.[162] With these successes, California is pursuing further decarbonization of its electricity sector, which will continue to drive changes in how the grid is managed.

Update on System Performance and Infrastructure: 2017–2018

As discussed in the *2017 IEPR*, the state's increasing use of solar photovoltaic (PV) is changing hourly loads in California. Year-over-year changes in the California Independent System Operator's (California ISO's) average hourly loads for January through June are shown in Figure 8. The dip in midday load can be largely attributed to distributed solar PV additions.

Figure 8: Average California ISO Hourly Loads, January Through June 2016–2018 (Megawatts [MW])



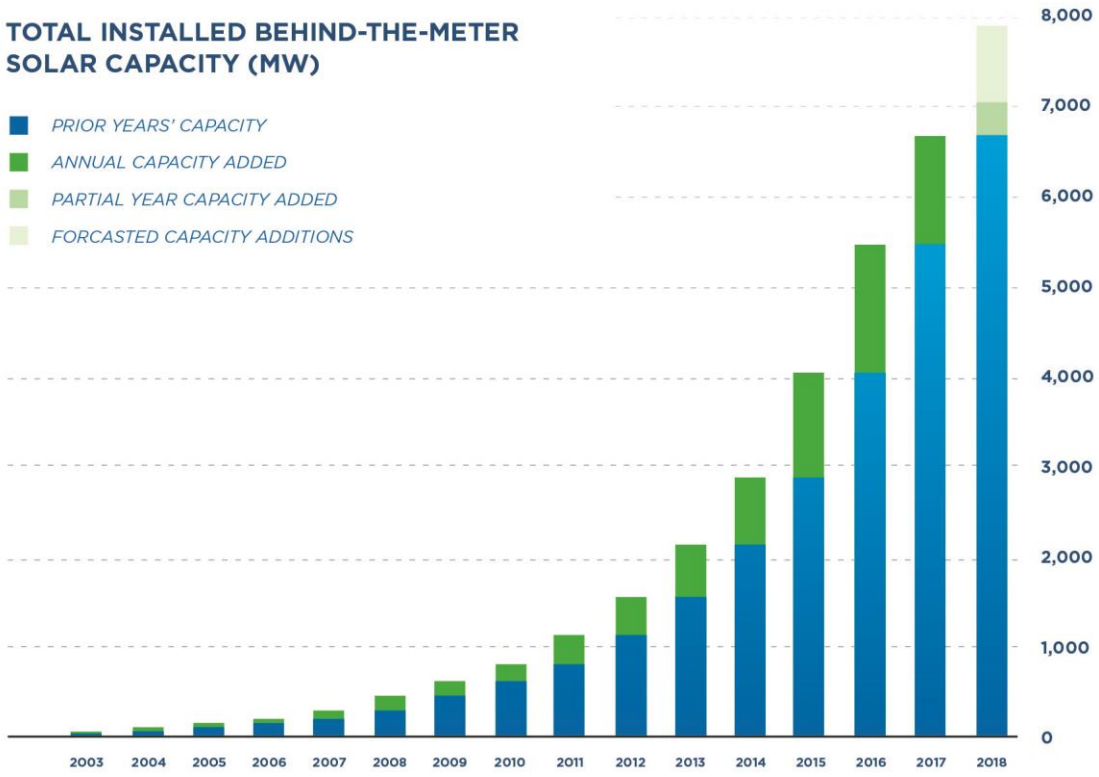
Source: California ISO

161 As of the end of 2018, about 17,470 MW of solar capacity interconnected on the utility side of the meter and almost 8,000 MW of behind-the-meter capacity serves California loads. Source: Energy Commission, Tracking Progress, Renewable Energy, updated December 2018, http://www.energy.ca.gov/renewables/tracking_progress/documents/renewable.pdf.

162 California Department of Finance and U.S. Bureau of Economic Analysis.

California continued to add behind-the-meter solar capacity in 2017. As illustrated in Figure 9 Californians installed 1,200 MW of behind-the-meter solar in 2017 and again in 2018, bringing the total installed to nearly 7,900 MW by the end of 2018.[163]

Figure 9: California Behind-the-Meter Solar Capacity (Cumulative)



Source: California Energy Commission, Tracking Progress, Renewable Energy Appendix, updated December 2018

Customer-sited solar installations in 2017 slowed slightly compared to 2015–2016. Installations in investor-owned utility (IOU) service territories totaled slightly more than 121,100, compared to more than 150,000 in each of the preceding two years, bringing total installations in the IOU service territories to more than 725,000.[164]

Solar additions on both sides of the meter continue to pose ramping and minimum net load[165] concerns for the California ISO. The changes in net load as solar is added to the system result in both an increase in the number of hours of overgeneration and the size of the morning and late afternoon/evening ramps. In the morning, resources that have provided energy overnight must ramp down quickly. In the evening, more energy is

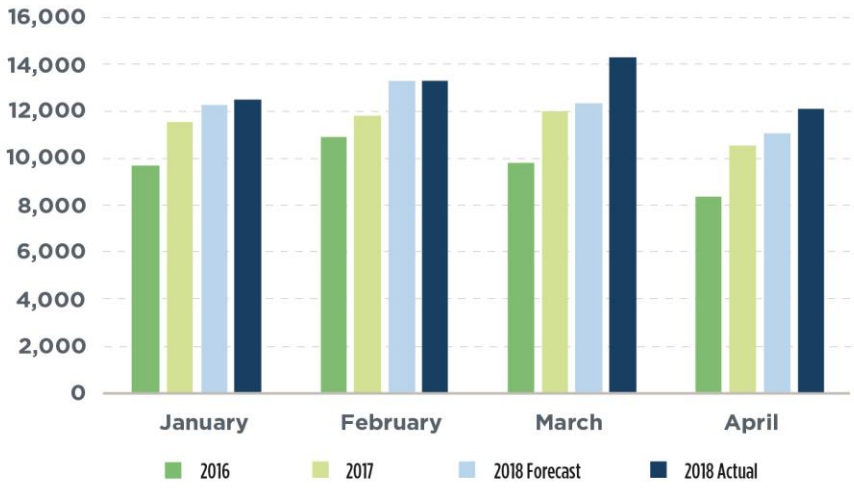
163 California Energy Commission, Renewable Tracking Progress Appendix, Appendix Figure 3, https://www.energy.ca.gov/renewables/tracking_progress/documents/renewable_appendix.pdf.
164 CPUC, *California Solar Initiative Annual Program Assessment*, June 2018, p. 14.

165 *Net load* is the amount of energy that must be provided net of wind and solar generation.

needed from other sources over a three-hour period as solar output falls dramatically, while loads remain largely unchanged or increase.[166]

As Clyde Loutan with the California ISO reported at the June 20, 2018, IEPR workshop on Renewable Integration and Electric System Flexibility, ramps and minimum loads are four years ahead of the California ISO's original estimates, largely due to the rapid growth in renewable generation.[167] Maximum monthly three-hour ramps between January and April 2018 substantially exceeded projections from the prior year in two of the four months, as seen in Figure 10.[168]

Figure 10: Maximum Monthly Three-Hour Upward Ramps, California ISO (MW)



Source: California ISO data

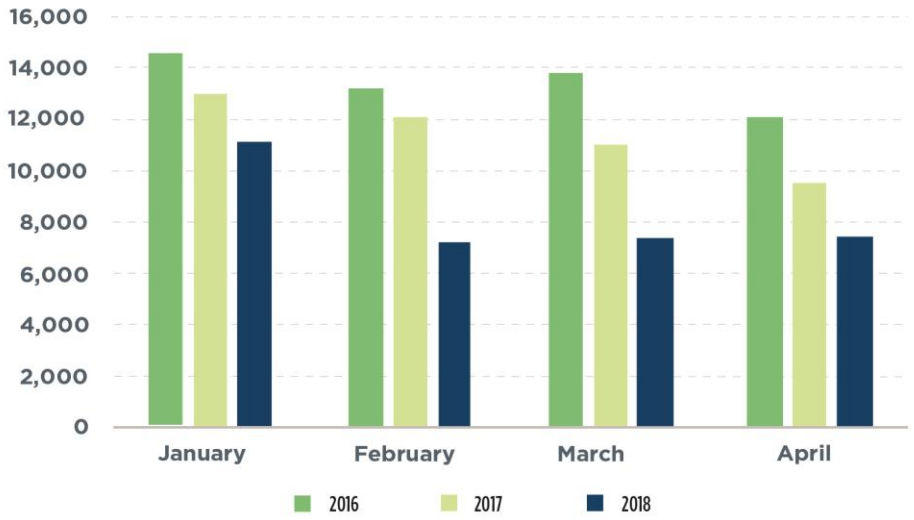
Managing increasing one- and three-hour upward ramps requires sufficient dispatchable generation, storage, and demand response capacity capable of starting and ramping up quickly. Minimum net loads are falling more quickly than expected, according to Mr. Loutan. The changes in minimum monthly net loads are presented in Figure 11.

166 These problems are illustrated with use of the "duck curve"; see *2017 IEPR*, p. 9, https://efiling.energy.ca.gov/getdocument.aspx?tn=223205.

167 Presentation by Clyde Loutan with the California ISO at the June 20, 2018, IEPR workshop on Renewable Integration and Electric System Flexibility, https://efiling.energy.ca.gov/GetDocument.aspx?tn=223856.

168 Based on hourly California ISO data; one-minute data would yield values slightly higher.

Figure 11: Minimum Monthly California ISO Net Loads, January Through April 2016–2018 (MW)



Source: California ISO data

The drop in minimum net loads contributes to negative market prices and renewable curtailment. Compared to 2016, renewable curtailment and the number of hours with negative prices in the California ISO increased substantially in the first five months of 2017. This increase was due to renewable additions and an increase in hydro generation serving the California ISO from 6,400 GWh in 2016 to more than 10,600 GWh in 2017.[169] In 2018, hydro generation returned to 2016 levels (6,700 GWh), which contributed to a reduction in the frequency of negative prices in the first four months of 2018. (See Table 7.)

Table 7: Percentage of Hours With Negative Prices, California Real-Time Market, January Through May 2017–2018

	2017	2018
January	6.58%	0.63%
February	13.67%	3.28%
March	21.19%	8.97%
April	14.86%	5.32%
May	6.93%	9.61%

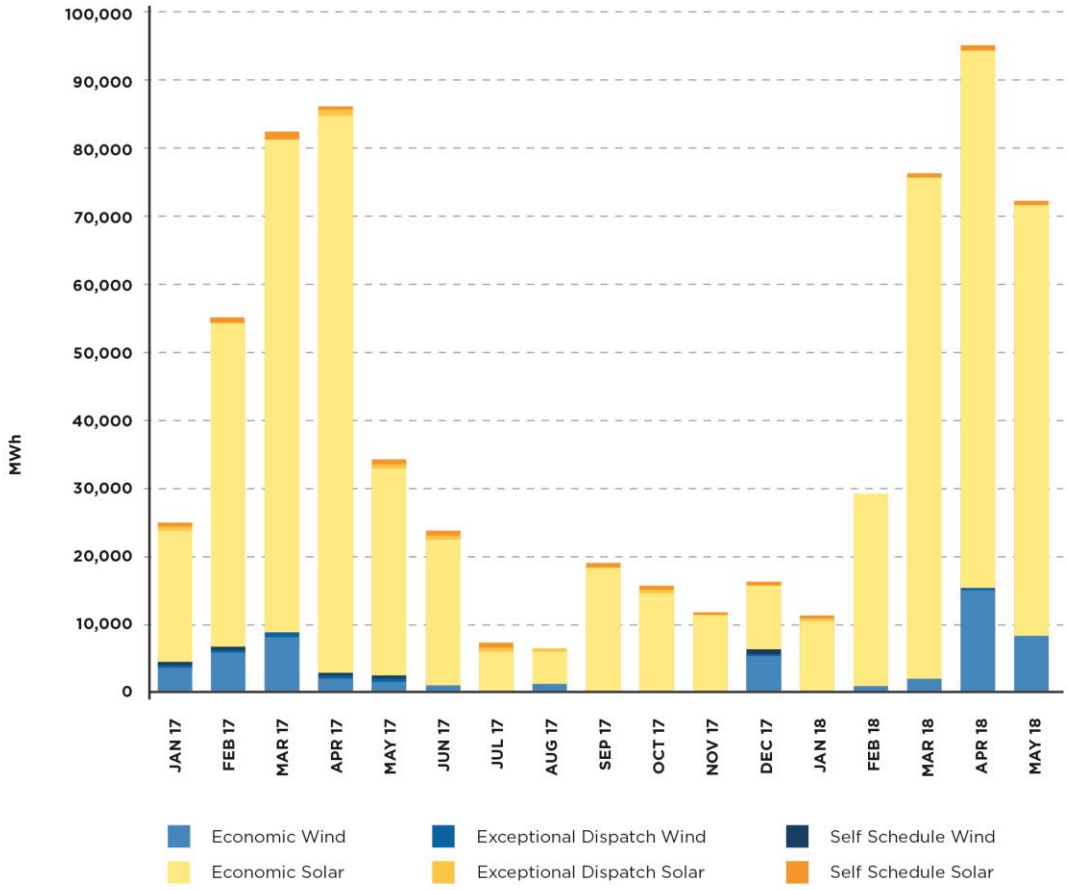
Source: California ISO Monthly Market Performance Reports

Renewable curtailment is greatest in the spring. Curtailment remained at 2017 levels in the first five months of 2018, exceeding those levels in April and May. (See Figure 12.)

169 Negative prices and renewable curtailment are highest in February–April, when loads are moderate, hydroelectricity in California and the Pacific Northwest are relatively abundant, and the number of hours of sunlight is increasing from December lows.

(For a discussion of incorporating curtailment provisions into contracts, see "Curtailment Provisions in Utility-Scale Variable-Energy Resource Contracts" below.)

Figure 12: Renewable Curtailment by Resource Type, January 2017 to May 2018

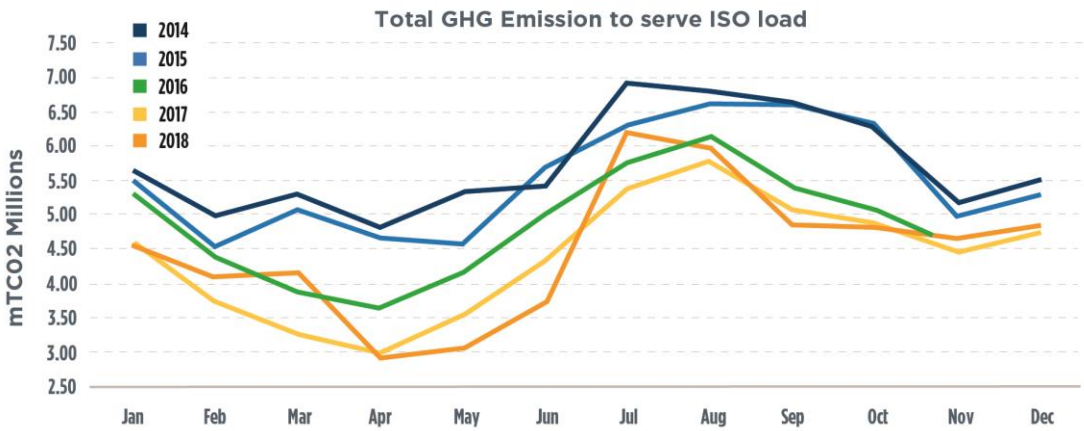


Source: California ISO, Monthly Market Performance Report, May 2018

While GHG emissions from the electricity sector are falling overall, short-run changes may be affected by one-time events or transient conditions. For example, sector emissions increased in 2012 due largely to the sudden loss of the San Onofre Nuclear Generation Station and the need to replace it with energy from natural gas-fired plants. (See Chapter 6 for information on related energy reliability issues.) Figure 13 shows that GHG emissions in the California ISO service area in the fourth quarter of 2017 and first quarter of 2018 were higher or unchanged from a year earlier; this was due in large part to intertie derates (reducing the amount of energy that can be imported) and, in early 2018, lower hydro availability. In May and June, sector emissions resumed the downward trend, as year-over-year reductions in hydro availability (roughly 1,600

average MW) were more than offset by decreases in net load (1,975 average MW and 2,450 average MW in May and June, respectively.)[170] In July, however, the year-over-year decrease in hydro generation (1,400 average MW) was greater than the decrease in net load (580 average MW), contributing to an increase in thermal generation of 1,800 average MW and GHG emissions exceeding 2017 levels.

Figure 13: California ISO GHG Emissions, (2015 to December 2018)



Source: California ISO

The California ISO has experienced more difficulty in meeting control performance standards of the North American Electric Reliability Corporation (NERC) in the past year. According to Mr. Loutan, increased uncertainty regarding energy from variable energy resources (VER) during morning and evening ramps is making it more difficult for the California ISO to respond accurately to deviations in system frequency.[171] One way the California ISO is addressing this challenge is by improving its forecasting capabilities. For example, it now forecasts output from variable energy resources using actual output nine minutes before real time, rather than 15 to 20 minutes before real time, improving forecast accuracy.

170 Data from the California ISO.

171 NERC is a non-profit corporation established by the electric utility industry to promote the reliability of the bulk transmission system and is responsible for developing standards for power system operation, monitoring and enforcing compliance with those standards, and assessing resource adequacy. NERC requires that balancing authorities demonstrate a threshold ability to support system frequency, and not be under- or overgenerating when the frequency is below and above 60 Hertz (Hz), respectively.

Generation Additions, Retirements, and Resource Adequacy

Retirements Since July 2017

As shown in Table 8, almost 2,900 MW of summer peak natural gas-fired generation capacity retired between July 1, 2017, and December 31, 2018, all within the California ISO service territory.

Table 8: Generation Plant Retirements, July 2017 to December 31, 2018

Plant/Units	Fuel	Peak MW	Retirement Date
San Joaquin Cogen	Natural Gas	43	7/19/2017
Broadway 3	Natural Gas	65	8/3/2017
Zond Windsystems	Wind	8	8/24/2017
Graphic Packaging Cogen	Natural Gas	24	12/30/2017
King City Energy Center	Natural Gas	39	12/31/2017
Wolfskill Energy Center	Natural Gas	41	12/31/2017
Kearney GT3	Natural Gas	61	1/9/2018
Mandalay 1-3	Natural Gas	560	2/15/2018
Etiwanda 3-4	Natural Gas	640	6/1/2018
Bell Bandini Commerce Refuse	Biomass	10	6/30/2018
Tracy Biomass	Biomass	5	8/29/2018
Encina Units 1-5	Natural Gas	859	12/12/2018
La Paloma Units 3-4*	Natural Gas	516	12/21/2018
North Island	Natural Gas	36	12/31/2018
Division Naval Station	Natural Gas	44	12/31/2018
NTC/MCRD Cogeneration	Natural Gas	20	12/31/2018
Total		**2,891**	

Source: California ISO Market Notice, January 10, 2019, * Postponed, may return to service

More than 1,200 MW is expected to retire in 2019, as presented in Table 9.

Table 9: Expected Generation Plant Retirements, 2019

Plant/Units	Fuel	Peak MW	Retirement Date
La Paloma Units 1-2*	Natural Gas	520	2/20/2019
Greenleaf 1*	Natural Gas	47	3/11/2019
Calpine American Cogen	Natural Gas	87	5/1/2019
Redondo Beach Unit 7	Natural Gas	344	10/31/2019
Huntington Beach Unit 1	Natural Gas	226	10/31/2019
Total		**1,224**	

Source: California ISO Market Notice, January 10, 2019, *Proposed for postponement, may return to service

With the exception of Calpine American Cogen, the 2019 retirements are conditional upon the California ISO finding that the units are not needed for reliability. (The

Huntington Beach retirement is conditional upon completion of replacement capacity being constructed onsite.)

Utility-Scale Generation Additions Since July 2017

California continues to add utility-scale generation, almost all of which is renewable. As shown in Table 10, 59 of the 73 projects added since July 1, 2017, through December 2018, are solar photovoltaic (1,339 MW), with three of them combusting natural gas (557 MW).

Table 10: Utility-Scale Generation Additions in California From July 2017 Through December 2018

	< 20 MW		≥ 20 MW		Total	
Technology	**Number**	**MW**	**Number**	**MW**	**Number**	**MW**
Solar	36	107	23	1232	59	1,339
Wind	3	5	3	306	6	311
Biofuel	3	3	2	55	5	58
Natural Gas	1	4	2	553	3	557
Total	**43**	**119**	**30**	**2,146**	**73**	**2,265**

Source: California Energy Commission

Resource Adequacy

The *2017 IEPR* reported on the risk of natural gas power plant retirements due to insufficient revenues and the need for market mechanisms to ensure that any necessary flexible gas-fired units remained operational. Natural gas plants without a capacity contract, which have generally been merchant facilities that exceed resource adequacy needs, are often incapable of earning revenues sufficient to meet going-forward capital costs and are thus at risk of retirement. While generation from natural gas plants will fall as renewable resources are developed to meet the state's GHG emissions reduction goals, at least some fast-ramping natural gas-fired generation capacity remains necessary in the near term to meet local reliability needs and to ensure sufficient flexibility exists to meet demand as solar production falls off in the late afternoon and early evening.

At the *2018 IEPR Update* workshop on June 20, 2018, Michelle Kito of the CPUC reported that the CPUC's Resource Adequacy (RA) program has come under increasing strain in the past year. Historically, the markets for local RA have been competitive with prices offered for local RA, reflecting the cost of its provision. Market power mitigation for local RA has become increasingly necessary; however, 11 of the 27 load-serving entities subject to year-ahead RA showings filed waivers with the CPUC for 2018 (compared to two filings in total in all previous years), claiming that capacity was not available at competitive prices. The California ISO is increasingly providing "backstop" contracts; for example, in 2018 these were awarded to six units (totaling more than 1,700 MW) at an average cost of more than $6.68/kW. This compares to bilateral local RA contracts, under which 85 percent of local capacity in each area was procured for $2.50–$4.43/kW.

Contracting for system RA capacity beyond the required one year ahead has also fallen, due in part to substantial and increasing uncertainty regarding the migration of load from IOUs to community choice aggregators (CCAs). (See Chapter 7 for information about changes in the Energy Commission's energy demand forecast in support of RA.)

To address the potential near-term retirement of generators needed for maintaining system and local reliability, the CPUC has authorized the IOUs to negotiate RA contracts for 2019 and longer with any generators who submit retirement notices to the California ISO. SCE has been authorized to contract with the owner of the Ormond Beach and Ellwood units for 2019, as the California ISO has found these resources necessary for local reliability.

For 2020 and beyond, the CPUC has issued a proposed decision[172] which would require a three- to five-year-forward local RA requirement, with all needed local RA capacity to be purchased through competitive solicitation by a single central buyer — the distribution utility — in each of the three transmission access charge areas.[173] The buyer would purchase 100 percent of the local RA capacity needed in the next two calendar years and 80 percent of the capacity needed in the third year, as estimated in the California ISO's annual local capacity technical analyses.[174] If the decision is adopted, the performance of this mechanism for multiyear procurement of local RA will be monitored to inform discussions of its being expanded to include system and flexible RA capacity procurement.

Day-Ahead Market Enhancements Initiative

The California ISO's Day-Ahead Market Enhancement consists of two phases:

- Phase 1 will change the day-ahead scheduling granularity from one hour to 15 minutes and allow 15-minute interval bidding into the day-ahead and real-time markets.
- Phase 2 will examine two alternative market designs to deliver improved efficiency of day-ahead market solutions and increased reliability.

The California ISO posted a revised proposal for 15-minute scheduling on August 27, 2018, and held a stakeholder call on September 4, 2018. Increased granularity is intended to encourage market participation by reducing risks for sellers while allowing the California ISO to better handle intrahour and day-ahead uncertainty with respect to ramping needs.

172 Issued in R.17-09-020 on November 21, 2018, the CPUC tabled consideration of the decision at its meeting on January 10, 2019, and placed it on the agenda for its meeting on February 21, 2019.

173 These areas correspond to the PG&E, Southern California Edison (SCE), and SDG&E service territories.

174 Each year the California ISO performs these analyses to estimate local RA capacity needs for the following year and five years out. The year-ahead study will inform local capacity requirements for the first two years; the five-year study will inform the third year requirement.

The California ISO announced, during a Phase 2 working group meeting on November 30, 2018,[175] that a new course was required following a determination that the previous focus of Phase 2, combining the optimization of the integrated forward market and residual unit commitment process,[176] was infeasible. While a day-ahead ramping product to address uncertainty between the day-ahead and real-time markets remains a design objective, much work remains before stakeholders are able to engage effectively in a complex market design assessment.

Flexible Resource Adequacy Products

During 2018, the California ISO continued revising its Flexible Resource Adequacy Criteria and Must-Offer Obligation–Phase 2 program, in which it pays generators for providing capacity quickly on a standby basis. It also pays for capacity that has the flexibility to start up and shut down relatively rapidly. It released a draft framework proposal in spring 2018 and responded to initial stakeholder comments. Proposed changes would result in flexible RA products that more closely align with opportunities for market dispatch. The California ISO has proposed three flexible RA products:

- 5-minute dispatchable flexible capacity
- 15-minute dispatchable flexible capacity
- Day-ahead ramping range capacity

In June 2018, the California ISO posted a draft final proposal, which was also submitted as a proposal in the CPUC's RA proceeding.[177] In July 2018, the California ISO issued a market notice recognizing that challenges in the Day-Ahead Market Enhancements initiative would force a deferral of the Flexible Resource Adequacy Criteria and Must-Offer Obligation — Phase 2 initiative.[178]

Update on Grid Regionalization

Regional coordination is a key component of California's strategy for realizing its renewable energy and GHG emission reduction goals. Much of this coordination follows naturally from peak load diversification; the Northwest peaks in winter, and the rest of the West in summer, allowing each region to rely on the other for a share of its peak

175 The California ISO presentation is available at http://www.caiso.com/Documents/Presentation-Day-AheadMarketEnhancementsPhase2-Nov30-2018-withpresentation.pdf.

176 In its integrated forward market process, the California ISO simultaneously clears the day-ahead markets for energy and ancillary services (various reserves needed for reliability) based on supply and demand bids. If the markets clear at values less than the California ISO forecast of needed energy and capacity, the California ISO has to *subsequently* procure additional resources through its residual unit commitment process, in advance of the real-time markets.

177 See California ISO's Proposals for Modifications to the Resource Adequacy Program pursuant to Scoping Memo and Ruling dated January 18, 2018, filed in R.17-09-020 on February 26, 2018, available at http://docs.cpuc.ca.gov/publisheddocs/published/g000/m216/k633/216633681.pdf.

178 See the California ISO notice at http://www.caiso.com/Documents/FlexibleResourceAdequacyCriteriaandMustOfferObligationsPhase2InitiativeDelayed.html.

capacity needs. Regional coordination also provides for geographic diversification in renewable energy, allowing for more consistent supply. The *2017 IEPR* identified several undertakings that will result in the more efficient use of renewable and zero-carbon energy across the western grid, improve reliability, and reduce carbon emissions and costs.

In 2018, a legislative proposal to address grid regionalization (Assembly Bill 813) failed to pass in the California Legislature. At its September 5, 2018, board of governors meeting, the California ISO noted that this was a "missed opportunity."[179] The California ISO went on to state that grid regionalization is critical to supporting additional renewable resource development, lowering costs, increasing grid reliability, and achieving grid decarbonization. Despite this setback, the state will continue to advocate for grid regionalization.

Western Energy Imbalance Market

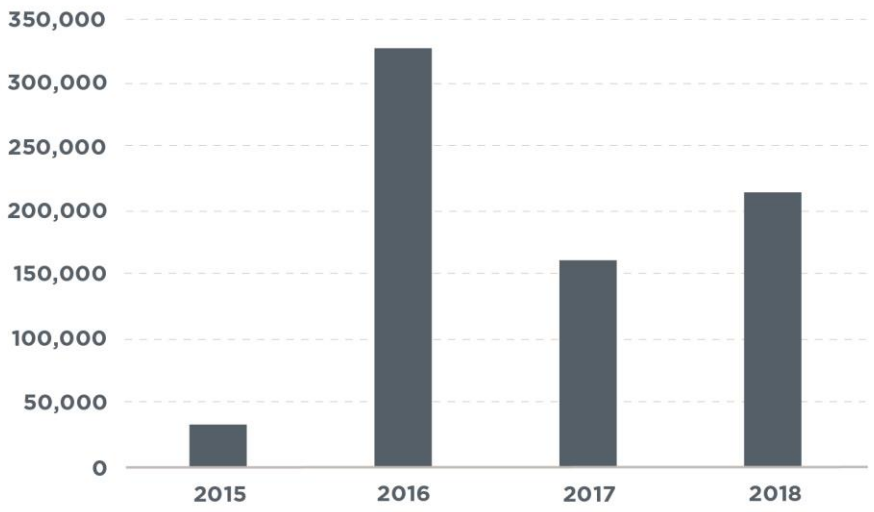
Idaho Power and Powerex[180] (British Columbia) joined the Western Energy Imbalance Market (Western EIM)[181] in April 2018, bringing the number of out-of-state balancing authorities to seven. One benefit of the Western EIM is that excess renewable energy in the California ISO balancing area can be transferred to other areas in real time, reducing renewable curtailment and GHG emissions. Figure 14 illustrates annual reductions in renewable curtailment attributable to the Western EIM.

179 https://im.csgsystems.com/cgi-bin/confCast.

180 Powerex is the first Western EIM entry participating as a marketer rather than a balancing authority.

181 The Western EIM, established in 2014 and operated by the California ISO, is a real-time bulk power trading market, which meets customer demand with the least-cost generation across its participating balancing authorities.

Figure 14: Annual Avoided Renewable Curtailment due to Western EIM (MWh)



Source: California ISO, 2018 data as of September 30, 2018

Reductions in renewable curtailment in 2018 exceeded those for 2017; total reductions through December 31, 2018, since 2015 exceed 757,000 MWh. Associated reductions in GHG emissions are more than 324,000 metric tons CO_2e.[182]

Table 11 illustrates the gross benefits associated with the Western EIM since its inception. Annual benefits increase each year as more balancing authorities participate; total gross benefits exceed $564 million through the end of 2018.

Table 11: Gross Benefits of Western EIM (Million $US)

Balancing Authority	2014	2015	2016	2017	2018	Total
Arizona Public Service			$5.98	$34.56	$45.30	$85.84
California ISO	$1.24	$12.66	$28.34	$36.96	$67.94	$147.14
Idaho Power					$26.88	$26.88
NV Energy		$0.84	$15.57	$24.20	$25.55	$66.16
PacifiCorp	$4.73	$26.23	$45.47	$37.41	$61.68	$175.52
Portland Gen'l Electric				$2.83	$27.57	$30.40
Powerex					$7.84	$7.84
Puget Sound Energy			$1.56	$9.86	$13.68	$25.10
Total	**$5.97**	**$39.73**	**$96.92**	**$145.82**	**$276.44**	**$564.88**

Source: California ISO, https://www.westerneim.com/Pages/About/QuarterlyBenefits.aspx

182 *Western EIM Benefits Report, Fourth Quarter 2018*, California ISO, January 31, 2019, pp. 14-15. GHG emissions reductions are based on an emissions factor for energy displaced by additional renewable generation of 0.428 metric tons CO_2e per MWh.

The Balancing Authority of Northern California plans to join the Western EIM in spring 2019. The Los Angeles Department of Water and Power (LADWP) has stated that a spring 2020 joining may be delayed. Seattle City Light and the Salt River Project (Arizona) plan to join in spring 2020.[183] Northwestern Energy plans to join in spring 2021. The Public Service Company of New Mexico also plans to join in spring 2021. Furthermore, the Bonneville Power Administration (BPA)[184] is also considering joining the Western EIM, as discussed below. Assuming all these entities join as noted, in 2022 the balancing authorities participating in the Western EIM will account for more than 70 percent of the load in the Western Electricity Coordinating Council.

Bonneville Power Administration Collaboration With California

On February 15, 2018, the Energy Commission and CPUC formally requested that the California ISO's 2018–2019 planning process include a study of options for increasing the transfer of low-carbon electricity between the Pacific Northwest and California. The aim is to evaluate the potential for addressing reliability issues in the Greater Los Angeles Area arising from the phase-out of the Aliso Canyon natural gas storage facility. (See Chapter 6 for more information about Aliso Canyon and related reliability issues in Southern California.) Public comments on a draft scope were received April 26, 2018, and the final study plan was issued May 23, 2018. As reported by Mr. Millar at the June 20, 2018, IEPR workshop, the scope includes:

- The potential for increasing the transfer capacity of the alternating current (AC) and direct current (DC) interties (the major high-voltage transmission lines that connect California with the Pacific Northwest), including a near-term increase in the north-south direction of the AC intertie from 4,800 MW to 5,100 MW, and addressing operational limits on the DC intertie in the south-north direction.
- Assessing the costs and benefits of increasing the dynamic transfer limit on the AC intertie from the 600 MW recently implemented by BPA.[185]
- Automating manual controls on BPA infrastructure to promote subhour scheduling.
- Reviewing historical availability of import capacity and constraints on Pacific Northwest hydroelectric generation to assign resource adequacy value to firm zero-carbon imports.

183 As reported by Neil Millar with the California ISO, Baja California's Centro Nacional de Control de Energía (CENACE) is exploring joining the EIM.

184 The Bonneville Power Administration is a nonprofit federal power marketing administration in the Pacific Northwest. Although it is part of the U.S. Department of Energy, it is self-funded and covers its costs by selling its products and services. BPA markets wholesale electrical power from 31 federal hydroelectric projects in the Northwest, one nonfederal nuclear plant, and several small nonfederal power plants. BPA provides about 28 percent of the electric power used in the Pacific Northwest and operates and maintains about three-fourths of the high-voltage transmission in its service territory. https://www.bpa.gov/news/AboutUs/Pages/default.aspx.

185 On June 11, 2018, BPA increased its limit on dynamic transfers from 400 to 600 MW, effective July 1, 2018. https://bpa.gov/transmission/Doing%20Business/bp/Redlines/Increasing-DTC-on-NWACI.pdf.

Preliminary results on this informational special study were presented at the November 26, 2018, California ISO 2018–2019 Transmission Planning Process Stakeholder Meeting. The California ISO reported to its transmission planning process stakeholders that preliminary studies have not revealed any significant barriers to increasing AC intertie capacity on either near-term or long-term bases. In addition, the studies show that opportunities exist to increase dynamic transfer capability on the AC intertie and potentially even remove all dynamic transfer limits. The California ISO noted that additional analyses by BPA and LADWP will be needed to assess the feasibility of sub-hourly scheduling on the Pacific Direct Current Intertie. The California ISO concluded its report with a summary of the process for securing imports from RA resources and identified several potential barriers to higher levels of RA contracting between California ISO load serving entities and Pacific Northwest hydro resources. The barriers included procedural timelines that do not align with capacity commitment and contracting decision points along with market preferences in the wholesale energy and bulk transmission markets. The results will be included in the *Draft 2018–2019 Transmission Plan*, which will be posted on January 31, 2019.[186]

At the June 20, 2018, workshop, Doug Marker with the BPA restated its commitment to work with the California ISO and other stakeholders on market redesign issues, including the development of flexible capacity products that would encourage the Pacific Northwest to provide hydroelectricity in the California ISO's day-ahead market. These products would compensate hydro asset owners for the capacity value of their resources, while giving California access to firm, flexible generation that reduces the need for instate variable energy resources and eases the integration of energy procured from the Pacific Northwest.

BPA's *2018 Integrated Program Review*[187] includes grid modernization efforts that will promote greater regional coordination. These efforts include greater and longer-term regional coordination for planned and unplanned outages of generation or transmission, as well as modernization of generation control, to allow a more efficient dispatch. Improved metering capabilities will allow customers to schedule on a 15-minute basis, which will, in turn, align transmission products and services with western markets and allow for dynamic scheduling on the DC Intertie. In addition, the following grid modernization projects for the 2020 fiscal year are intended specifically to allow BPA to join the Western EIM should it decide to do so:

- Develop the capability to submit bid curves to the Western EIM that meet market requirements and timelines.

186 For more information, see http://www.caiso.com/planning/Pages/TransmissionPlanning/2018-2019TransmissionPlanningProcess.aspx.

187 Performed biennially, a summary of the *2018 Integrated Program Report* is available at https://www.bpa.gov/Finance/FinancialPublicProcesses/IPR/2018IPR/IPR%202018%20Grid%20Mod%20Final%20Appendix.pdf.

- Develop the ability to receive and process Western EIM market awards, process them to represent specific generation dispatches, and integrate those dispatches into BPA's automatic generation control system.
- Develop and implement interfaces to supply planned transmission and generation outages from BPA's outage management system(s) to the California ISO's Outage Management System. These interfaces will provide the California ISO information needed to manage the Western EIM if BPA becomes a member.
- Implement changes to systems, processes, and practices to carry out the real-time and near real-time interactions necessary to participate in the Western EIM market.

These projects will be cancelled if BPA decides not to join the Western EIM. BPA held the first of several stakeholder workshops on the possibility of joining the Western EIM on July 24, 2018. Major issues that BPA is reviewing include:

- Treatment of transmission.
- Generation participation model alternatives.
- Governance.
- Relationship of the Western EIM to other emerging markets.
- Balancing authority resource sufficiency.
- Market power.
- Western EIM settlements.
- Carbon obligation.

At its second stakeholder workshop on October 11, 2018, BPA provided updates on three issues (treatment of transmission, generation participation model alternatives, and governance). The November 14, 2018, stakeholder meeting covered timeline/process issues and local market power mitigation. The next stakeholder meeting is scheduled for December 18, 2018. Should BPA decide to join the Western EIM, the projected implementation date is April 2022.[188]

Update on Solar Integration and Performance

Increasing reliance on utility-scale solar generation has been made possible by cost decreases and numerous advances in technology, performance requirements, cointegration with storage, and incorporation of curtailment provisions into power purchase agreements. A variety of tools are available to help integrate increasing

188 For more information, see https://www.bpa.gov/Projects/Initiatives/EIM/Pages/Energy-Imbalance-Market.aspx.

amounts of solar generation, including advances in inverters and energy storage and time-of-use rates, demand response, and flexible plug-in electric vehicle charging.[189]

Advances in Inverters Provide Reliability

Increasing dependence on variable energy resources for energy and capacity has been accompanied by technological advances in inverters,[190] which enable these resources to provide additional advanced reliability. At the June 29, 2018, IEPR workshop, Mr. Loutan reported that the California ISO continues to work with existing solar PV generators to demonstrate the ability of these devices to provide regulation, voltage control, frequency response, and inertia and is testing a 131 MW wind facility for these services in 2018.

Developing Standards for Transmission-Level Interconnected Inverter-Based Resources

As reported in the *2017 IEPR*, disturbances — or *line faults*[191] — resulted in up to 1,178 MW of transmission-level inverter-based resources tripping off-line on four occasions on August 16, 2016.[192] Since that date, there have been nine more events, the latest on April 20, 2018. While these transmission line faults have cleared very quickly, none of them should have caused inverters to trip. The California ISO and SCE brought this problem to the attention of NERC and WECC in January 2017. In June 2017, a NERC alert called for a review of existing inverters to better understand whether an otherwise inconsequential voltage change would trigger the inverter to disconnect the generator from the grid rather than "ride through" the change. In response, the California ISO worked with generators to use settings that minimized the likelihood of tripping and associated reliability problems.[193]

The California ISO held a stakeholder workshop on July 24, 2017, where participants agreed that NERC should require the development of standards specifically for inverter-based resources interconnected at the transmission level. Generator owners typically specify inverters to comply with existing national and state standards for inverters

189 For a discussion, see Lazar, Jim. January 2014. *Teaching the "Duck" to Fly*, Regulatory Assistance Project. Available at http://www.raponline.org/wp-content/uploads/2016/05/rap-lazar-teachingducktofly-2014-jan.pdf.

190 An *inverter* is an electronic device or circuitry that converts power from a direct current (DC) source (such as solar panels or a wind turbine) to alternating current (AC), so that it can be moved over the transmission and distribution system and be used by consumers.

191 Transmission lines carry normal levels of voltage and current. A *line fault* is a change in these levels that must be restored to normal values to ensure the reliable operation of the system.

192 Such tripping is also referred to as "momentary cessation." Inverter terminal voltage falls to a level that results in real and reactive power output falling to zero until the terminal voltage recovers, at which point power output is restored. The entire event can take from less than one second to tens of seconds.

193 There are three relevant inverter settings: the frequency (deviation) at which the unit is tripped, the time lag before terminal voltage recovery, and the number of seconds it takes to restore full output (the inverse of the ramp rate). The smaller the deviation, the longer the time lag, and the slower the ramp rate, the more likely it is that tripping creates a reliability problem.

connected to the distribution system,[194] but these are not appropriate for interconnections to the high-voltage system.

Since the publication of the *2017 IEPR*, the NERC Inverter-Based Resource Performance Task Force has developed performance specifications for inverter-based resources that prohibit momentary cessation in newly interconnected resources and reduce existing resources use of momentary cessation to the greatest extent possible. It recommended that "[m]omentary cessation during transient low-voltage conditions … be eliminated for future solar PV resources connecting to the [bulk power system], and should be mitigated to the greatest extent possible for existing solar PV resources." It also recommended that the task force "provide guidance as to the recommended performance of solar PV resources during ride-through conditions," specifically, the type of current injection (for example, active vs. reactive current priority) during ride-through.[195] During an Energy Commission IEPR workshop on June 20, 2018, the California ISO reiterated the need for new transmission-specific inverter standards and provided a status update on the efforts of the task force. It reported that in May 2018, it filed a request to NERC for the development of new standards. In September 2018, NERC issued draft guidelines for inverter-based generation that provided operational guidelines for operators, while noting that bulk electric system resources are subject to NERC reliability standards, whereas distribution resources are subject to IEEE 1547 requirements. Subsequently, the California ISO decided at their November 14, 2018, board of governors meeting to implement the NERC guideline recommendations for inverters in future interconnection processes.

The task force also found that most models of the electricity system did not accurately capture the operating characteristics of inverter-connected solar and wind generators. In February 2018, NERC issued a "modeling notification" that required older resources subject to tripping to provide accurate information on how they operate under various conditions by July 31, 2018. Planners, grid operators, and coordinators will use this information to better understand grid operations.

On May 1, 2018, NERC issued a second alert, based on its assessment of a pair of faults that occurred October 9, 2017.[196] It found that tripping was most often caused by erroneous frequency estimates — when faults occurred, the supply-demand imbalance was interpreted by inverters as changes in frequency. As these faults are corrected

194 Institute of Electrical Engineers 1547 and UL 1741 are the national standards. California has Rule 21.

195 When a drop in frequency or voltage occurs, some solar systems are programmed to disconnect from the grid. *Riding through* the drop means continuing to operate for some period of time, delaying the decision to disconnect (or not) until it is absolutely necessary to make it. Frequently, the drop is transient and normal frequency is restored within a second or two.

900 MW Fault Induced Solar Photovoltaic Resource Interruption Disturbance Report, Southern California Event: October 9, 2017, Joint NERC and WECC Staff Report, February 2018.

196 NERC, *900 MW Fault Induced Solar Photovoltaic Resource Interruption Disturbance Report*, February 2018.

almost instantly, requiring that frequency be reestimated (a few seconds later) before reacting has reduced the problem.

While tripping due to erroneous frequency estimates is no longer a problem, tripping due to transient voltages and high voltage levels continues to occur. To deal with this, the alert calls for existing generator owners to work with inverter manufacturers to lessen momentary cessation with dynamic VAR injection where possible. Where momentary cessation remains necessary, the alert directs owners to set voltage thresholds as high and low as possible, reduce the recovery delay to one to three cycles, and increase recovery ramp rates to 100 percent or more, with a goal of reducing the response (to tripping) time from the tens of seconds frequently observed to one second or less.

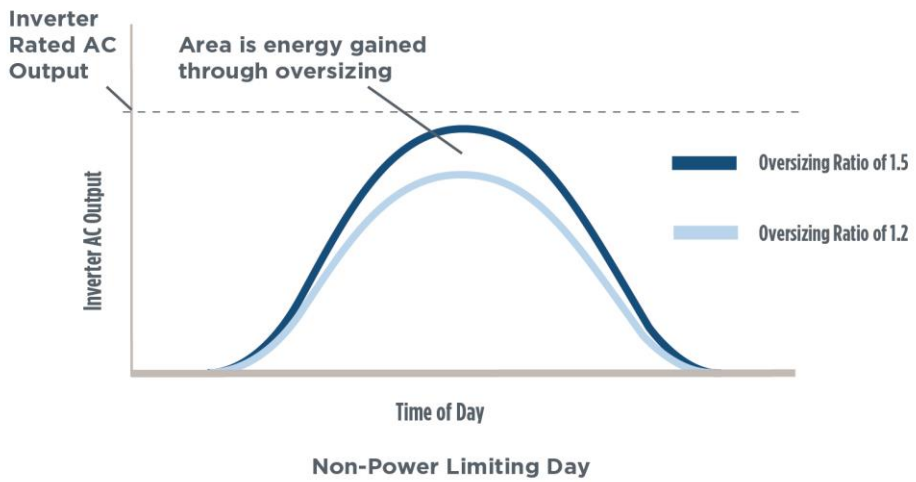
In addition to (or because of) the NERC-related activities above, the California ISO has:

- Updated generator interconnection agreements to include recommendations of the second NERC alert as requirements.
- Developed a solar PV database to include data on existing inverters and related control settings.
- Worked with generators and inverter manufacturers to obtain accurate models of inverter behavior under stress.
- Adjusted contingency reserves to account for possible tripping.
- Filed a request at NERC for a new standard for inverter-based generation.

Impact and Significance of Correctly Sizing Inverters

One option for managing PV generation is to limit the output of the inverter relative to the capacity of the panel array, the effect of which is seen in Figure 15.

Figure 15: Solar Inverter Power Output Profile



Source: Civic Solar/Solectria Renewables

2017 Solar Eclipse

On the morning of August 21, 2017, a total solar eclipse passed over the western United States. While eclipses obscuring the sun are not new, solar power is now a significant source of electricity for California. Although the totality area passed through Oregon and Wyoming, the entire Pacific Northwest was significantly affected by reduced solar levels, beginning about 9:00 a.m. when insolation began to drop. At the peak of the eclipse around 10:30 a.m., California's solar generation levels were about 6,000 MW lower than the California ISO generally expects for an August day. After 10:30 a.m. the eclipse began to taper off, and solar production began rising quickly until it reached normal levels about noon. Despite the rapid decline and steep upward ramp of solar generation that morning, there were no grid reliability problems.

The California ISO had been preparing for this eclipse for about a year, through efforts to procure alternative resources such as in-state and imported hydro power, and frequent planning and coordination calls with California energy utilities, generators, and other states' grid operators. California ISO planners also conferred with their European counterparts about energy production during a 2015 eclipse in Europe. The California ISO's preparation resulted in California being able to respond to this unusual, very concentrated event with flexibility and power to spare.

A solar eclipse with totality in Northern California will occur August 12, 2045. This is the same year that SB 100 sets a target for California to serve 100 percent of its load with zero-carbon energy.

This option limits output when the power available from the panel array exceeds the rated input power of the inverter (for example, during midday hours when overgeneration is most likely to be a system-level concern). Referred to as *clipping*, this option results in increased output during shoulder hours, when the capacity of the inverter is not limiting, reducing the size of the evening ramp (but exacerbating any

problems associated with the morning downward ramp).[197] The optimal sizing depends on several factors, including the value of the energy produced at different times of day. This option is becoming increasingly viable as solar PV panel costs fall.

Clipping can be coupled with a battery capable of storing the excess energy beyond what the inverter delivers to the grid to provide greater benefits. (See section below on energy storage.) At the June 20, 2018, IEPR workshop, Alex Au with NEXTracker described how new projects can include a battery on the DC side of the inverter to capture the clipped energy and save it for later use.[198] Any energy produced during morning hours that exacerbates problems associated with the morning ramp can also be stored. Energy is lost due to charging and discharging the battery, but storage allows for discharge five to eight hours later during the evening ramp, when the energy is far more valuable and GHG-emitting generation resources are displaced.

Curtailment Provisions in Utility-Scale Variable Energy Resource Contracts

Increasing reliance on solar and wind and associated increases in the need for economic curtailment flexibility have required that power purchase agreements (PPAs) with variable energy resources evolve. Early PPAs did not address economic curtailment. At the June 20, 2018, IEPR workshop, Sandra Burns with PG&E reported that PG&E did not include terms relating to economic curtailment until 2011–2014, when the utility paid for economic curtailment for 200–250 hours per year.

Since 2015, PG&E has entered into PPAs where the utility pays for an unlimited amount of economic curtailment. It bids projects economically into the California ISO market and pays the project for metered energy plus what would have been produced during periods when the bid is not accepted by the operator (an estimate based on the California ISO variable energy resource forecast). This arrangement benefits the utility, by limiting its exposure to negative prices, and the seller, by protecting it against reliability curtailments (for which it is not paid) that would occur if system issues are not resolved economically.

Since a significant share of PG&E's renewable portfolio was contracted for before 2015, increasing curtailment flexibility has required modifying existing PPAs. Ms. Burns reported that curtailment rights for roughly 1,000 MW of such resources have been negotiated and that 53 percent of the utility's renewable fleet is flexible.

197 During midmorning hours, solar output increases faster than demand, requiring that those generation resources sharply curtail output. Measures that increase solar output during these hours increase the needed curtailment of these resources.

198 Existing projects can add a battery on the AC side, but this must be accompanied by an inverter on the AC side as well, resulting in higher costs and greater inefficiency (DC-to-AC conversion occurs twice for stored energy.) Cost differences include receiving a production tax credit for energy stored on the DC side, but not on the AC side.

Update on Flexible Loads and Resources

Energy Storage Procurement

Energy storage is an important tool to help integrate increasing amounts of solar- and wind-powered electricity into the grid. For example, it can be used to store renewable generation when production exceeds demand and then reinject the energy into the system when supply is short. Energy storage can also be used in place of natural gas peaking plants in high electricity demand hours and can provide several services to the electric grid, including frequency regulation, (maintaining the alternating current frequency within acceptable levels), voltage support, resource adequacy, time-of-use bill management, and demand charge reduction.[199] Energy storage is helping alleviate energy reliability issues in Southern California. (See Chapter 6, "Preferred Resources," for more information.) Large systems, such as pumped storage (also referred to as *pumped hydro*) that typically uses pumps and generators to move water between upper and lower reservoirs, can help meet California ISO requirements for resource flexibility. Energy storage technologies include batteries, flywheels,[200] compressed air,[201] pumped storage,[202] and thermal storage (such as molten salt used to store heat for later use in electricity production and thermal ice systems that produce ice that can be used later for cooling purposes), and *green electrolytic hydrogen*.[203] Energy storage can interconnect at the transmission system, distribution system, or behind the customer

199 *Demand charges* are electric bill charges that are based on the peak electricity usage of a customer.

200 *Flywheel* energy storage is a mechanical system that converts kinetic energy to electricity using a spinning rotor.

201 *Compressed air energy storage* systems compress and store air under pressure in an underground cavern or large storage tanks. When electricity is needed, the pressurized air is heated and expanded to drive a generator for power production. Such systems have not been widely developed, with only two systems operational worldwide.

202 *Pumped storage* projects move water between two reservoirs located at different elevations (for example, an upper and lower reservoir) to store energy and generate electricity. Generally, when electricity demand is low (such as at night), excess electric generation capacity is used to pump water from the lower reservoir to the upper reservoir. When electricity demand is high, the stored water is released from the upper reservoir to the lower reservoir through a turbine to generate electricity.

203 Senate Bill 1369 (Skinner, Chapter 567, Statutes of 2018) added green electrolytic hydrogen to the list of storage technologies. *Green electrolytic hydrogen* is defined in the statute as "hydrogen gas produced through electrolysis and does not include hydrogen gas manufactured using steam reforming or any other conversion technology that produces hydrogen from a fossil fuel feedstock." Hydrogen production through the electrolysis of water was discussed in the *2017 IEPR* in Chapter 3 and Chapter 9.

meter.[204] The market for energy storage has expanded greatly in California in the last year, largely as a result of declining costs and statutory and regulatory targets aimed at increasing the use of energy storage. In October 2013, in accordance with Assembly Bill 2514 (Skinner, Statutes of 2010, Chapter 469), the CPUC adopted a 1,325 MW energy storage procurement target by December 31, 2020, with a final installation deadline of 2024. The CPUC allocated targets to each IOU in four biennial solicitations through 2020.[205]

Primus Power Flow Batteries

With a $95,000 grant from the Energy Commission in 2006, Primus Power successfully tested the feasibility of a flow battery utility applications using zinc-chlorine chemistry, which is nontoxic and environmentally safe.[1] The test demonstrated improved performance, longer storage time, and reduced maintenance costs compared to typical lithium-ion batteries. Primus Power has since been awarded funding to participate in the Department of Energy's Smart Grid Demonstration Program, the Marine Corps Air Station Miramar, and the Rialto Resilient Clean Power Microgrid. Primus Power has seen global interest in its products and grown to a workforce of 50 employees, holds 34 patents, and has 26 additional patents pending.

Photo credit: Primus Power

1 Sotero, Maria. 2013. Public Interest Energy Research 2012 Annual Report. California Energy Commission, Energy Research and Development Division. Publication Number: CEC-500-2013-013-CMF, pp. 72-73, https://www.energy.ca.gov/2013publications/CEC-500-2013-013/CEC-500-2013-013-CMF.pdf.

As of early August 2018, California's three IOUs have installed about 332 MW and procured, or requested approval to procure, almost 1,500 MW of energy storage related to Assembly Bill 2514 requirements. (See Table 12.)

Much of the storage procured uses lithium-ion batteries. The high demand for lithium-ion batteries in the electricity and transportation markets has helped reduce battery costs to the benefit of both sectors. (See "Transportation Electrification" below for more information.) Also, repurposed lithium-ion batteries that were used in electric vehicles have the potential to be an important source of batteries in the electricity sector at reduced cost.[206] An alternative to lithium-ion batteries are flow batteries. Flow batteries are designed to convert the chemical energy of two electrolytes (often separated by a membrane) to electricity and have the potential to address the large-scale storage needs of the grid. (See sidebar on Primus Power flow batteries.)

204 Energy Commission Tracking Progress, Energy Storage, http://www.energy.ca.gov/renewables/tracking_progress/documents/energy_storage.pdf.

205 The CPUC established AB 2514 targets of 580 MW for PG&E and SCE, and 165 MW for SDG&E.

206 Energy Commission, Tracking Progress, Energy Storage, http://www.energy.ca.gov/renewables/tracking_progress/documents/energy_storage.pdf.

Table 12: IOU Existing and Proposed Energy Storage Procurement

Pacific Gas and Electric					
	Target	**On-Line Storage**	**Approved, Some are in Progress**	**Pending Approval**	**TOTAL PROCURED**
Transmission	310	0	567.5	125	692.5
Distribution	185	6.5	10	20	36.5
Customer	85	26.1	0	20	46.1
Southern California Edison					
	Target	**On-Line Storage**	**Approved, Some are in Progress**	**Pending Approval**	**TOTAL PROCURED**
Transmission	310	20	100	0	120
Distribution	185	56	65.5	10	131.5
Customer	85	110	195	0	305
San Diego Gas & Electric					
	Target	**On-Line Storage**	**Approved, Some are in Progress**	**Pending Approval**	**TOTAL PROCURED**
Transmission	80	40	39	0	79
Distribution	55	43.6	13.5	0	57.1
Customer	30	30	0	0	30
TOTAL – All IOUs	**1,325**	**332.2**	**990.5**	**175**	**1,497.7**

Source: California Energy Commission, Tracking Progress, Energy Storage, updated August 2018 and CPUC Resolution E-4949, approved November 8, 2018. Cancelled or decommissioned projects are not included in this table.

Storage can also help displace natural gas-fired generation. For example, on January 11, 2018, the CPUC directed PG&E to hold one or more solicitations for energy storage and preferred resources to eliminate or reduce the need for California ISO-issued backstop contracts for three natural gas-fired generation plants (totaling 675 MW). The California ISO determined that these contracts were needed for local reliability in Northern California in 2018.[207] On June 30, 2018, PG&E requested approval of four contracts, totaling 567.5 MW/2.27 GWh, for lithium-ion, four-hour battery storage in the South Bay-Moss Landing subarea of the Greater Bay Area local reliability area, as summarized in Table 13. These contracts were approved by the CPUC on November 8, 2018.

207 E-4909, issued January 11, 2018. The facilities are the Feather River and Yuba City Energy Centers (Sierra LRA, 47.6 MW each) and the Metcalf Energy Center (Greater Bay Area LRA, 580 MW).

Table 13: CPUC-Approved PG&E Contracts for Storage to Replace Natural Gas-Fired Generation in Northern California

Project	Size (MW)	Term (Years)	On-Line Date
Vistra Moss Landing	300	20	12/1/2020
Hummingbird	75	15	12/1/2020
mNOC AERS	10	10	10/1/2019
Tesla Moss Landing	182.5	20	12/31/2020

Source: Pacific Gas and Electric

Hybrid Gas Storage and Clutch Technology Development

Falling battery costs have not only encouraged the deployment of stand-alone battery energy storage, but the integration of battery storage with natural gas-fired generation. In April 2017, Wellhead Electric Co. installed 10 MW/5 MWh batteries at SCE's Center (47 MW) and Grapeland (46 MW) peaking plants. The resources can now respond instantaneously with storage injections/discharges and are providing various reliability services without GHG emissions. Traditional gas-fired generation can provide these services only by operating at an inefficient intermediate load. At the June 20, 2018, workshop, Greg McDaniels with Wellhead reported that SCE found the additions reduced GHG emissions and criteria pollutant emissions from the peaking power plants by 60 percent.

Long-Term Storage

Marked declines in the cost of lithium-ion batteries are rapidly making two- to four-hour storage a cost-effective tool for balancing the grid and integrating increasingly large amounts of variable-energy renewable generation in California. The transformation to a carbon-free electricity sector across larger geographic areas — such as the entire United States — will require storage of a much longer duration.

A recent analysis of 36 years of global weather data concludes that 12-hour storage is needed to "overcome" the daily solar cycle and meet 80 percent of California's energy needs with wind and solar resources. Higher levels of reliance, however, would require addressing seasonal cycles and the occurrence of unpredictable weather events with a broad geographic impact. Specifically, meeting peak demand during low wind-power events of long duration would require storing energy for up to several weeks.[1]

1 Shaner, M. R., Steven J. Davis, Nathan S. Lewis, and Ken Caldeira. 2018. *Geophysical Constraints on the Reliability of Solar and Wind Power in the United States*, on-line paper, Royal Society of Chemistry. (DOI: 10.1039/c7ee03029k).

The Stanton Energy Reliability Center (98 MW, approved by the Energy Commission on November 9, 2018) will have two 10 MW/4.3 MWh batteries. It will also use synchronous condenser clutch technology, which allows the engines (combustion turbines) to be disconnected from the generator. The generator is then rotated using a small amount of energy from the grid to provide dynamic VAR support, or spinning reserves and inertia needed by the system. Like integrated battery storage, this technology provides ancillary services without combusting natural gas and producing GHG emissions. It also does so without producing energy that crowds out renewable generation, which will become increasingly important as California moves toward its goal of a carbon-free electricity system by 2045. LADWP has fitted existing units at its Scattergood and Haynes facilities with clutches to meet ancillary service needs from these resources.

Time-of-Use Rates Expanded use of time-varying retail prices can encourage energy consumers to use electricity when it is clean and abundant and reduce usage at other times. While this expanded use does not reduce consumption, instead merely shifting it, the shift reduces peak loads, costs, GHG emissions, stress on the transmission grid, and reliance on fossil peaking plants, allowing greater integration of renewable generation resources.

Almost all nonresidential customers are on time-varying rates, but most residential customers are not, and until recently, the peak and off-peak periods used by the IOUs did not align price signals with grid conditions.

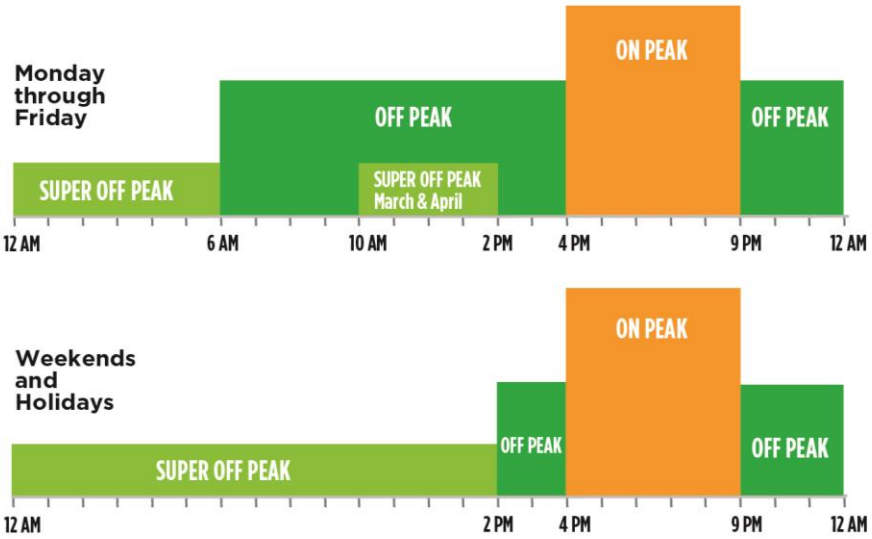
The CPUC has established that periods used in time-of-use (TOU) rates should align with expected grid conditions and costs. In December 2017, SDG&E began implementing this policy, with peak periods from 4:00 p.m. to 9:00 p.m., when energy costs and grid needs are greatest. PG&E and SCE will implement similar TOU periods in 2019. This shift to periods that are aligned with hourly variation in prices should be largely complete by 2020 and will affect nonresidential and residential customers.

Benefits from time-sensitive rates can be greatly expanded by making them the default rate for residential customers, which will be implemented by the IOUs and SMUD. SDG&E will begin this transition in March 2019, and SCE and PG&E in October 2020. SMUD began transitioning customers in October 2018 and will continue implementation in 2019.

To prepare customers for a successful transition, the utilities are performing communication campaigns to help customers understand how their rate choice and amount and timing of energy usage affects their bills and how they can take action to reduce negative impacts. SMUD has begun mass market efforts to introduce customers to TOU rates.[208] At the June 20, 2018, IEPR workshop, Sabrina Butler with SDG&E highlighted efforts to communicate the potential benefits of TOU rates and SDG&E's offer to its customers to try it risk free for one year. IOUs are evaluating outreach tactics for increasing engagement and awareness through channels that include mass market media and engagement through community-based organizations. They are also fielding large-scale default pilots to ensure operational readiness, launch test communication, and launch education measures such as improved bill design, dedicated Web pages, online tools, and welcome kits. SDG&E's pilot offers two plans; the default "three-peak plan" is illustrated in Figure 16.

208 Board Strategic Development Committee and Special SMUD Board of Directors Meeting, August 14, 2018, https://www.smud.org/-/media/Documents/Corporate/About-Us/Board-Meetings-and-Agendas/2018/Aug/Strategic-Development-Committee---August-14-2-TOD-Presentation-WITH-VIDEO1.ashx?la=en&hash=799349B3574C0534D5B179E74F1316C04CD5B663.

Figure 16: San Diego Gas & Electric Residential TOU Three-Peak Plan



Source: San Diego Gas & Electric

SMUD will move all residential customers to default TOU rates with a year-round 5:00 p.m. to 8:00 p.m. peak period (with higher peak period rates in the summer than in winter), with the option to opt out and choose an alternative fixed rate. At the same time, low-income rates are being restructured to better target the neediest customers.

As customers become more familiar with time-varying rates, an expanded menu of rate options can address different customer needs and encourage efficient use of clean, distributed resources. Looking beyond TOU rates, SMUD plans to develop a strategic pricing roadmap for programs that allow customers "to optimize the technology of their choice, from storage, to a connected thermostat, to charging of electric vehicles."[209] IOUs are developing alternative rate options, for example, midday super-off-peak rates that would be advantageous for electric vehicle charging and rates designed to better align distributed energy technologies, such as storage or storage plus solar, with grid needs.[210]

Flexible Loads Including Demand Response

Increasing the flexibility of generation to help integrate renewable energy and deploy storage to effectively modify the output profile of variable energy resources are only

209 2018 Budget Letter, GM 17-285, November 3, 2017, https://www.smud.org/-/media/Documents/Corporate/About-Us/Reports-and-Documents/2018/2018-Budget-letter.ashx?la=en&hash=F6B319BA76B8113B66D9C9B05BE8ABB3976778BB.

210 PG&E Rate Design Window A.17-12-011, Volume 1; SCE Rate Design Window 2018 A.17-12-012 and SCE 2018 Phase 2 General Rate Case, A.17-06-030.

part of the strategy needed to transition to a lower-carbon electricity sector. Shifting loads is needed as well. It is also more cost-effective, as it captures zero-emission power from California's investments in renewable energy.[211] In a 2017 analysis of cost-effective demand response potential, Lawrence Berkeley National Laboratory found significant opportunities for load-shifting demand response to provide value to the operation of a renewable-powered electricity system.[212] Demand response that can participate in California ISO markets can reduce the need for ramping resources not only by reducing load, but by providing ancillary services.

Demand response can be used for reducing load when electricity supply is tight and for increasing load when renewable generation is abundant and inexpensive. Demand response is typically implemented using a combination of communications and direct control technologies, time-variant pricing, programs that provide incentives for load reduction, and wholesale markets that treat load like a generation resource.

In the *2017 IEPR*, the Energy Commission reported on the additional work needed to capture the largely untapped potential for demand response in California. While the amount of demand response being counted for resource adequacy has not increased significantly, there has been progress in demonstrating the performance capabilities of the technology, as well as supply- and demand-side program designs and pricing alternatives. These efforts point to a significant potential that presently available customer options barely touch.

The Demand Response Auction Mechanism (DRAM) is a procurement mechanism designed to gain experience with bidding aggregated demand response directly into the wholesale California ISO market. In essence, demand-side resources are procured similarly to traditional supply, and automation via new technology solutions allows aggregated groups of customers to act as a virtual power plant.

In December 2014, the CPUC required PG&E, SCE, and SDG&E to implement the DRAM.[213] The initial auction took place in spring 2015 with delivery in 2016. A second auction was held in spring 2016 with delivery in 2017. These auctions yielded 40 MW and 124 MW of DR capacity, respectively. The procured resources provide system, local, or flexible RA capacity or a combination and has identical must-offer obligations (into California ISO day-ahead and real-time markets) to supply resources.

In 2016, the CPUC authorized $27 million for a third auction in 2017 with delivery in 2018, which resulted in applications for more than 200 MW of contracts in July 2017.[214]

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211 William Westerfield, Sacramento Municipal Utility District, Comments of the Sacramento Municipal Utility District on IEPR Commissioner Workshop on Renewable Integration, July 5, 2018, p. 1, available at https://efiling.energy.ca.gov/GetDocument.aspx?tn=224066.

212 LBNL, 2025 California Demand Response Potential Study, 2017 LBNL-2001113, http://eta-publications.lbl.gov/sites/default/files/lbnl-2001113.pdf.

213 CPUC D. 14-12-024.

214 CPUC D.16-06-29.

CPUC Commissioners continued the momentum to create new demand-response opportunities late in 2017. In November 2017, the CPUC instituted a fourth solicitation in 2018 for contracts to be delivered in 2019,[215] with a combined funding cap of $13.5 million (50 percent of the cap in each of the two previous solicitations). Reasons for this additional auction include supporting the emerging competitive demand-response market while CPUC considers the merits of the DRAM Pilot, gaining evidence to see if the market is too limited in opportunities for third parties, and testing the procurement guidelines adopted in D.16-09-056 but not incorporated into this pilot design. This decision expressly allows CCAs and direct access providers to file with the CPUC to determine if their demand response programs are similar to those of the IOUs, meaning that competing utilities must cease cost recovery for customers signed up in the third-party programs.

Applications totaling 595 MW were submitted on May 1, 2018; contracts for 166.5 MW are under CPUC review. The CPUC's November 2017 decision initiated two working groups: Supply Side to work on perceived and continuing barriers to market integration, with a final report by June 30, 2019, and Load Shift to define new demand response models by January 31, 2019, for consideration in a future rulemaking. Each working group will file quarterly status reports.

As directed by the CPUC in 2016, the Energy Division is also evaluating[216] the pilot to inform the division's future decision whether to adopt the DRAM as a permanent procurement mechanism. The CPUC has since released an interim evaluation report that covers four of its six evaluation criteria — the two outstanding criteria address the California ISO's wholesale energy market.[217] At the June 20, 2018, IEPR workshop, Arthur Haubenstock, executive director of the California Energy Efficiency and Demand Management Council, commented that "the industry is really very concerned about" the CPUC's delay in completing the program evaluation. He cautioned that this delay has created uncertainty regarding the future of demand response programs, and that may slow the momentum of industry participation.[218] He also noted that the changes in the electricity market structure affect the industry and that "complexity is not a friend of demand response." (See sidebar earlier in the chapter titled "Changing Market for Renewable Energy.")

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215 CPUC D. 17-10-017, October 26, 2017, in R. 13-09-011.

216 CPUC D.16-09-056.

217 CPUC, Energy Division's Evaluation of Demand Response Auction Mechanism, Interim Report, July 24, 2018.

218 WebEx recording of IEPR Commissioner Workshop on Renewable Integration at 3:33, available at http://www.energy.ca.gov/2018_energypolicy/documents/2018-06-20_workshop/2018_06-20_IEPR_Workshop_Renewable_Integration_and_Electric_System_Flexibility.mp4.

The structural shift in the California ISO-set peak summer (April–October) hours from 1:00 p.m.–6:00 p.m. to 4:00 p.m.–9:00 p.m. necessitated a Federal Energy Regulatory Commission (FERC) tariff waiver from the must-offer obligation during those hours for those DRAM resources that had already been awarded contracts. The California ISO submitted, and on March 29, 2018, FERC granted, a tariff waiver that exempted contracted-for DRAM resources from changes in must-offer requirements.

The CPUC recognized the need for evolving DR models in D.17-07-017219 and created the Load Shift Working Group (LSWG) in coordination with Gridworks,[220] whose mission is to convene, educate, and empower stakeholders to decarbonize electricity grids. *Load shift* is enabling and offering incentives to customers to use more power during periods of surplus renewable generation and lower energy prices/emissions, while using less power during periods of scarcity and relatively high-energy prices/emissions. A positive attribute of load shifting is that it potentially addresses renewable power overgeneration and curtailment. The LSWG developed a proposal that included a range of California ISO market integration and out-of-market dispatch options and recommendations that future load-shift activities should be coordinated with the Energy Commission and the California ISO.

The California ISO's energy storage and distributed energy resources (ESDER) initiative is intended to lower barriers and enhance the ability of California ISO-connected and distribution-connected resources to participate in the California ISO market (including rooftop solar, energy storage, plug-in electric vehicles, and demand response). The July 2018 ESDER Phase 3 scope included proposed enhancements to current demand response participation models, such as new bidding and real-time dispatch options, removal of single-entity LSE aggregation requirements, and the development of an

2018 Legislation to Reduce Carbon Emissions From the Transportation Sector

AB 2127 (Ting, Chapter 365) supports the state's goal of achieving 5 million ZEVs on the road by 2030 by affirming the Energy Commission's authority to assess the need for charging infrastructure to support adoption of zero-emission vehicles, including freight and off-road vehicles.
AB 2885 (Rodriguez, Chapter 366) continues the legislative priority of ensuring that California's incentive programs serve all communities by extending the requirement that the CARB conduct outreach to low-income households and communities as part of the Clean Vehicle Rebate Project and continue to prioritize rebates to low-income applicants until January 1, 2022.
SB 1000 (Lara, Chapter 368) requires the state to assess whether vehicle-charging infrastructure is sufficient to encourage the purchase of electric vehicles, and ensures that plug-in electric vehicles and zero-emission vehicles have equal access to charging infrastructure.

For a more complete listing of these and other bills signed by the former Governor to address climate change, see https://www.gov.ca.gov/2018/09/13/aboard-hybrid-electric-ferry-on-the-san-francisco-bay-governor-brown-signs-bills-to-promote-zero-emission-vehicles-reduce-carbon-emissions/.

219 CPUC. D.17-07-017

220 Gridworks, https://gridworks.org/initiatives/load-shift-working-group/.

energy storage load-shift product.[221] The California ISO Board of Governors approved the Phase 3 proposal on September 5, 2018, and a tariff filing with the Federal Energy Regulatory Commission are pending approval.

Transportation Electrification

California is working to transform the transportation sector's diverse vehicle segments away from petroleum to near-zero-emission vehicles operating with low-carbon fuels and zero-emission vehicles (ZEVs) that run on electricity from batteries or hydrogen fuel cells. Including emissions from refineries, the transportation sector accounts for more than 50 percent of the state's GHG emissions as of 2016.[222] Electrification is a fundamental part of the state's efforts to reduce GHG emissions and improve air quality.[223] In 2018, the former Governor signed a suite of bills to help dramatically reduce GHG emissions from transportation. (See sidebar on previous page.) As usage grows, zero-emission vehicles will have an increasing role in grid management and the integration of renewables in particular.

PEV Growth in China

California is not alone in its efforts to increase the use of plug-in electric vehicles (PEVs). There is a growing market for ZEVs globally. China leads the world in the development of lithium-ion battery gigafactories, which are expected to reduce battery storage costs through increasing economies of scale. A primary market for these batteries is PEVs, with China again leading internationally (Figure 17). China is also requiring batteries to be recycled and repurposed, allowing them to be used in a "second life" as energy storage for the electricity sector. China is considering a timeline to completely phase out the sale and use of fossil-fueled vehicles and has adopted regulations that the Natural Resources Defense Council estimated could result in the production of more than 1 million electric vehicles per year by 2020.[1,2]

1 Reuters, "China Sets 2019 Deadline for Automakers to Meet Green-Car Sales Targets," September 28, 2017, https://www.reuters.com/article/us-autos-china-electric/china-sets-2019-deadline-for-automakers-to-meet-green-car-sales-targets-idUSKCN1C30ZL. These regulations include allowances for automakers to trade NEV credits, while individual vehicles can generate multiple credits, depending on performance.

2 Energy Commission Tracking Progress, Energy Storage, http://www.energy.ca.gov/renewables/tracking_progress/documents/energy_storage.pdf.

The primary regulatory driver for transportation electrification is the ZEV regulation administered by CARB. The ZEV regulation requires each manufacturer to produce a certain number of ZEVs and plug-in hybrid vehicles each year, based on the total number of cars sold in California by that manufacturer. Each vehicle receives credits based on electric driving range, and excess generated credits can be banked, sold, or traded to other manufacturers. As of summer 2018, CARB staff estimate that about 8 percent of new California vehicle sales will be ZEVs or plug-in hybrids by 2025 to

221 http://www.caiso.com/Documents/RevisedDraftFinalProposal-EnergyStorage-DistributedEnergyResourcesPhase3.pdf.

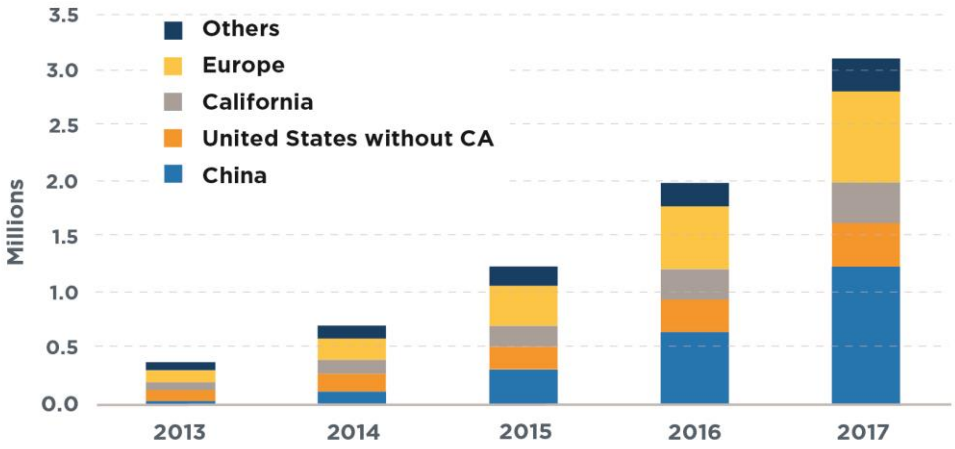
222 CARB. California Greenhouse Gas Emission Inventory – 2018 Edition. July 11, 2018, https://www.arb.ca.gov/cc/inventory/data/data.htm.

223 As reported in the *2017 IEPR*, motor vehicles are the largest source of air pollution that harms human health, accounting for nearly 80 percent of nitrogen oxide emissions and 90 percent of diesel particulate matter emissions.

comply with the credit requirements of the ZEV regulation.[224] The ZEV regulation has also been adopted by nine other U.S. states, collectively representing nearly 30 percent of the nation's annual new car sales.

Former Governor Brown also issued two executive orders that are primary policy drivers for expanding ZEV deployment. In 2012, then-Governor Brown signed Executive Order B-16-2012 to set a long-term goal of reaching 1.5 million ZEVs on California's roadways by 2025.[225] In January 2018, he issued Executive Order B-48-18 to extend the state's support of ZEVs.[226] This executive order calls on the state to advance ZEVs and sets goals to put at least 5 million ZEVs on California's roads by 2030 and spur the installation and construction of 250,000 plug-in electric vehicle chargers, including 10,000 direct current fast chargers, and 200 hydrogen refueling stations by 2025. PEVs are expected to form the majority of these ZEVs, with hydrogen fuel-cell electric vehicles accounting for a notable share. (Expected changes in electricity demand resulting from transportation electrification are being estimated and included in the *California Energy Demand Updated Forecast, 2018–2030,* as discussed in Chapter 7.)

Figure 17: California Leads United States' Growth in Electric Vehicles (2013–2017)



Source: International Energy Agency, Global EV Outlook 2018, http://www.iea.org/gevo2018/ and IHS Markit.

Meeting the goals of Executive Order B-48-18 requires close coordination with the electricity sector and policies to electrify buildings. If managed well, increasing electric loads from the transportation sector, including plug-in electric vehicle charging and

224 https://www.arb.ca.gov/msprog/zevprog/factsheets/zev_regulation_factsheet_082418.pdf.

225 https://www.gov.ca.gov/2012/03/23/news17472/.

226 https://www.gov.ca.gov/2018/01/26/governor-brown-takes-action-to-increase-zero-emission-vehicles-fund-new-climate-investments/.

power-to-gas for hydrogen fuel cell vehicles[227] can help integrate increasing amounts of renewable energy.

Flexible Plug-In Electric Vehicle Charging

Flexible charging is one critical strategy, out of many, to achieve the state's transportation electrification goals. Energy Commission staff worked with the National Renewable Energy Laboratory (NREL) to quantify the types and locations of charging infrastructure needed to ensure that California meets its plug-in electric vehicle deployment goals as required by Executive Orders B-16-2012 and B-48-18 and enables drivers to meet their transportation needs. The Energy Commission and NREL developed the Electric Vehicle Infrastructure Projection computer simulation tool to conduct this analysis. For instance, the analysis for 2025 indicates that between 51,000 and 57,000 Level 2 chargers[228] are needed at workplaces statewide to meet travel demands for light-duty vehicles used for personal travel. Three-quarters of the workplace charging sessions are for charging plug-in hybrids to maximize the electric miles driven during daily commutes.[229]

The Electric Vehicle Infrastructure Projection analysis also quantified the load profiles resulting from the typical charging behaviors of 1.3 million PEVs occurring on weekdays and weekends, using travel schedules representative of mainstream California drivers. The resulting load profile from unmanaged residential, workplace, public, and fast charging may account for nearly 1 gigawatt (GW) of demand at 8:00 p.m. weekdays in 2025. Residential Level 1 chargers contribute three-fourths of the increase in charging load from 4:00 p.m. to 7:00 p.m. — the hours during which demand increases fastest. Increased flexibility in charging demand depends on the deployment of Level 2 chargers at residential and at nonresidential locations, the ability to automate demand-responsive chargers capable of receiving dynamic utility prices, and the use of distributed generation or storage.

Other recent analyses confirm the potential for value from flexible smart charging. Lawrence Berkeley National Laboratory (LBNL) found that managing charging and enabling the use of electric vehicle batteries as dischargeable vehicle-to-grid capacity

227 The *2017 IEPR* (Chapter 3) identified hydrogen production as a potential pathway for preserving the value of excess renewable electricity. The electricity can be used in electrolysis of water into hydrogen and oxygen. Optionally, the hydrogen could be combined with waste or captured carbon dioxide to create methane. End-uses for this renewable hydrogen or methane include fuel cell electric vehicles, storage in tanks, or injection into natural gas or dedicated hydrogen pipelines.

228 Level 2 chargers use 208/240 volts, up to 19.2 kW (80 Amps), whereas Level 1 chargers use 110/120 volts, 1.4 to 1.9 kW (12 to 16 Amps). For reference, 1,000 kW is roughly enough electricity for the instantaneous demand of 750 homes at once.

229 Bedir, Abdulkadir, Noel Crisostomo, Jennifer Allen, Eric Wood, and Clément Rames. 2018. *California Plug-In Electric Vehicle Infrastructure Projections: 2017-2025*. California Energy Commission. Publication Number: CEC-600-2018-001.

could serve as the equivalent of about 5 GW of stationary storage in 2025, with the savings in avoided capacity cost enabling greater investment in vehicle electrification.[230]

A separate LBNL study found that TOU rates and smart charging controls are capable of shifting loads to reduce peaks and generation costs, but smart charging is better able to adapt to seasonal operational ramping and generation conditions. This analysis compared renewable energy curtailment levels associated with managed and unmanaged charging strategies for 5 million PEVs in 2025. LBNL found that while charging according to TOU rates may slightly exacerbate curtailment relative to unmanaged vehicles, smart charging would reduce curtailment by nearly 50 percent.[231]

In addition to vehicle simulations, LBNL managed a vehicle-to-grid research project at the Los Angeles Air Force Base in El Segundo (Los Angeles County), which was funded by the U.S. Department of Defense and the Energy Commission's Alternative and Renewable Fuel and Vehicle Technology Program. This project demonstrated the technical potential for light- and medium-duty electric vehicle fleets to provide grid support. It also helped identify and address the complexities of participating in frequency regulation, a dynamic electricity market service for the California ISO, and the challenges of engineering development of the bidirectional vehicle equipment, charging hardware, and fleet energy management software.[232] One barrier was that few of the components used in the project were "fully mature," defined by the Air Force Research Laboratory as readily available in the marketplace with a history of satisfied customers.[233] PEV and EVSE hardware and control system faults hindered the ability to respond to frequency regulation dispatch signals and maintain resource certification with the California ISO.[234] The Air Force Research Laboratory concluded that the project advanced the technology readiness level of several bidirectional power systems, but that vehicle-to-grid products are not fully commercialized. This project also provided information about the revenue potential from electricity markets, as well as the impacts of vehicle-to-grid services on battery life, warranty, and fleet use. The Energy Commission continues research on these issues.[235]

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230 Coignard, Jonathan, Samveg Saxena, Jeffrey Greenblatt, and Dai Wang. May 2018. "Clean Vehicles as an Enabler for a Clean Electricity Grid," *Environmental Research Letters*. http://iopscience.iop.org/article/10.1088/1748-9326/aabe97/meta.

231 Sheppard, Colin J. R., Julia Szinai, Niki Abhyankar, and Anand R. Gopal. "Grid Impacts of Electric Vehicles and Managed Charging in California: Linking Agent-Based Electric Vehicle Charging with Power System Dispatch Models." Lawrence Berkeley National Laboratory, report forthcoming fall 2018.

232 Black, Douglas and Jason MacDonald. "Los Angeles Air Force Base Vehicle-to-Grid for Ancillary Services Demonstration," June 20, 2018, IEPR workshop on Renewable Integration and Electric System Flexibility, https://efiling.energy.ca.gov/GetDocument.aspx?tn=223865.

233 Brendlinger, Jennifer, Matthew Campbell, James Hlivko, Heidi Kaltenhauser, Brian Wechtenhiser, and Greg Halfter. E2 Technologies LLC. *Environmental Quality, Energy, and Power Technology Task Order 012: Plug-In Electric Vehicle, Vehicle-to-Grid*, final report, AFRL-RX-WP-TR-2017-0417, Air Force Research Laboratory.

234 SCE, Department of Defense Vehicle-to-Grid Final Report, submitted pursuant to California Public Utilities Commission Resolution E-4595, December 22, 2017.

235 http://www.energy.ca.gov/research/energystorage/tour/af_v2g/.

The *2017 IEPR* included recommendations on standardizing electric vehicle charging equipment to enable resource dispatch to realize these potential electric procurement cost savings, and updating the *Vehicle-Grid Integration Roadmap* to reflect the needs to use open standards[236] in the design of charging equipment; to share the financial benefits of avoided electrical infrastructure upgrades with EV drivers, ratepayers, and others; and to commercialize prior investments in research.[237] Recent technology demonstrations in California are proving solutions to enable smart charging.[238] An enabling technology that could quantify the flexible load profiles of vehicle charging distinctly from other local loads are "submeters" — meters embedded with charging equipment. Submetering pilots conducted between 2014 and 2018 by the IOUs and charging service providers examined grid integration capabilities.[239] A final evaluation of the pilot is pending from Nexant. The *2017 IEPR* also highlighted the need for further research, discussion, and attention to medium- and heavy-duty vehicle charging, given vehicle and equipment incentives available from the state and select electric utilities and the potential operational costs associated with unmanaged high-power charging. Senate Bill 100 (Lara, Chapter 368, Statutes of 2018) requires the CPUC to consider easing the development of technologies that provide submetering capability to residential charging stations, along with other policies to support the deployment of electric vehicles and smart charging, including for fleets and heavy-duty vehicles. The *2017 IEPR* also identified the need to sustain education to broaden customer awareness about ZEVs to encourage adoption. These topics remain relevant to stakeholders in considering how to ensure that PEV charging is made flexible to minimize costs and integrate renewables.

Repurposed, or "second life," PEV batteries can also enhance grid integration of direct current fast chargers (DCFC) or other loads that would benefit from energy storage. This idea is aligned with Assembly Bill 2832 (Dahle and Ting, Chapter 822, Statutes of 2018), which requires the Secretary of Environmental Protection to convene a lithium-ion car battery recycling advisory group to help identify policies that maximize the reuse or recycling of batteries used in California safely and cost-effectively. For example, using EPIC and NRG settlement technology demonstration funds, respectively, Greenlots[240]

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236 The *2017 IEPR* (Appendix H) stated *open standards* include those listed within the Smart Grid Interoperability Panel Catalogue of Standards, the National Institute of Standards and Technology Smart Grid framework, or those that are adopted by the American National Standards Institute or other international standards organizations, including the International Organization for Standardization, International Electrotechnical Commission, International Telecommunication Union, Institute of Electrical and Electronics Engineers, or Internet Engineering Task Force.

237 California Energy Commission staff. 2017. *2017 Integrated Energy Policy Report*. California Energy Commission. Publication Number: CEC-100-2017-001-CMF. p.141.

238 Patadia, Shana, Chargepoint. "Residential Controlled Charging & 15118 Integration (ChargePoint EPC 14-078)," June 20, 2018, IEPR Commissioner Workshop on Renewable Integration and Electric System Flexibility, https://efiling.energy.ca.gov/GetDocument.aspx?tn=223870.

239 CPUC. Plug-In Electric Vehicle (PEV) Submetering, http://www.cpuc.ca.gov/General.aspx?id=5938.

240 Keerthi Shankar Ravikkumar, Greenlots, *Improving the Commercial Viability of Fast Charging by Providing Renewable Integration and Grid Services with Integrated Multiple DC Fast Chargers*, Fourth Annual California Multi-Agency Update on Vehicle-Grid Integration December 5, 2017, Research

and EVgo[241] improved the affordability of fast charging by leveraging used batteries to address utility demand charges and renewable curtailment on the electric system.[242] (See sidebar on "PEV Growth in China" for information on battery recycling in China.)

As the use of DCFC grows, economically interconnecting and operating DCFC are critical. For example, battery electric vehicles used in fleet ride-hailing services are fast-charged for more than 95 percent of the duty cycle.[243] At the May 23, 2018, staff workshop on California PEV infrastructure projections, Jamie Hall with Maven stated that future automated vehicles may mirror this usage pattern.[244] Duty-cycle analyses are needed to characterize the charging infrastructure requirements for ZEVs that provide ride-hailing services and to assess the associated impacts on electric operations. Such research could assist in developing emissions reduction targets for such travel as directed by Senate Bill 1014 (Skinner, Chapter 369 Statutes of 2018).

Further action is needed to ensure that potential benefits to the driver and the electric system are realized. The Energy Commission is collaborating with other state agencies and stakeholders to update the *Vehicle-Grid Integration Roadmap* to ensure that infrastructure investments in the near future are capable of smart charging in response to time-of-use rates and demand response requests.[245] Specifically, agencies and industry are addressing how policies can leverage vehicle-grid integration as a distributed energy resource, consistent with other procurement and market efforts, while acknowledging that electric vehicles travel across networks, utilities, and balancing areas.[246]

Recommendations

- **The California Independent System Operator (California ISO) should continue to work toward a market framework that promotes the delivery of flexible zero-carbon energy from Northwest resources to serve California loads and to work with the California Public Utilities Commission to ensure that such resources contribute to resource adequacy needs**. This work includes the continued

http://www.energy.ca.gov/research/notices/2017-12-05_workshop/presentations/04_Greenlots_EPC16-055.pdf.

241 Glen Stancil, EVgo, *Technology Demonstration Project: Modular Micro-Grid DC Charging*, July 3, 2013, http://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=6442453062 and EVgo, "EVgo Announces Grid-Tied Public Fast Charging System with Second-Life Batteries," July 10, 2018, https://www.evgo.com/about/news/evgo-announces-grid-tied-public-fast-charging-system-second-life-batteries/.

242 https://www.energy.ca.gov/business_meetings/2017_packets/2017-04-27/index.php.

243 Hall, Jamie, Maven. "CA EV Infrastructure Projections," May 23, 2018 Staff Workshop: California Plug-In Electric Vehicle Infrastructure Projections: 2017-2025, https://efiling.energy.ca.gov/GetDocument.aspx?tn=224123.

244 Ibid.

245 http://www.energy.ca.gov/transportation/vehicle-grid-integration/.

246 California Energy Commission Staff, *California Vehicle-Grid Integration Roadmap Update Public Workshop*, October 29-30, https://efiling.energy.ca.gov/getdocument.aspx?tn=225126.

expansion of the Energy Imbalance Market, enhancements to the day-ahead market that encourage participation of Northwest resources while meeting the California ISO's operational needs, and greater regionalization of grid operation and management.

- **California must increase the roles that demand response and time-of-use rates play in shaping load and managing grid needs.** Increasing the flexibility of loads is key to successfully integrating variable energy renewable generation, reducing curtailment, and achieving reductions in greenhouse gas emissions from the electricity sector at the lowest possible cost.
- **The energy agencies should assess the value of adding battery storage or synchronous condenser clutch technology to increase the grid support capabilities of existing flexible, fast-ramping natural gas-fired generation.** When considering options to cost-effectively address the need for dynamic VAR support, pairing these technologies with gas-fired generation should be compared alongside other alternatives such as variable energy generation and transmission system upgrades. Such resources may cost-effectively provide reserves and ancillary services without crowding out renewable generation and producing greenhouse gas emissions.
- **The Energy Commission should continue research and development supporting widespread transportation electrification**. Research through the *Electricity Program Investment Charge: 2018-2020 Triennial Investment Plan*[247] will accelerate "grid-friendly plug-in electric vehicle mobility" to advance vehicle communications that improve aggregation, dispatch potential, and smart cities, and will prepare California for growth in autonomous, connected, electric, and shared vehicles. In addition, research on "battery second use" to characterize plug-in electric vehicle battery health and improve packaging will promote operational efficiency from additional grid storage in support of Assembly Bill 2832.
- **The energy agencies must accelerate the research, development, and deployment of smart inverters statewide with advanced capabilities that enable inverter-based resources to decrease grid disturbances, allow for desired output levels of real and reactive power, and enable resource owners to participate in ancillary service markets.** In situations where smart inverters are not required, California's energy agencies should encourage transmission and distribution system operators with interconnected inverter-based resources to evaluate the operational benefits that they provide. Also, the Energy Commission should continue research and development advancing the performance of smart inverters. Research through the *Electricity Program Investment Charge: 2018-2020 Triennial Investment Plan* will improve the ability of solar photovoltaic to support the grid by enhancing the functionality of smart inverters using advanced communication and control

247 https://efiling.energy.ca.gov/getdocument.aspx?tn=217347.

capabilities. This optimization will improve power quality, reduce the chance of outages, and increase the amount of solar photovoltaic that can be installed without upgrades to grid equipment.

- **The California ISO should continue working toward developing standards and testing for transmission-level inverter-based resources by the Institute of Electrical and Electronics Engineers and the Underwriters Laboratory.**
- **The Energy Commission should consider the market transformation potential of its investments in support of the Executive Order B-48-18 directive for 250,000 electric vehicle chargers in California by 2025**. For example, to maximize savings for customers and grid flexibility, infrastructure deployments could promote the use of chargers that are certified to ENERGY STAR efficiency requirements and are capable of automating demand response via open communication standards. The Energy Commission should leverage best practices in charging system designs from international markets to allow economies of scale to reduce product costs and thus maximize the efficacy of private investments.
- **In updating the *Vehicle-Grid Integration Roadmap*, the Energy Commission should investigate how cost and grid impact mitigation strategies learned from passenger vehicle technology research may be transferred to electrification efforts in the medium- and heavy-duty fleet sectors.** Vehicle-grid integration technologies and methods should be considered for the potential to simplify customer participation in grid management programs and ease widespread electric vehicle adoption, especially within low-income and disadvantaged communities. These vehicle-grid integration programs should be designed to complement other state distributed energy resource efforts.
- **As recommended in Chapter 1, the Energy Commission should consider opening a load management standard proceeding to achieve greenhouse gas reducing load shifting.**

CHAPTER 4: Energy Equity

Increasing Access to Clean Energy Benefits

California is committed to increasing the equitable distribution of clean energy benefits and creating an inclusive clean energy economy. As stated in former Governor Edmund G. Brown Jr.'s inaugural address on January 5, 2015, "California has made bold commitments to sustain our environment, help the neediest, and build for our future."[248] Later that year, then-Governor Brown signed into law the Clean Energy and Pollution Reduction Act, Senate Bill 350 (De León, Chapter 547, Statutes of 2015). In addition to codifying ambitious clean energy targets, SB 350 took steps to ensure the benefits of clean energy transformation are realized by all Californians, especially those in the most vulnerable communities. Investments within the low-income sector help the neediest achieve the energy bill savings other Californians enjoy, and contribute to economic developments.

Specifically, SB 350 required the Energy Commission and the California Air Resources Board (CARB) to publish two studies that identify barriers limiting access to the benefits of clean energy and clean transportation for low-income customers and those living in disadvantaged communities. These studies, which include actionable recommendations to overcome structural, market, and policy barriers, were informed by an extensive literature review, local community meetings across the state, and several technical workshops. The recommendations outlined in the two studies now serve as a guiding framework to increase energy equity across California. SB 350 also directs the California Public Utilities Commission (CPUC) and publicly owned utilities (POUs) to report energy efficiency savings in disadvantaged communities, as discussed in Chapter 2.

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

On December 14, 2016, the Energy Commission adopted the *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* (Barriers Study Part A).[249] As directed by SB 350, the report examines barriers to energy efficiency and weatherization investments, renewable energy generation, and

248 Former Governor Edmund G. Brown Jr. Inaugural Address, January 5, 2015, https://www.gov.ca.gov/2015/01/05/news18828/.

249 California Energy Commission, *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*, https://efiling.energy.ca.gov/getdocument.aspx?tn=214830.

contracting opportunities for local small businesses in low-income and disadvantaged communities.

The report offers 12 key recommendations to address barriers to clean energy access. Table 14 shows high-level summaries of each recommendation, many of which contain multiple parts. For example, the fourth part of the first recommendation focuses on multifamily housing: "Develop a comprehensive action plan on improving opportunities for energy efficiency, renewable energy, demand response, energy storage, and electric vehicle infrastructure for multifamily housing, with attention to pilot programs for multifamily rental properties in low-income and disadvantaged communities."[250]

The report recommendations aim to offer scalable, sustainable solutions; address low-income customers' inability to access traditional financing mechanisms available to most Californians; and help maximize public investments. Implementation efforts are underway for many of the recommendations (as discussed in a following section), while others require further analysis and stakeholder discussion.

250 For more information, see Scavo, Jordan, Suzanne Korosec, Esteban Guerrero, Bill Pennington, and Pamela Doughman. 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. Publication Number: CEC-300-2016-009-CMF.

Table 14: Low-Income Barriers Study Part A Recommendations

	Recommendation
1	Organize a multiagency task force to facilitate coordination across state-administered programs.
2	Enable community solar offerings for low-income customers.
3	Formulate a statewide clean energy labor and workforce development strategy.
4	Develop new financing pilot programs to encourage investment for low-income customers.
5	Establish common metrics and encourage data sharing across agencies and programs.
6	Expand funding for photovoltaic and solar thermal offerings for low-income customers.
7	Enhance housing tax credits for projects to include energy upgrades during rehabilitation.
8	Establish regional outreach and technical assistance one-stop shop pilots.
9	Investigate consumer protection issues for low-income customers and small businesses in disadvantaged communities.
10	Encourage collaboration with community-based organizations in new and existing programs.
11	Fund research and development to enable targeted benefits for low-income customers and disadvantaged communities.
12	Conduct a follow-up study for increasing contracting opportunities for small businesses located in disadvantaged communities.

Source: *Senate Bill 350 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*

Low-Income Barriers Study, Part B: Overcoming Barriers to Clean Transportation Access for Low-Income Residents

CARB released the *Low-Income Barriers Study, Part B: Overcoming Barriers to Clean Transportation Access for Low-Income Residents* (Barriers Study Part B) in February 2018.[251] As directed by SB 350, the report examines barriers faced by low-income residents, including those in disadvantaged communities, to access zero-emission and near-zero-emission transportation and mobility options. The report emphasized the importance of equity and building understanding of some of the core challenges facing overburdened populations across the state. SB 350 also established widespread transportation electrification as a priority to meet California's air quality and climate goals.

The report recognizes that all California residents face similar barriers to access clean transportation and mobility options, but notes that barriers low-income residents and disadvantaged communities face are magnified. Furthermore, many barriers are

251 California Energy Commission, *Low-Income Barriers Study, Part B: Overcoming Barriers to Clean Transportation Access for Low-Income Residents,* https://www.arb.ca.gov/msprog/transoptions/sb350_final_guidance_document_022118.pdf.

localized and shaped by geographic, economic, demographic, social, or cultural attributes within a community. This finding underscores the importance of understanding community-specific needs, developing equitable solutions, and targeting resources to those residents facing disproportionate barriers to access. The barriers to clean transportation options for low-income residents identified in the report include:

- Community-specific barriers (such as access, convenience, and safety).
- Affordability.
- Lack of sustainable, long-term funding to expand clean transportation and mobility investments.
- Insufficient awareness of clean transportation and mobility options and program funding and participation opportunities.

The recommendations of the report aim to increase awareness and understanding of these barriers and identify clear pathways to increase access across communities to programs and technologies. The recommendations include steps that the Legislature, communities, and state and local agencies focused on planning, transportation, public health, and air quality can take to formulate innovative and meaningful solutions. In addition to the priority recommendations, CARB identified other ongoing efforts that are working to increase access, as well as recommendations under consideration for future implementation. (See Table 15.)

Table 15: Low-Income Barriers Study Part B Priority Recommendations

	Recommendation
1	Expand assessments of low-income resident clean transportation and mobility needs to ensure feedback is incorporated in transportation planning and for guiding investments.
2	Develop an outreach plan targeting low-income residents across California to increase residents' awareness of clean transportation and mobility options.
3	Develop regional one-stop shops to increase consumer awareness and technical assistance.
4	Develop guiding principles for grant and incentive solicitations to increase access to programs and maximize low-income resident participation.
5	Maximize economic opportunities and benefits for low-income residents from investments in clean transportation and mobility options by expanding workforce training and development.
6	Expand funding and financing for clean transportation and mobility projects, including infrastructure, to meet the accessibility needs of low-income and disadvantaged communities.
Supporting Actions	
Develop metrics to measure progress in addressing barriers and increasing clean transportation and mobility access.	
Coordinate closely with related state, local, and regional clean transportation programs and planning efforts.	

Source: *Low-Income Barriers Study, Part B: Overcoming Barriers to Clean Transportation Access for Low-Income Residents*

On August 29, 2018, the California Energy Commission hosted a joint agency workshop on SB 350 Equity Milestones and Implementation Progress in collaboration with the CPUC, CARB, and the Governor's Office. The workshop highlighted the cross-disciplinary nature of energy equity efforts. As Energy Commissioner David Hochschild noted, "The two big challenges we face today are climate change and inequity, and we have to address both at the same time."[252] In addition to providing an update on implementation progress for the recommendations in the Barriers Study Part A and Barriers Study Part B, panelists also discussed lessons learned and the path forward.

One key theme revisited throughout the workshop was the need for pragmatic and flexible community engagement that can be refined over time in response to changing needs and feedback. Many speakers emphasized the need to understand existing knowledge, efforts, and history within the community and to build upon existing channels. During a panel discussion on sustained investment, Tyson Eckerle with the Governor's Office of Business and Economic Development explained, "Investment means more than just money. It means building relationships and trust. It means human resources and insights from the people in the community … the recipe for success is to

252 August 29, 2018, Joint Agency Workshop on Senate Bill 350 Equity Milestones and Implementation Progress Transcript, https://efiling.energy.ca.gov/getdocument.aspx?tn=224914, p. 11.

build local buy-in and knowledge."[253] Matt Abularach-Macias with the League of Conservation Voters echoed that sentiment, adding, "Always see communities and the members of that community as the experts. They know what they need, they can tell you firsthand what the experience is there, and what's going to be the best way to invest or make changes there."[254]

Mr. Abularach-Macias also emphasized that programs and outreach will not be perfect and should allow for flexibility to adapt to community needs. Program administrators should "be willing to take risks and leave room for failure," while adapting to challenges, such as language and cultural barriers.[255] Jamie Lemus provided a case study on the Sacramento Metropolitan Air Quality Management District's (SMAQMD) car-share pilot program in which he described the iterative refinements to the program to accommodate feedback from the community. During rollout of the program, district representatives encountered several barriers; for instance, they found not everyone had the technical expertise to download and use the car-share app. Many community members also lack driver's licenses, and some do not have bank accounts, which leaves them unable to register with a bank account or credit card.

In response, SMAQMD shifted outreach to include the residents' children and sought their assistance in helping their parents with the phone app. It also launched a ride hail program to reach participants who do not have a license or do not drive and is developing a card that be connected to multiple mobility programs — including the car-share program, Jump Bike, transit, Envoy, and Lyft — to assist participants without bank accounts. Mr. Lemus acknowledged limitations in the infrastructure of the car-share program, noting that charging stations must be "strategically located where it's safe, where it's accessible, and in most cases where it's close to a[n electric] panel, because the farther away it is from a panel, … the more it costs."[256]

A second theme from the workshop was acknowledging and accounting for cobenefits of energy equity efforts, including comfort, health, and safety. As Eugene Lee of the Energy Commission noted while presenting on the Clean Energy in Low-Income Multifamily Buildings report, "Benefits are benefits … we do not need to necessarily bifurcate energy benefits with non-energy benefits. These are all benefits and we need to think holistically."[257] At a more specific level, Amy Dryden of Build-It Green explained that healthy homes are "dry, clean, safe, well-ventilated, pest and contaminant free, well maintained, and thermally controlled. And any deficiencies in those can result in health

253 Ibid., p. 154.

254 Ibid., p. 77.

255 Ibid., p. 78.

256 Ibid., p. 181.

257 Ibid., p. 111.

impacts."[258] Yet, while building cleaner, more energy-efficient homes can help improve indoor air quality and health, Sarah White of the California Workforce Development Board added, "Cobenefits don't just happen … you have to design them intentionally if you want to get equity."[259]

Several panelists underscored the relationship between climate efforts and housing. Maria Stamas of the Natural Resources Defense Council emphasized, "Efforts to address the climate crisis really, really have to go hand in hand with the housing crisis."[260] Further, she noted, "If you come down to what energy burdens are about for low-income and disadvantaged communities, a lot of it is really linked to housing burdens."[261] Michael Massie, senior vice president at Jamboree Housing, presented a case study on Jamboree Housing's West Gateway Place, an award-winning multifamily affordable housing development in West Sacramento. Mr. Massie affirmed transit-oriented affordable housing "located near jobs, near schools, near grocery stores, near libraries, near healthcare" is a major sustainability measure and key to reducing transportation emissions.[262]

Low-Income Barriers Study: Implementation Progress

The two-part Barriers Study outlines critical recommendations to move toward an equitable clean energy future and ensure the benefits of clean energy and clean transportation are accessible to all Californians. Many of the recommended actions are underway or in planning and stakeholder engagement phases, as was discussed at the August 29, 2018, joint agency workshop on SB 350. Selected updates listed below illustrate progress made to date to implement the recommendations in the report.

SB 350 Governor's Office Task Force

The Governor's Office, with support from the Energy Commission and CARB, launched the SB 350 Governor's Office Task Force in May 2017. The task force includes representatives from 15 state agencies administering energy, water, resilience, housing, and low-emission transportation infrastructure programs for low-income customers and disadvantaged communities. Participants meet bimonthly to coordinate implementation across priority clean energy and transportation recommendations in the SB 350 Barriers Study.

SB 350 Disadvantaged Communities Advisory Group

SB 350 also required the CPUC and the Energy Commission to create a Disadvantaged Communities Advisory Group to ensure clean energy programs are reaching and

258 Ibid., p. 213.

259 Ibid., p. 161.

260 Ibid., p. 132.

261 Ibid., p. 132.

262 Ibid., p. 120.

benefiting communities burdened by pollution and socioeconomic challenges, including rural and tribal communities. In February and March 2018, the Energy Commission and the CPUC approved the appointment of 11 advisory group members, consisting of representatives of disadvantaged communities who provide advice on state programs proposed to advance clean energy and reduce pollution.[263] The advisory group members reflect the geographic and demographic diversity of disadvantaged communities throughout the state, including urban, rural, and tribal communities. The advisory group members also represent a broad range of technical expertise, including renewable energy, energy efficiency, and transportation electrification.

The advisory group first met in April 2018 to select officers, learn more about clean energy programs at the Energy Commission and the CPUC, and receive public comment on which clean energy programs should be prioritized for review. The group has since convened several more times to create and adopt an energy equity framework and determine which programs they will review and provide recommendations on in their annual report. The advisory group also selected liaisons to develop collaborative relationships with CARB's Environmental Justice Advisory Group and the CPUC's Low-Income Oversight Board who help ensure energy equity efforts align across multiagency clean energy programs.

Increased Access to Solar Programs

Financial barriers, including a lack of capital for a down payment, lack of access to credit, and the inclusion of costs that cannot be financed (such as a roof repair or an electrical service upgrade), limit access to rooftop solar for low-income households in California. Building-related issues, including shading and suboptimal roof orientation, as well as complex property ownership models, can also make rooftop installations technically infeasible for many low-income residents.

To alleviate these hurdles, the *Barriers Study Part A* Recommendations 2 and 6 outline strategies to increase opportunities for low-income and disadvantaged communities to access solar technologies, including specific actions to enable the economic advantages of community solar. Furthermore, Assembly Bill 327 (Perea, Chapter 611, Statutes of 2013) directs the CPUC to develop specific alternatives designed to increase adoption of residential renewable distributed generation in disadvantaged communities.

New CPUC Solar Programs

Since 2017, the CPUC has established four new programs (described below) to ensure that low-income households in disadvantaged communities have opportunities to access clean and innovative technology offerings. Three of these programs — the Disadvantaged Community Single-Family Affordable Solar Homes Program (DAC-SASH), the Disadvantaged Community Green Tariff Program (DAC-GT), and the Community

263 http://www.energy.ca.gov/sb350/DCAG/.

Solar Green Tariff Program (CSGT) — were adopted in CPUC Decision 18-06-027.[264] These programs are modeled after existing programs that have successfully increased access to renewable distributed generation and will be funded through GHG allowance proceeds. If insufficient GHG allowance revenues are available in a given year, the programs will be funded through public purpose program funds. The fourth program, Solar on Multifamily Affordable Housing (SOMAH), was adopted in CPUC Decision 17-12-022.[265] SOMAH provides a vehicle for implementing of Assembly Bill 693 (Eggman, Chapter 582, Statutes of 2015), which mandates an incentive program for the installation of distributed solar on existing multifamily affordable housing. SOMAH will also receive funding from GHG allowance proceeds.

DAC-SASH

Modeled after the Single-Family Affordable Solar Homes program, DAC-SASH will provide assistance in the form of upfront financial incentives toward the installation of rooftop solar systems for low-income homeowners who reside in disadvantaged communities. While the current Single-Family Affordable Solar Homes program is limited to designated affordable housing units, DAC-SASH will be available to a broader group of low-income homeowners in disadvantaged communities. The program will have an administrator and an annual budget of $10 million per year beginning January 1, 2019, and continuing through the end of 2030.[266]

DAC-GT

This program will allow low-income residents who live in California disadvantaged communities to subscribe to receive 100 percent renewable energy from projects located in disadvantaged communities. The program includes a 20 percent electricity bill discount for participants. This discount will allow customers to choose clean energy options without the need to own their home or install a rooftop solar system. To be eligible, participants will need to live in the top 25 percent of disadvantaged communities, as identified by CalEnviroScreen, and meet the income eligibility requirements for the California Alternate Rates for Energy or Family Electric Rate Assistance programs. The program is anticipated to serve up to 158 megawatts (MW) and 39,000 customers across the IOUs.

CSGT

The CSGT program will allow primarily low-income Southern California Edison (SCE), Pacific Gas and Electric (PG&E), and San Diego Gas & Electric customers in disadvantaged communities to benefit from the development of solar generation projects located in their own or nearby disadvantaged communities. As in the DAC-GT program,

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264 CPUC Decision 18-06-027, June 21, 2018, http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M216/K789/216789285.pdf.

265 CPUC Decision 17-12-022, December 18, 2017, http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M201/K940/201940057.pdf.

266 CPUC Decision 17-12-022 Section 3.5.1, http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M201/K940/201940057.pdf.

subscribers to this tariff will receive a 20 percent electricity bill discount. Unlike that program, however, CSGT requires community involvement with the solar project though a local sponsor. CSGT projects must be sited in a top 25 percent disadvantaged community, and the subscribers to the project must be within 5 miles of the project and within a top 25 percent disadvantaged community. Customers in a San Joaquin Valley pilot program will also be eligible, even if not within a top 25 percent disadvantaged community. CSGT will serve up to 41 MW and 6,800 customers across the IOUs.

SOMAH

SOMAH, created as part of AB 693, will provide incentives for the installation of solar distributed generation projects sited on existing multifamily affordable housing. SOMAH will help unlock bill savings for low-income customers in eligible IOU or community choice aggregator locations by requiring each participating multifamily affordable housing owner to use a competitive process to select an eligible solar system, providing a subsidy for the cost of solar generation, and allocating net energy metering tariff credits. The program has an energy efficiency component, as well as a job training and local hire component. As directed by AB 693, the CPUC will authorize the allocation of $100 million or up to 66.67 percent of the available IOU portion of GHG allowance proceeds, whichever is less, to implement the program for up to 10 years. The program has an overall goal to install at least 300 MW of generating capacity on qualified properties by 2030.

New Department of Community Services and Development (CSD) Solar Programs

CSD has launched two new programs to increase access to solar. The Community Solar Pilot Program makes the benefits of solar energy more available to eligible low-income households, lowering residents' energy bills and providing cobenefits to communities, including economic and workforce development. CSD released a notice of funding availability on August 1, 2018, to award up to $5 million total for two or more eligible community solar projects. These pilot projects will help test and prove several prototype delivery options.

CSD's second solar program, Single-Family Energy Efficiency and Solar Photovoltaics Program—Farmworker Housing, will provide integrated energy efficiency and solar services to low-income farmworkers and their families living in two multicounty regions. CSD released draft program guidelines on June 22, 2018, in anticipation of an upcoming competitive procurement that will award a total of $10 million to two farmworker housing administrators. Services will vary by housing type, building age, and general condition but can include cost-effective energy efficiency measures, solar photovoltaics, limited home repair, and health and safety measures.

Clean Energy in Low-Income Multifamily Buildings

While state agencies recognize there are barriers to clean energy access in single-family and multifamily homes, this update focuses on challenges specific to multifamily housing, highlighting the findings of the recently released *Clean Energy in Low-Income*

Multifamily Buildings (CLIMB) Action Plan.[267] To improve access to clean energy in low-income multifamily buildings, the Barriers Study Part A, Recommendation 1 called for the development of a "comprehensive action plan to improve opportunities for energy efficiency, renewable energy, demand response, energy storage, and electric vehicle infrastructure for multifamily housing, with attention to pilot programs for multifamily rental properties in low-income and disadvantaged communities."[268]

The CLIMB Action Plan was developed as a joint effort with six other agencies: the CPUC, the California Air Resources Board, CSD, the California Department of Housing and Community Development, the California Department of Health, and the State Water Resources Control Board. The report identifies current programs and policies, remaining challenges, and concrete actions that the state can take to accelerate the implementation of distributed energy resources within California's multifamily housing stock. The Energy Commission released a draft report in May 2018 for discussion at the May 30, 2018, joint agency workshop on Clean Energy in Low-Income Multifamily Buildings. The final report was adopted in November 2018.[269] The plan calls for actions to:

- Expand coordination among existing programs.
- Develop a cohesive, segmented understanding of the multifamily market.
- Improve existing and future program design.
- Provide additional resources and identify deployment opportunities.
- Increase strategic outreach, awareness, and access.

Expand Coordination Among Existing Programs

To expand coordination among existing programs, the CLIMB report recommends actions to:

- Efficiently leverage efforts of existing working groups relevant to multifamily housing.
- Align efforts across existing programs to maximize benefits.

At the May 30 IEPR workshop, Jeanne Clinton, former special advisor for energy efficiency to the Governor's Office and CPUC, provided a recap of workshop themes and noted a "need for solutions to be easy to manage by the owners and managers of properties, as well as by the participants. There was a lot of discussion on the single

267 Haramati, Mikhail, Eugene Lee, Tiffany Mateo, Brian McCollough, Shaun Ransom, Robert Ridgley, and Joseph Sit. 2018. *Clean Energy in Low-Income Multifamily Buildings Action Plan.* California Energy Commission. Publication Number: CEC-300-2018-005-SF.

268 See Recommendation 1, subparagraph (d) in Scavo, Jordan, Suzanne Korosec, Esteban Guerrero, Bill Pennington, and Pamela Doughman. 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. Publication Number: CEC-300-2016-009-CMF. Available online at https://efiling.energy.ca.gov/getdocument.aspx?tn=214830.

269 https://www.energy.ca.gov/business_meetings/2018_packets/2018-11-07/Item_06.pdf.

point of contact or a one-stop shop or concierge as a way to help with this ease of management on solutions."[270]

Additional overarching themes of public comments include support for a one-stop-shop model for clean energy program outreach and increased consideration for non-energy benefits, such as water savings and GHG emissions reductions along with health, safety, and comfort. One commenter, Envoy Technologies, encouraged the Energy Commission to include car-sharing with electric vehicle charging infrastructure measures.[271] The Sierra Club also urged for the decarbonization of buildings, stating that "building electrification provides significant non-energy benefits including improved air quality and health, safety, comfort and climate resiliency, increased investment in local economy, and local jobs."[272] This supports the Energy Commission's efforts to ensure low-income and disadvantaged communities benefit from efforts to decarbonize energy sources and the state's broad goal of reducing GHG emissions.

Development of a one-stop shop is one of the actions recommended in the 2016 Barriers Study. An update on implementing this recommendation is provided toward the end of this chapter. Specifically, the report recommended:

> The state, in consultation with Energy Commission, CPUC, CARB, Department of Community Services and Development, and other related state and local agencies, should establish a pilot program for multiple regional one-stop shops to provide technical assistance, targeted outreach, and funding services to enable owners and tenants of low-income housing across California to implement energy efficiency, clean energy, zero-emission and near-zero-emission transportation infrastructure, and water-efficient upgrades in their buildings. This pilot program should also support a range of local service delivery providers, coordinate with local government energy programs, and leverage existing Web portals, such as Energy Upgrade California®, with information provided in a variety of languages and in a format relevant to local low-income communities. Regional pilot programs should build on the best models for comprehensive one-stop models both in California and other states.

Develop a Cohesive Understanding of the Multifamily Market

The CLIMB report recommends the following actions to develop a cohesive understanding of the multifamily market:

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270 May 30, 2018, IEPR workshop transcript, https://efiling.energy.ca.gov/getdocument.aspx?tn=224288, pp. 244.

271 https://efiling.energy.ca.gov/GetDocument.aspx?tn=223809.

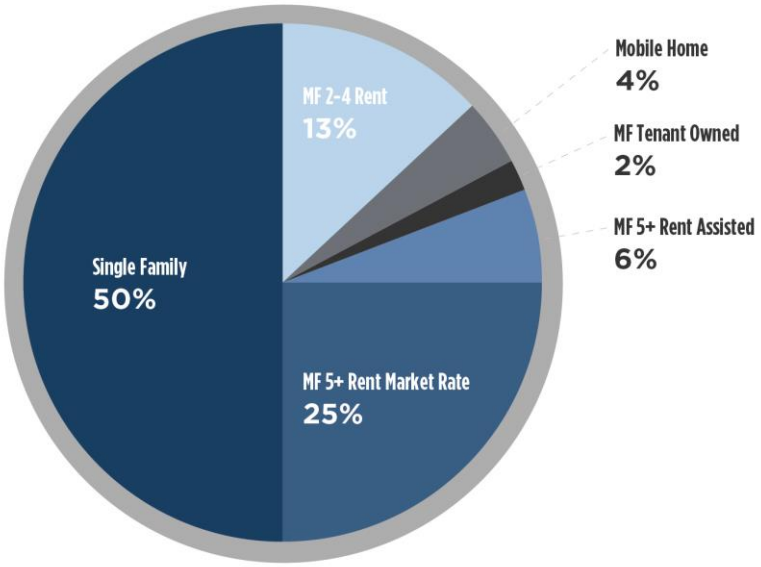
272 Sierra Club. June 13, 2018. Sierra Club REVISED Comments on CLIMB Action Plan and Workshop. Submitted to Energy Commission Docket 08-IEPR-08, https://efiling.energy.ca.gov/GetDocument.aspx?tn=223812.

- Gather data on the various distinct segments of the diverse multifamily housing stock.
- Determine economic and energy savings potential of the multifamily buildings by segment.

With a significant portion of Californians living in multifamily housing, these buildings offer a critical avenue to achieving the state's climate and energy goals, as discussed in Chapters 1 and 2.

Nearly half of all low-income households in California live in multifamily rental housing (Figure 18), and the vast majority of multifamily units are rented at market-rate levels. The burden of insufficient energy efficiency and renewable energy programs for renters falls disproportionately upon low-income residents.

Figure 18: Low-Income Housing Profile by Housing Type



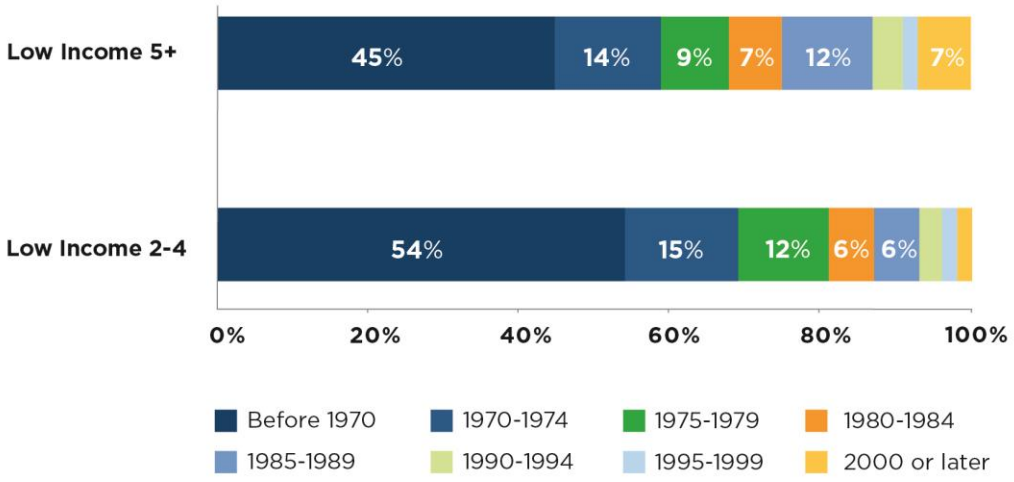
Source: NRDC Staff Presentation. The Cadmus Group. "ESA Program Multifamily Segment Study Vol. 1" (2013). & U.S. Census Bureau.

Most multifamily housing was built before 1980, as shown in Figure 19. Older buildings represent an opportunity for envelope and equipment measures, which can reduce energy consumption, particularly in the form of heating and cooling loads. The San Joaquin Valley, for instance, is in a climate zone that experiences extreme heat and has a high concentration of low-income households.[273] Older buildings in these extreme heat climate zones may be good candidates for energy upgrades, leading to a reduction in

273 https://efiling.energy.ca.gov/getdocument.aspx?tn=214830.

energy consumption and greenhouse gas (GHG) emissions. Moreover, the top non-energy benefits for the low-income multifamily sector include reduced thermal stress, reduced asthma, increased work productivity due to improved sleep, and reduced economic need for food assistance.[274]

Figure 19: Low-Income Multifamily Housing Vintage



Source: NRDC Staff Presentation. The Cadmus Group. "ESA Program Multifamily Segment Study Vol. 1" (2013)

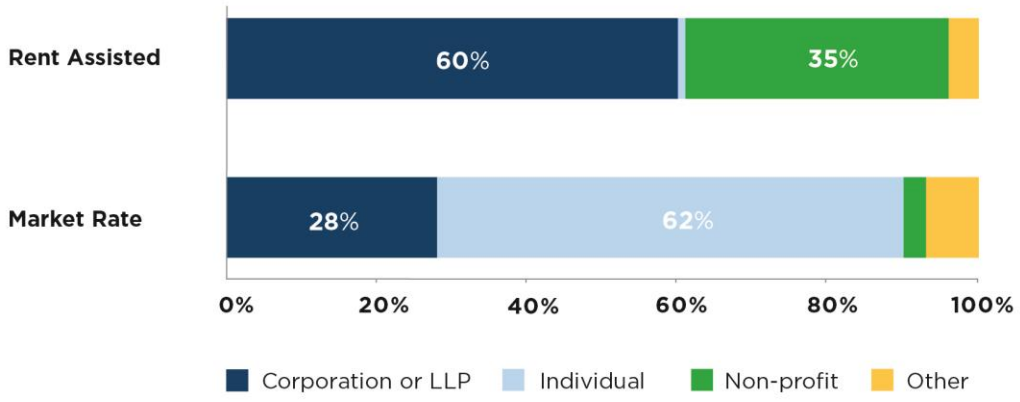
There have been utility programs designed to deliver energy efficiency upgrades for multifamily buildings, but adding energy equity to the list of program objectives, while desirable, does not guarantee that incentive structures will overcome existing barriers. A key consideration in addressing the multifamily sector is the complexity of diverse building types, ownership structures (Figure 20), and tenant populations. Rent-assisted properties are often owned by corporations and nonprofit organizations, while market-rate properties are owned largely by individuals. In the multifamily sector, owners often include multiple stakeholders, requiring multiple approvals for any decision.

The split incentive poses additional complexity. Property owners may hesitate to invest in unit upgrades because they will not benefit directly from these upgrades. On the other hand, tenants are often unable to finance in-unit upgrades and are often unauthorized or unwilling to invest in upgrades because, as renters, they may not live in the unit for the long term and may benefit only temporarily. For either party, these dynamics may result in a limited return on investment from an energy upgrade to a

274 Tonn et al., Oak Ridge National Laboratory. 2014. *Health and Household-Related Benefits Attributable to the Weatherization Assistance Program.* https://weatherization.ornl.gov/wp-content/uploads/pdf/WAPRetroEvalFinalReports/ORNL_TM-2014_345.pdf.

multifamily housing unit. Understanding such barriers is essential to designing and implementing effective clean energy programs in the multifamily housing sector.

Figure 20: Ownership of Multifamily Housing



Source: NRDC Staff Presentation. The Cadmus Group. "ESA Program Multifamily Segment Study Vol. 1" (2013)

Improve Existing and Future Program Designs

The CLIMB Action Plan recommends the following actions to improve existing and future program designs, including actions to:

- Determine best practices and assess program impacts on multifamily buildings and residents.
- Leverage data and research to prioritize implementation.
- Expand and improve current building DER program offerings.
- Incorporate program features supporting small business and workforce development goals.

The CLIMB Action Plan identifies examples of programs in California to assess the effects of current tariff structure, utility programs, and split incentives for DER for this sector. Examples include the new CPUC programs to advance deployment of renewable distributed generation in low-income and disadvantaged communities (DAC-SASH, DAC-GT, CSGT, and SOMAH, discussed earlier in this chapter).

At the May 30, 2018, workshop, panelists pointed out unnecessary programmatic roadblocks and arbitrary restrictions limiting participation in energy retrofit programs.

Meredith Milet with the California Department of Public Health stated, "There are health benefits from energy efficiency upgrades and programs,"[275] which was echoed by workshop presenters and panelists. Stakeholders suggested a shift away from strict cost-effective analysis based only on energy benefits. As Stephanie Chen with the Greenlining Institute stated, "I would actually suggest that we think about benefits, not as energy benefits and non-energy benefits, but just as benefits."[276] These sentiments support Energy Commissioner Andrew McAllister's statements regarding the importance of targeting innovative clean energy program design for multifamily buildings and low-income and disadvantaged communities. Improving the energy performance of multifamily buildings "touches many points of policy and equity and [has a] social importance beyond energy and [the] environment."[277] CLIMB strategies aligned with these comments include:

- Streamlining program enrollment and coordinating program eligibility.
- Reviewing and aligning program guidelines and requirements to allow flexibility in using and combining funds to address health and safety issues.
- Assessing, quantifying, and including non-energy benefits in the benefit-cost analysis used in program design.

Several stakeholders submitted public comments on the CLIMB Action Plan, including the California Housing Partnership Corporation, the Natural Resources Defense Council, and the Sierra Club. Many of these comments supported the strategy outlined in CLIMB to establish a state funding source for the Low-Income Weatherization Program. Commenters pointed out the success of the program, stating that the "Low-Income Weatherization Program service track for multifamily buildings is a national model for excellent program design and delivery."[278]

Identify Additional Resources and Deployment Opportunities

The CLIMB report includes the following actions to identify additional resources and deployment opportunities for clean energy in multifamily buildings:

- Research low-income housing tax credit properties and the building efficiency improvement opportunities when reapplying for low-income tax credit allocations.
- Secure state funding for underserved multifamily sectors and for expansion of successful programs.

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275 May 30, 2018, IEPR workshop transcript, https://efiling.energy.ca.gov/getdocument.aspx?tn=224288, p. 76.

276 Ibid.

277 May 30, 2018, IEPR workshop transcript, https://efiling.energy.ca.gov/getdocument.aspx?tn=224288, p. 9.

278 Natural Resources Defense Council. June 13, 2018. Comments on *CLIMB Action Plan*. Submitted to Energy Commission Docket 18-IEPR-08, https://efiling.energy.ca.gov/GetDocument.aspx?tn=223811.

- Mobilize capital prioritizing match funding and private capital to fund multifamily building efficiency programs and projects.

At the May 30, 2018, workshop, Andrew Brooks with the Association for Energy Affordability suggested "pooling sources of funding that are beyond just energy. Integrating health dollars and other kinds of housing-related program dollars into a more central location where building owners not just access the technical assistance, but the funding through a streamlined mechanism"[279] would greatly increase program participation and potential for clean energy measures. Combining funding opportunities available for building retrofits and informing multifamily building owners and managers in a streamlined manner hold potential for increasing participation in clean energy programs in support of building decarbonization.

The CPUC's Energy Savings Assistance Program has been chronically underspent due in part to some of the implementation barriers detailed in the CLIMB Action Plan. The CPUC has authorized the IOUs to move ahead with targeted efficiency upgrades in common areas of multifamily properties. Larger impacts could be achieved through further use of Energy Savings Assistance program funds for comprehensive measures to decarbonize and improve the performance of entire multifamily properties, for example, in deed-restricted properties when reapplying for low-income tax credit allocation.

Increase Outreach, Awareness, and Access

The CLIMB Action Plan includes the following actions to increase outreach, awareness, and access for clean energy in multifamily buildings:

- Identify and follow successful outreach models.
- Implement strategic marketing, education, and outreach.

As stated by Jeanne Clinton at the May 30, 2018, workshop, "One of the themes that I kept hearing from the dais today was inviting people to submit real examples of good solutions that are out there."[280] The Commissioners urged panelists and stakeholders to submit comments with examples of successful solutions for reaching low-income multifamily buildings. Commissioner McAllister encouraged public comments to include "how best we can move forward interacting with local communities, nonprofits, and stakeholders that can help us get success locally."[281]

State agencies should continue to collaborate to address the action items identified in the CLIMB Action Plan. The development of the CLIMB Action Plan is a significant step toward broader deployment and integration of distributed energy technologies in multifamily buildings, making buildings healthier, more livable, and more resilient.

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279 May 30, 2018, IEPR workshop transcript, https://efiling.energy.ca.gov/getdocument.aspx?tn=224288, p. 173.

280 Ibid., p. 247.

281 Ibid., p. 111.

As discussed in Chapter 1 on SB 350 energy efficiency doubling, the Energy Commission is required to report on progress in achieving the targets, including specific tracking of efficiency efforts in low-income and disadvantaged communities. The Energy Commission will combine this reporting on progress in achieving the doubling targets with updating the various building action plans, including the *Low-Income Barriers Study* and the *Clean Energy in Low-Income Multifamily Building Action Plan*, into a consolidated report to coincide with the IEPR cycle. Measuring progress in reaching low-income and disadvantaged communities and identifying additional actions the state can take will help address equity issues.

Data Collection and Evaluation Metrics

Staff began developing energy equity indicators in 2017 to implement Recommendation 5 in the *Low-Income Barriers Study*. Staff consulted with stakeholders, coordinated with sister agencies, received input from U.S. Department of Energy's Clean Energy for Low-Income Communities Accelerator program,[282] issued a public request for comments, discussed the draft indicators at a public workshop, and provided an update of the indicators at an Energy Commission business meeting.

In June 2018, staff held an IEPR webinar to launch the Energy Equity Indicators, which are available as an interactive mapping application, an interactive story map, and a Tracking Progress report (Equity Indicators Report).[283] The indicators identify opportunities to improve clean energy access, investment, and resilience in California's low-income and disadvantaged communities. (See Figure 21.)

Figure 21: California Energy Equity Objectives and Indicators

Source: California Energy Commission, Energy Equity Indicators, Tracking Progress

The nine energy equity indicators aim to track and advance progress toward three primary objectives:

282 The Clean Energy for Low Income Communities Accelerator aims to lower energy bills in low-to-moderate-income communities through expanded installation of energy efficiency and distributed renewables. https://betterbuildingsinitiative.energy.gov/accelerators/clean-energy-low-income-communities.

283 https://www.energy.ca.gov/sb350/barriers_report/equity-indicators.html.

- **Access:** Expanding access to clean energy, including the availability of product selection options, access to high-quality jobs, expansion of small business contracting opportunities, and improved access to nondebt financing options.
    - Tracking the number of residents served across programs can help identify key barriers and refine program implementation moving forward.
    - The state aims to award at least 25 percent of California state contract dollars to small businesses annually. Tracking along this indicator will help identify areas that can benefit from additional assistance with certification, registration, and navigation to support local small businesses in accessing state contracts.
    - Comparing job numbers, as well as job growth rates, can indicate which regions would benefit from investments in the local workforce through educational institutions and additional clean energy job opportunities. Further work is needed to evaluate job quality, apprenticeship and preapprenticeship opportunities, and career growth opportunities.
- **Investment:** Increasing clean energy investment, including technology development and demonstration funding, infrastructure investment, emergency preparedness, technical assistance, and capacity building (for example, workforce development, small business support, outreach, and clean energy education).
    - Identifying areas with low levels of program participation helps highlight opportunities to launch additional regional service centers or one-stop shop pilots to improve market delivery and streamline services, potentially also driving increased participation in energy efficiency programs and resultant efficiency savings.
    - Energy Commission staff plans to track trends in energy savings across low-income and disadvantaged communities annually. Identifying areas with low energy savings can indicate which areas could benefit from additional energy efficiency upgrade investments and improved program offerings.
    - Increasing access to rooftop solar for low-income customers can reduce energy burden, especially in summer months and particularly when energy use coincides with solar generation or when combined with energy storage that can be discharged after the sun sets.
- **Resilience:** Bolstering local energy-related resilience by improving energy services that support the ability of communities to recover from grid outages and access affordable energy in a changing climate.
    - Greater awareness of and access to energy efficiency programs, as well as development of new energy efficiency pilots focusing on these low-

income areas, can strengthen energy resilience by improving affordability and relieving energy burden.

- The Barriers Study reported that high energy bills relative to income may drive low-income households to make do with insufficient heating or cooling, which can increase the incidence of asthma, especially in children.[284] Areas including the Central Valley and Southern California deserts also face an increasing threat of heat-related illness as average daily temperatures increase due to climate change. Identifying areas with relatively high occurrences of health and safety issues helps target program investments, particularly in clean transportation and energy efficiency.
- Electrical grid reliability and outages can have a significant impact on the health and safety of customers, especially in regions affected by extreme heat. This indicator will help track progress on local reliability as it relates to low-income and disadvantaged communities specifically and include efforts such as reducing the risk of fire to energy infrastructure and the development of microgrids to keep power to critical loads when the larger grid is down.

The report is accompanied by an interactive story map,[285] which highlights key opportunities to improve access to clean energy technologies for low-income customers and disadvantaged communities, increase clean energy investment in those communities, and improve community resilience to grid outages and extreme events. A complementary interactive map of selected data layers is available to support additional research and analysis related to energy equity progress. An example of a data layer available on the interactive map is Electric Vehicle Infrastructure and Rebates (as shown in Figure 22).

The data on EV sales indicate that the number of EVs and percentage of EV ownership are lower in the Central Valley than in other parts of the state, suggesting an opportunity to provide greater access to EVs and support charging infrastructure. The map highlights low-income areas of California with low uptake of Clean Vehicle Rebate Program rebates. For example, some areas of the Central Valley have lower EV sales than other parts of California, indicating an opportunity to expand awareness of the Clean Vehicle Rebate Program, which is a key driver of EV adoption.

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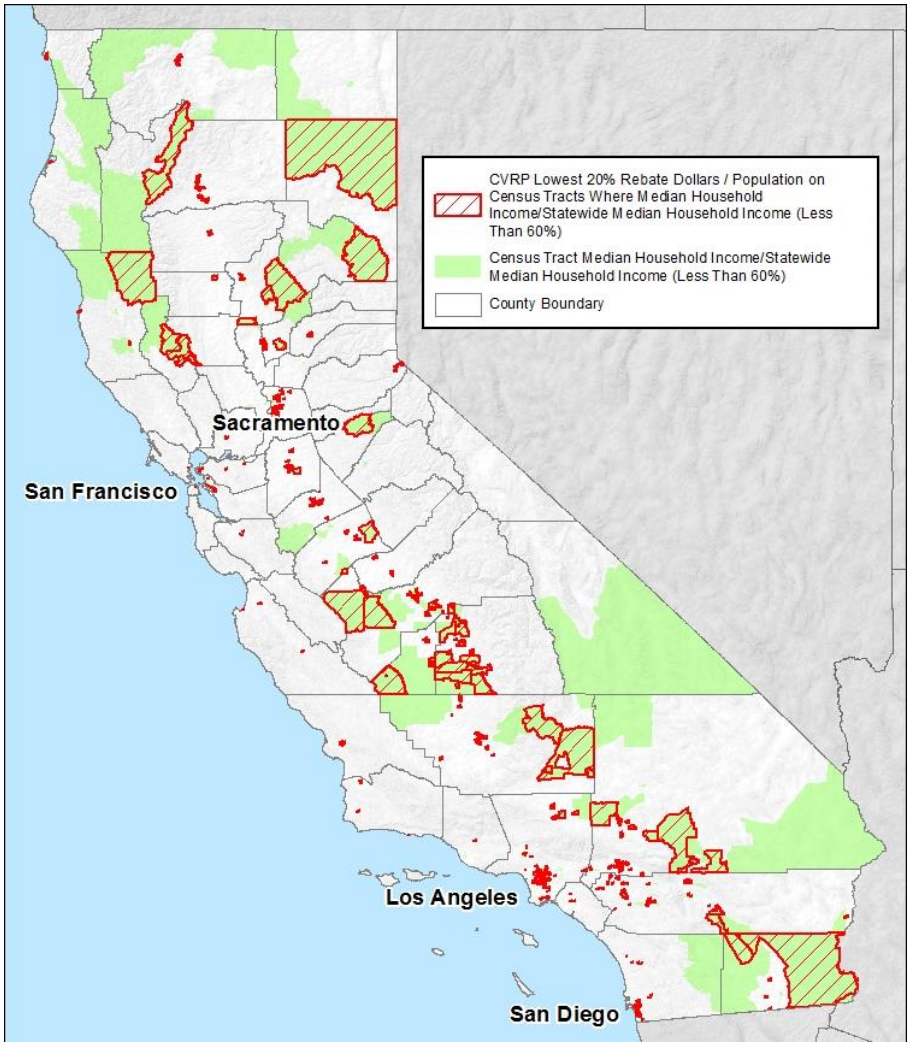
284 Scavo, Jordan, Suzanne Korosec, Esteban Guerrero, Bill Pennington, and Pamela Doughman. 2016. *Low-Income Barriers Study, Part A: Overcoming Barriers to Energy Efficiency and Renewables for Low-Income Customers and Small Business Contracting Opportunities in Disadvantaged Communities.* California Energy Commission. Publication Number: CEC-300-2016-009-CMF, page 13. This statement is based on information provided in Drehobl, Ariel and Lauren Ross. 2016. *Lifting the High Energy Burden in America's Largest Cities: How Energy Efficiency Can Improve Low-Income and Underserved Communities.*

285 https://caenergy.maps.arcgis.com/apps/MapJournal/index.html?appid=d081a369a0044d77ba8e80d2ff671c93.

Figure 22: Clean Vehicle Rebate Program Incentive Opportunities in Low-Income Areas



Source: https://caenergy.maps.arcgis.com/apps/MapJournal/index.html?appid=d081a369a0044d77ba8e80d2ff671c93

The health and safety issues abated indicator includes maps that show areas of overlap between emergency room visits due to asthma and low investment from investor-owned utility energy efficiency programs. These data highlight locations, many of which are in the Central Valley, that may see better health outcomes as a result of increased investment. In addition, the data show many counties with high levels of heat-related illness also have higher numbers of utility non-CARE disconnections, indicating an opportunity for increased energy efficiency to lower energy burdens and targeted efforts to minimize disconnections during periods of extreme heat.

CARB's One-Stop Shop Pilot Project

CARB, in consultation with supporting agencies and the public, is working to increase access and awareness for low-income residents on clean transportation and mobility options. CARB's efforts concentrate on expanding education and outreach and

developing a single application for CARB's low carbon transportation equity programs. The One-Stop-Shop Pilot Project will focus initially on low-carbon transportation equity programs and will be expanded to include additional consumer-based clean transportation, clean energy, and other related incentive programs.

CARB has up to $5 million in Volkswagen Settlement[286] funds available to develop and deploy a single application for low-income consumers to apply and qualify for CARB's Low Carbon Transportation Equity Projects, and to provide coordinated community-based outreach in disadvantaged communities, low-income communities, and low-income households. In August 2018, CARB selected Grid Alternatives to provide these services. CARB's one-stop-shop grant agreement is anticipated to be executed by September 2018, with a program launch expected in mid-2019.

In addition to the one-stop shop pilot, Recommendation 4 also called on CARB to increase awareness of clean transportation and mobility options, including the development of a clean transportation access targeted outreach plan. CARB has compiled feedback on outreach and best practices in engaging with communities, as well as identified goals and recommendations to be included in the outreach plan. An external working group and a stakeholder advisory group have been formed and meet regularly to monitor progress and provide input on plan development. CARB plans to release a public draft of the plan, solicit public feedback, and finalize in early 2019.

Clean Transportation Community Needs Assessment

The California Department of Transportation (Caltrans), in consultation with other agencies, is working to expand assessments of low-income residents' transportation and mobility needs. It has been working closely with regional and local governments to describe plans for expanding assessments in communities and has solicited feedback for how this can be achieved. Caltrans is also coordinating closely with CARB to allow needs assessment considerations to be included in the September 2018 Senate Bill 150 (Allen, Chapter 646, Statutes of 2017) report to the Legislature on regional changes in GHG emissions related to SB 375 implementation.

Caltrans anticipates significant progress on the following activities in the coming year:

- Beginning education and outreach within Caltrans and with CTC and external agency partners on SB 350 and Caltrans-led priority actions
- Updating the Sustainable Transportation Planning Grant guidelines for the 2019 grant award cycle

286 To remedy the harm caused from the use of illegal emission test defeat devices, Volkswagen agreed to a series of penalties and investments for the benefit of the people of California. Volkswagen will pay $422 million to address excess nitrous oxide emissions, $153.8 million in civil penalties, and $25 million for low-income consumer vehicle replacement programs. In addition, Volkswagen, through its subsidiary Electrify America, will invest $800 million over a 10-year period in zero-emission vehicle-related projects in California.

- Establishing policy and technical advisory committees for the California Transportation Plan 2050 and including representatives from low-income and disadvantaged community-based organizations and tribal communities
- Completing tribal listening sessions, focus groups, and scenario development workshops
- Kicking off the Caltrans district pedestrian and bicycle plans contract and beginning public outreach, including specific outreach to disadvantaged and low-income communities in each district.

Expanding Economic and Workforce Training and Development

The California Workforce Development Board, in consultation with a broad range of state agencies and stakeholders, is convening a series of climate and job discussions related to the development of the Assembly Bill 398 (Garcia, Chapter 135, Statutes of 2017) workforce report. The report will address labor market strategies to achieve the state's climate goals while ensuring that all Californians can access benefits of a low-carbon economy.

These conversations allow the state to plan for economic and workforce development in a low-carbon economy. One of the key goals of this effort is to determine how California can advance equity, mobility, and job quality and skills for workers; deliver skills and competitiveness for employers; and address the challenges of climate change throughout the economy. The California Workforce Development Board is developing an action plan to address these challenges.

Directed Research and Development Funding to Low-Income Customers and Disadvantaged Communities

Assembly Bill 523 (Reyes, Chapter 551, Statutes of 2017) was signed into law in October 2017, requiring 25 percent of all Energy Commission's Electric Program Investment Charge (EPIC) Technology Demonstration and Deployment (TD&D) funding to support projects with sites located in and benefiting disadvantaged communities. AB 523 also specifies that an additional 10 percent of funding must be spent at sites located in and benefitting low-income communities[287] and that the Energy Commission consider localized health impacts to the extent possible when making EPIC funding decisions. In 2017, 32 percent of EPIC TD&D funding was allocated to 97 project sites in disadvantaged communities, exceeding the 25 percent goal.[288] As of August 2018, 41 percent of EPIC's TD&D funding encumbered in 2018 has gone to projects in disadvantaged communities.

287 Defined as census tracts with median household incomes at or below 80 percent of the statewide median income or the applicable low-income threshold defined by the Department of Housing and Community Development.

288 http://www.energy.ca.gov/2018publications/CEC-500-2018-005/CEC-500-2018-005-CMF.pdf.

Bringing New Clean Energy Technology Solutions and Related Benefits to Disadvantaged and Low-Income Communities

Effectively sealing the envelope of a home — including the roofs, walls, and floors — can go a long way toward improving energy efficiency and comfort. However, sealing the envelope can be a difficult, labor-intensive, and not always effective process typically involving caulk, spray foam, weather stripping, or other materials.

In 2012, the Energy Commission awarded funding to the UC Davis Western Cooling Efficiency Center to develop a portable automated process for sealing gaps and tightening the envelope of a building.[289] Now called AeroBarrier, the system sprays a cloud of waterborne acrylic sealant droplets that coagulate around a leak until they seal it. In less than three hours, a two-person team was able to reduce the air leakage of a 2,200-square-foot, three-bedroom house by an additional 68 percent over what was accomplished by traditional sealing methods that required more than 20 hours of labor. Tests showed that AeroBarrier can seal holes as tiny as a human hair and as large as a half-inch across, and tests show it can reduce leakage by up to 90 percent in new buildings.

AeroBarrier was awarded the 2018 Most Innovative Building Product and Best in Show by the National Association of Homebuilders in January 2018 and is being called the decade's most disruptive energy efficiency product.[290] AeroBarrier hit the commercial market in January 2018 after five years of research and development supported by the Energy Commission's Public Interest Energy Research Program and the Department of Energy's Building America program. During this period, AeroBarrier was tested in new and retrofitted single-family and multifamily housing, including homes built by Habitat for Humanity and retrofits to improve multifamily buildings in disadvantaged communities.

Address Barriers in Rural Communities

California's rural communities face unique challenges to accessing clean energy and transportation technologies, including remote location and aging or limited energy infrastructure. Yet efforts in the San Joaquin Valley highlight an opportunity to use clean and affordable energy options in place of dirtier alternatives in rural areas.

In December 2018 the CPUC passed Decision 18-12-015 (proceeding R.15-03-010), approving $56 million in funding for 11 pilot projects to replace propane and wood-burning appliances in disadvantaged communities in the San Joaquin Valley. Many residents in these communities lack access to natural gas infrastructure. The pilot projects will be compare the option of extending natural gas lines to electric alternatives that can provide clean and affordable energy to these communities. These projects have

289 More information available at https://wcec.ucdavis.edu/wp-content/uploads/2013/01/WCEC_Case-Study-Aeroseal_2010-10.pdf.

290 "The 2018 Most Innovative Building Product Goes to AeroBarrier," https://www.prnewswire.com/news-releases/the-2018-most-innovative-building-product-goes-to-aerobarrier-300581832.html.

a budget of $48.2 million and will be administered by PG&E and SCE. SoCalGas was allocated $6.1 million for natural gas pilots in three communities. These pilots, along with relevant data collection, will inform an economic feasibility study, as required by Assembly Bill 2672 (Perea, Chapter 616, Statutes of 2014).

Tribal Collaboration

The Energy Commission has a strong commitment to engage and collaborate with California tribes. In September 2011, then-Governor Brown issued Executive Order B-10-11, which directed state agencies and departments to engage in effective government-to-government cooperation, collaboration, communication, and consultation with tribes concerning the development of legislation, regulations, rules, and policies. In furtherance of this commitment, the Energy Commission adopted a Tribal Consultation Policy on December 10, 2014, and an updated policy on December 13, 2017.[291] The Energy Commission's engagement has included consultation, outreach, information sharing, renewable energy planning, and research.

The SB 350 Barriers Study also afforded special attention to tribal communities and communities not served by utilities. During the April 20, 2018, IEPR workshop on the North Coast Regional Energy Perspective, which was held in Arcata (Humboldt County) and focused on energy opportunities and challenges in the North Coast, Peggy O'Neill, planning director for the Yurok Tribe, described the ongoing energy challenges at the Yurok Reservation. Roughly 50 percent of the tribe's residents do not have access to reliable electricity, although the tribe's efforts to electrify date back to 2000. Further, off-grid residents pay a disproportionate share of annual income for gas generators, propane appliances, wood stoves, propane, kerosene, and wood fuel.[292] Some of the barriers the Yurok face to access clean electricity include economic challenges, legal roadblocks to building energy infrastructure, and technical hurdles (such as shaded, mountainous terrain).

To strengthen existing relationships, share information, and advance government-to-government cooperation, the Energy Commission cohosted the California Tribal Energy Forum November 26-28, 2018, in Temecula, California. The Energy Commission sponsored the summit alongside the Pechanga Band of Luiseno Indians, the Governor's Office of the Tribal Advisor, and the CPUC. The California Independent System Operator also participated. The goal of the Tribal Energy Summit was to initiate or advance dialogue between California Native American tribes and the state's energy agencies. The event focused on state energy functions, programs, and services, and exhibiting areas where tribes have previously participated or have an opportunity to participate. There were approximately 120 participants representing 30 tribes and 5 state agencies. A staff summary report will document the event, key findings, and recommendations.

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291 http://www.energy.ca.gov/tribal/documents/2017CEC_Tribal_Consultation_Policy.pdf.

292 https://efiling.energy.ca.gov/GetDocument.aspx?tn=223274.

Next Steps

State agencies will move forward with planning and implementation of the efforts outlined in SB 350 and the *Barriers Study Part A and Part B* to increase access to clean energy and clean transportation technologies and programs. In 2019, state agencies will coordinate with the new administration to identify best path forward to continue these efforts.

CLIMB Action Plan

The Energy Commission, in coordination with five principal agencies, developed the *CLIMB Action Plan*, which was released in August 2018. The agencies will work to prioritize the actions identified in the plan and implement them.

Energy Equity Indicators

In June 2018, the Energy Commission released the *Tracking Progress Report for Energy Equity,*[293] which is designed to help identify opportunities to improve access to clean energy technologies and increase clean energy investment in low-income and disadvantaged communities. The energy equity tracking progress report will be updated annually and will serve as a mechanism to monitor performance of state-administered clean energy programs in low-income and disadvantaged communities across the state. The Energy Commission also developed an accompanying interactive Web map that will allow various data-viewing options to support ongoing research and program evaluation.

Clean Energy Workforce Development

The California Workforce Development Board hosted a series of nine consultation meetings throughout July and August 2018 to address labor market strategies for achieving the state's climate goals in a way that benefits all Californians. It will use the information gathered during meetings to support the development of a state plan for economic and workforce development in a low-carbon economy, scheduled for release in January 2019.

Stakeholder Engagement

The Governor's interagency task force, composed of more than 15 state agencies, met through the end of 2018 to ensure coordination across agencies. Lead agencies will work with the new administration to determine the path forward for continued implementation of the recommendations. The Disadvantaged Community Task Force will continue to engage with community-based organizations to ensure programs are reaching and benefiting low-income and disadvantaged communities as intended. Furthermore, CARB plans to release a draft outreach roadmap in early 2019 to identify best practices for outreach and engagement with local communities.

293 https://efiling.energy.ca.gov/GetDocument.aspx?tn=223922.

Community Solar

Both the CPUC and CSD will continue implementation of their community solar programs to enable the economic advantages of solar to be readily accessible to low-income and disadvantaged populations across California. As a next step, investor-owned utilities will file tariffs for CPUC's CSGT program. CSD anticipated the contract start date for the Community Solar Pilot Program is early 2019.

CHAPTER 5: Climate Adaptation and Resiliency

California is an international leader in advancing solutions to climate change and forward-looking energy policies. The state's work to reduce greenhouse gas (GHG) emissions and increase resiliency to climate change are founded on scientific assessments, such as *California's Fourth Climate Change Assessment*.[294] The assessment was developed to inform policies, plans, programs, and guidance to safeguard California from the effects of climate change. This chapter provides highlights on the impacts of climate change on California's energy system, as identified in *California's Fourth Climate Change Assessment*, and on recommendations for advancing former Governor Edmund G. Brown Jr.'s call to expand state adaptation activities.

In Executive Order B-30-15, then-Governor Brown directed California state agencies to integrate climate change into all planning and investment, including accounting for current and future climate conditions in infrastructure investment. State law also requires local governments to account for climate change when updating general plans.

Recent IPCC and Federal Climate Reports

In October 2018, the Intergovernmental Panel on Climate Change (IPCC) released a special report on global warming of 1.5 degrees Celsius. It shows that limiting global warming to 1.5°C (2.7 ° F) significantly reduces the impacts of climate change and avoids the catastrophic consequences of greater than 2°C (3.6 ° F) warming. To avoid going past 1.5°C warming, IPCC found that by 2030, global carbon dioxide emissions must decline by about 45 percent below 2010 levels and reach net zero by about 2050. The then-Governor's executive order calling for carbon neutrality by 2045 is consistent with the IPCC findings.

In November 2018, the U.S. Global Change Research Program published a report on the impacts, risks, and adaptation of climate change in the United States. A key finding is the need to expand climate adaptation and GHG reduction efforts: "Communities, governments, and businesses are working to reduce risks from and costs associated with climate change by taking action to lower greenhouse gas emissions and implement adaptation strategies. While mitigation and adaptation efforts have expanded substantially in the last four years, they do not yet approach the scale considered necessary to avoid substantial damages to the economy, environment, and human health over the coming decades."

Sources: IPCC, 2018: Summary for Policymakers. In: Global warming of 1.5°C. [V. Masson-Delmotte, P. Zhai, H. O. Pörtner, D. Roberts, J. Skea, P. R. Shukla, A. Pirani, W. Moufouma-Okia, C. Péan, R. Pidcock, S. Connors, J. B. R. Matthews, Y. Chen, X. Zhou, M. I. Gomis, E. Lonnoy, T. Maycock, M. Tignor, T. Waterfield [eds]). World Meteorological Organization, Geneva, Switzerland, 32 pp.

USGCRP, 2018: Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II (Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T.K. Maycock, and B.C. Stewart [eds.]). U.S. Global Change Research Program, Washington, DC, USA, 1515 pp. doi: 10.7930/NCA4.2018.

294 http://www.climateassessment.ca.gov/.

Continued state and stakeholder actions are critical to addressing major climate risks like sea-level rise, drought, extreme heat, extreme storms, subsidence, and others that may impact the state's communities and energy system, recognizing there are different vulnerabilities in the natural gas and electricity sectors. However, in response to the ongoing recovery effort from the 2017 wildfires and the terrible impact of the wildfires in 2018, this year's *Integrated Energy Policy Report* (*IEPR*) focuses attention on actions to address wildfire impacts on the electricity sector.

Extreme Wildfire in California: 2018 Was Worse Than 2017

In November 2018, the Camp Fire burned Paradise (Butte County), and caused days of unhealthy air in large sections of Northern California. To ensure safety, natural gas service remains down in much of the Paradise area, even where power has been restored. As of December 14, 2018, the California Department of Forestry and Fire Protection (CAL FIRE) reported that the fire had burned more than 150,000 acres, destroyed more than 18,800 structures, and caused 86 deaths, making it by far the deadliest and most destructive fire in state history. The second-most destructive California fire occurred in October 2017 (Tubbs Fire); it destroyed about 5,600 structures, less than a third of the number of structures destroyed in the Camp Fire. The largest California fire, the July 2018 Mendocino Complex fire, burned more than 450,000 acres. Previously, the largest California wildfire (the December 2017 Thomas Fire) burned about 280,000 acres.

In September 2018, former Governor Brown signed a package of new laws to greatly expand resources available to manage vegetation and take other steps to help reduce the occurrence of catastrophic wildfire. Key new laws to address wildfires include:[295]

- Senate Bill 901 (Dodd, Chapter 626, Statutes of 2018).
- Senate Bill 1260 (Jackson, Chapter 624, Statutes of 2018).
- Assembly Bill 2911 (Friedman, Chapter 641, Statutes of 2018).

On August 2, 2018, the California Energy Commission conducted a joint agency workshop with the California Public Utilities Commission (CPUC), the California Natural Resources Agency, the Governor's Office of Planning and Research (OPR), and

2018 Wildfire Legislation: Insurance Figures Prominently

In September 2018, Governor Brown signed 29 bills into law to strengthen wildfire prevention and recovery in California.

The legislation includes a number of new insurance requirements related to innovation (SB 30 Lara), renewal (SB 824 Lara; SB 894 Dodd), coverage (SB 917 Jackson; AB 1800 Levine; AB 1875 Wood), benefits (SB 1261 Nielsen; AB 1772 Aguiar-Curry), and other topics (AB 2594 Friedman).

Other legislation addressed fire prevention, including vegetation clearance (SB 901 Dodd; AB 2911 Friedman; SB 1079 Monning; AB 2126 Eggman), planning (SB 1260 Jackson; AB 2889 Caballero), and prescribed burns (AB 1956 Limon; AB 2091Grayson; AB 2551 Wood). The grant program established by AB 1956 (Limon) will also fund retrofitting structures to increase fire resistance.

A third group of bills focused on markets for innovative forest products (AB 1981 Limon; AB 2518 Aguiar-Curry) consistent with the state's climate objectives.

Other bills address emergency services (SB 821 Jackson; SB 833 McGuire; SB 1181 Hueso; AB 1877 Limon) and other fire-related topics (SB 896 McGuire; SB 969 Dodd; AB 1919 Wood; AB 2380 Aguiar-Curry). AB 2990 (Low) provides free tuition and fees at California's state colleges and universities for surviving dependents of a deceased firefighter.

295 https://www.google.com/amp/www.latimes.com/politics/la-pol-ca-wildfire-prevention-law-signed-20180921-story.html%3foutputType=amp.

the Governor's Office of Emergency Services to discuss changes in the risk of wildfire in California due to climate change and how the energy sector can prepare.[296] On August 30, 2018, the Energy Commission held a research workshop as part of the IEPR proceeding to discuss key energy-related findings from *California's Fourth Climate Change Assessment*. This chapter is informed by discussion at these workshops.

This chapter focuses on resilience and public safety related to climate-change impacts on wildfire and the energy sector. The chapter includes:

- An overview of California's international leadership on climate change.
- An update of technologies to help prevent potential wildfire ignition sources.
- Discussion of plans to incorporate the impact of climate change on wildfire risk into planning for natural and working lands.
- An update of regulatory processes at the CPUC related to climate adaptation and wildfires, including the potential for utilities to de-energize areas when extreme wind conditions are forecast.
- Discussion of climate change impacts and preparations addressing wildfire-related risks for vulnerable populations, critical facilities, and energy infrastructure.

2018 Climate Related Bills

SB 1013 (Lara, Chapter 375). In the face of federal reversals, this bill provides a critical backstop to ensure California does not backslide on lowering emissions of hydrofluorocarbons and achieves its short-lived climate pollutant reduction goals. The bill also creates the Fluorinated Gases Emission Reduction Incentive Program for low-global warming potential refrigerants.
SB 1072 (Leyva, Chapter 377). This bill establishes a regional climate collaborative program to assist under-resourced communities with accessing statewide public and other grant money for climate change mitigation and adaptation-related projects. The bill also requires the Strategic Growth Council to develop technical assistance best practices that state agencies may use and identify state grants that could benefit from technical assistance best practices.
SB 1477 (Stern, Chapter 378). This bill establishes two incentive programs aimed at reducing emissions from buildings – one to provide financial incentives for the deployment of near-zero emission building technologies and a second to offer incentives for the installment of low-emission space and water heating equipment for new and existing buildings.
AB 3232 (Friedman, Chapter 373). This bill requires state agencies to assess the potential for California to reduce emissions of GHGs from residential and commercial buildings.

For a more complete listing of these and other bills signed by the former Governor to address climate change, see https://www.globalclimateactionsummit.org/aboard-hybrid-electric-ferry-on-the-san-francisco-bay-governor-brown-signs-bills-to-promote-zero-emission-vehicles-reduce-carbon-emissions/.

California Continues Its Role as an International Leader

California continues to lead the nation and the world on climate policy. As has been reported in previous *IEPRs*, on September 8, 2016, former Governor Brown committed the state to reducing GHG emissions 40 percent below 1990 levels by 2030 by signing Senate Bill 32 (Pavley, Chapter 249, Statutes of 2016). The state is also committed to ensuring that implementation of its climate change policies is transparent and equitable, with

296 http://www.energy.ca.gov/2018_energypolicy/documents/#08022018.

benefits reaching disadvantaged communities, as required in Assembly Bill 197 (Garcia, Chapter 250, Statutes of 2016). (See Chapter 1 for more energy policy background and Chapter 4 for discussion of energy equity.)

California took additional groundbreaking steps to address climate change on September 10, 2018. Then-Governor Brown signed into law Senate Bill 100 (De León, Chapter 310, Statutes of 2018). (See sidebar *"2018 Climate Related Bills"* for additional legislation to address climate change.) SB 100 requires that by 2045, 100 percent of the retail sales of electricity in California be from eligible renewable energy and zero-carbon resources, without increasing carbon emissions elsewhere in the western grid. (See Chapter 3.) That same day, then-Governor Brown signed Executive Order B-55-18 with an even more ambitious policy of achieving a new statewide goal of carbon neutrality (zero net GHG emissions) by 2045, and achieving and maintaining net negative emissions thereafter. The executive order covers all sectors of the economy and includes consideration of carbon sequestration in natural and working lands. Executive Order B-55-18 follows the spirit of what is required at a global scale to achieve the climate goals of the Paris Agreement.[297] The executive order notes that "scientists agree that worldwide carbon pollution must start trending downward by 2020, and carbon neutrality — the point at which the removal of carbon pollution from the atmosphere meets or exceeds emissions — must be achieved by midcentury."[298]

Global Climate Action Summit

Former Governor Brown spearheaded the Global Climate Action Summit to step up the momentum of the Paris Agreement to limit global warming to well below 2 degrees Celsius. The summit resulted in a call to action for more ambitious commitments to address climate change ahead of 2020, the year that global greenhouse gas emissions must begin to fall sharply to avoid the worst impacts of climate change. Held in September 2018 in San Francisco, the summit brought together over 5,000 participants from 103 countries and resulted in more than 500 new commitments for a climate-safe future for all, including:

- Over 100 mayors, state and regional leaders, and CEOs have committed to becoming carbon neutral by 2050 in accord with the Paris Agreement.
- 488 businesses will set science-based targets to ensure that they help advance the climate solution.
- More than 60 CEOs, state and regional leaders and mayors are committed to delivering a 100 percent zero emission transportation fuel by 2030.
- 38 cities, major businesses, state and regional governments have committed to net-zero carbon buildings.
- More than 100 indigenous groups, state and local governments, and businesses launched a forest, food, and land-focused coalition to deliver 30 percent of climate solutions needed by 2030.
- Nearly 400 investors, with $32 trillion under management, committed to increase their low-carbon investments by 50 percent by 2020 which is equivalent to about $6.2 billion.

Source: https://www.globalclimateactionsummit.org/call-to-action/

297 The Paris Agreement set a target of no more than 2 degrees Celsius warming, with a goal of 1.5 degrees, to avoid catastrophic climate change. For more information, see http://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf.

298 https://www.gov.ca.gov/wp-content/uploads/2018/09/9.10.18-Executive-Order.pdf.

Recognizing that emission reductions in California are not enough to avert catastrophic climate change, what former Governor Brown calls the "existential threat of our time," the state continues to spearhead international action to reduce GHG emissions. For example, then-Governor Brown helped spur the Under2 Coalition, a coalition of subnational entities that have agreed to limit GHG emissions 80 to 95 percent below 1990, or limit to 2 annual metric tons of CO_2 equivalent per capita, by 2050. The coalition includes more than 220 governments spanning six continents and 43 countries.[299]

Former Governor Brown has signed accords with leaders from Mexico, China, Japan, Israel, Peru, Chile, the Netherlands, and others to reduce GHG emissions.[300] He was a leader at the 2015 United Nations Climate Change Conference in Paris and appointed the Special Advisor for States and Regions ahead of the 2017 United Nations Climate Change Conference. In July 2017, he announced that California would host a Climate Action Summit in San Francisco in September 2018 to strengthen the push for greater emissions reduction targets at the United Nations Framework Convention on Climate Change's 24th Conference of the Parties (COP 24). (See sidebar on *Climate Action Summit*.) At COP 24 in December 2018, leaders adopted a set of guidelines known as the Katowice Climate Package, which is needed to implement the 2015 Paris Climate Change Agreement.[301]

Energy-Related Climate Science Available From Cal-Adapt

Focusing on California, each region of the state will experience a different combination of impacts. *California's Fourth Climate Change Assessment* provides information about climate impacts that local governments and metropolitan areas can use to update planning to take climate change into account.

As discussed in the *2017 IEPR*, Cal-Adapt is an Energy Commission-funded climate science-sharing tool that provides free access to high-quality climate projections regarding the impacts of climate change at the local level in California.[302] Developed by University of California, Berkeley's, Geospatial Innovation Facility, with initial support from Google, Cal-Adapt includes interactive maps of projected scenarios and impacts, including charts showing projections for extreme heat (Figure 23), wildfire, drought, sea-level rise, and other variables. Data from Cal-Adapt can be downloaded in several formats or accessed through an application programming interface. It serves as a key

299 For the latest statistics, see http://under2mou.org/.

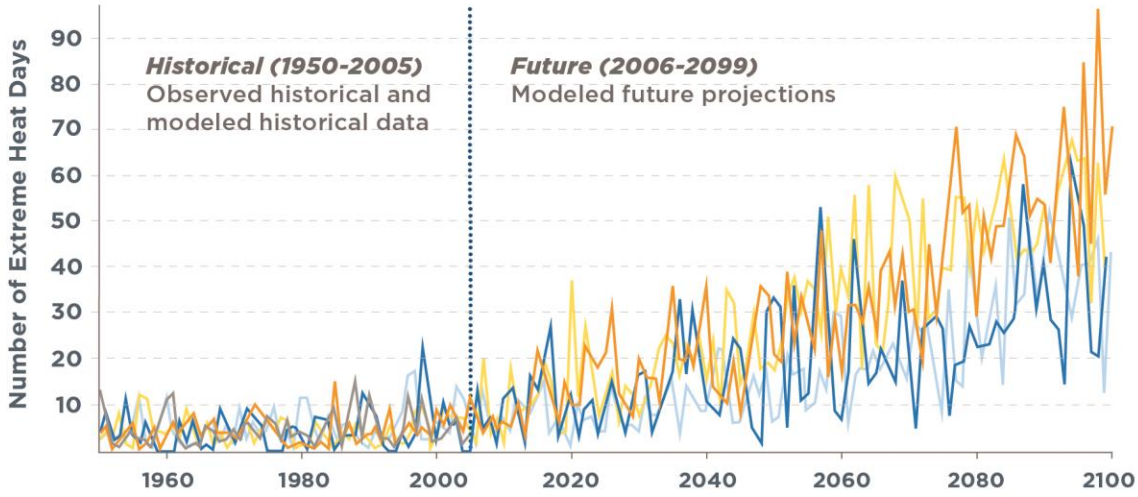
300 http://www.climatechange.ca.gov/climate_action_team/partnerships.html.

301 https://unfccc.int/news/new-era-of-global-climate-action-to-begin-under-paris-climate-change-agreement-0.

302 For more information, see https://cal-adapt.org.

resource to support local hazard mitigation efforts, energy sector planning, and climate-change adaptation.

Figure 23: Days/Year With Projected Sacramento Maximum Temperature Above 103.8 Degrees Fahrenheit (RCP 8.5 Scenario: Emissions Rise Strongly Through 2050, Plateau Around 2100)



Source: Cal-Adapt. Data: Localized Constructed Analogs (LOCA) Downscaled Climate Projections (Scripps Institution of Oceanography), Gridded Historical Observed Meteorological and Hydrological Data (University of Colorado, Boulder).

Cal-Adapt includes updated climate scenarios from *California's Fourth Climate Change Assessment*. As of September 2018, data visualization tools on the following topics are available from Cal-Adapt: annual average maximum temperature, minimum temperature, and precipitation; extreme heat; sea-level rise; snowpack; wildfire; cooling degree days and heating degree days; streamflow; and extended drought.

Data on the following topics are also available for download from Cal-Adapt (and many datasets are also available through the public Cal-Adapt Application Programming Interface):

- Temperature, precipitation, relative humidity, and solar radiation: LOCA downscaled projections and gridded observed data for temperature and precipitation; LOCA downscaled climate projections for relative humidity; incoming solar radiation downscaled using LOCA downscaled temperature and precipitation.
- Snowpack, long drought scenarios, and streamflow: snowpack information generated through the use of the variable infiltration capacity (VIC) model forced by LOCA; downscaled climate projections and gridded observed data; and long-

term drought, streamflow, and additional climate variables generated through the VIC model.

- Wildfire: Projections of annual averages of area burned in California.
- Sea-Level Rise: CalFloD-3D computer model (inundation depths for the San Francisco Bay Area, Sacramento-San Joaquin Delta, and the California coast during near 100-year storm events coupled with projected sea-level-rise scenarios); hourly sea-level projections from RCP 4.5 and RCP 8.5 using sea-level-rise projections at the 50th, 95th, and 99.9th percentiles.

New energy-related tools and data sets are introduced to Cal-Adapt with guidance from the Energy Commission, which manages grants development of energy-related elements of Cal-Adapt. To foster coordination with other agencies and processes, the Energy Commission considers input from the interagency Climate Action Team Research Working Group, the Cal-Adapt technical advisory committee, and specific agencies (such as OPR) with whom it is important for Cal-Adapt to harmonize.[303] Data sets and information available in Cal-Adapt, at a minimum, must have passed peer review. Going forward, other state agencies providing funding for non-energy impacts are expected to follow a similar vetting process.

An Update on Science Addressing Climate Change Impacts for Temperature Variation and Extremes

On August 27, 2018, OPR, the California Natural Resources Agency, and the Energy Commission released *California's Fourth Climate Change Assessment*. The compilation of original climate research includes 44 technical reports and 13 summary reports on climate change impacts to help prepare the state for a future punctuated by severe wildfires, more frequent and longer droughts, decreasing snowpack, rising sea levels, increased flooding, coastal erosion, and extreme heat. The peer-reviewed research translates global models into scaled-down, regionally relevant reports to fill information gaps and support decisions at the local, regional, and state levels (Figure 24). *California's Fourth Climate Change Assessment* underscores the need to acknowledge the climate is changing now (Figure 25) and the need to act now to adapt and safeguard communities from these climate challenges, particularly vulnerable populations that will be disproportionately affected.

303 Members of the Cal-Adapt technical advisory committee are listed on the Cal-Adapt Web page at https://cal-adapt.org/about/. The Web page lists technical advisory committee members from the following organizations: CPUC, California ISO, California Energy Commission, California Department of Water Resources, OPR, Cal OES, SCE, Sempra, PG&E, SMUD, the Local Government Commission, the Sierra Business Council, and Ascent Environmental.

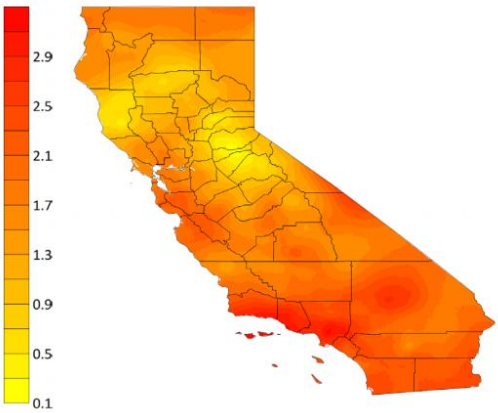
Regional climate collaboratives in California are helping raise awareness of *California's Fourth Climate Change Assessment* and advance planning and resilience across California.[304]

Figure 24: *California's Fourth Climate Change Assessment*

KEY FINDINGS	A concise summary of the Fourth Assessment's most important findings and conclusions.
STATEWIDE SUMMARY	An in-depth report on how California's people, built environment, and ecosystems will be impacted by climate change and how we can proactively adapt, based on the Fourth Assessment's findings.
SUMMARIES FOR REGIONS AND COMMUNITIES	Reports summarizing Fourth Assessment findings to provide a state of the science for nine regions, the ocean and coast, tribal communities, and climate justice in California.
ORIGINAL RESEARCH TO INFORM POLICY AND ACTION	Academic research that provides robust and detailed results on resilience and vulnerability to climate change.
ASSESSMENT FOUNDATION: UPDATED CLIMATE PROJECTIONS AND DATA	A shared foundation of updated climate change projections, data and ecosystem models developed for use by Assessment authors to permit cross-comparability of results and ensure the findings consider a robust range of future climate conditions. This data is available to the public via Cal-Adapt.org.

Source: California Natural Resources Agency

Figure 25: Historical Changes in Annual California Temperatures: 1901-1960 vs. 1986-2016 (Degrees Fahrenheit)

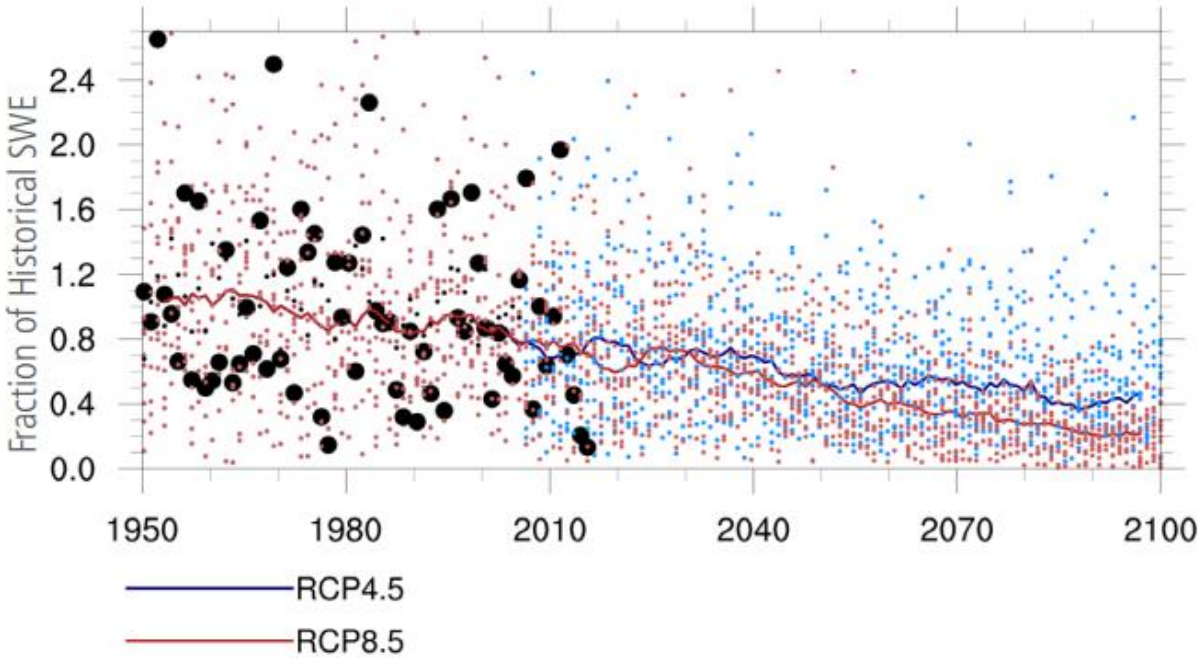


Source: Bedsworth, Louise, Dan Cayan, Guido Franco, Leah Fisher, Sonya Ziaja (California Governor's Office of Planning and Research, Scripps Institution of Oceanography, California Energy Commission, California Public Utilities Commission). 2018. *Statewide Summary Report. California's Fourth Climate Change Assessment*. Publication Number: SUM-CCCA4-2018-013. Data based on Vose, R. S., D. R. Easterling, K. E. Kunkel, A. N. LeGrande, M. F. Wehner. 2017. *Temperature changes in the United States. Climate Science Special Report: Fourth National Climate Assessment*, Volume I (Wuebbles, D.J., D.W. Fahey, K.A. Hibbard, D.J. Dokken, B.C. Stewart, and T.K. Maycock [Eds.]), 185–206. https://doi.org/10.7930/J0N29V45.

304 http://arccacalifornia.org/.

By 2050, the average water supply from California's Sierra snowpack is projected to decline by two-thirds from historical levels (Figure 26). Snowpack is a way to store low-carbon hydropower for use when it is valuable to the power system. For example, large hydropower provided about 15 percent of California's electricity in 2017. Models show management practices for California's large reservoirs could capture more water if adapted to changing timing and patterns of precipitation. If practices do not change, California is expected to have lower resilience to droughts.[305] With higher temperatures, California may experience more frequent and more intense droughts.[306]

Figure 26: Average Water Supply From Snowpack Is Declining in California



Source: Pierce, D. W., J. F. Kalansky, and D. R. Cayan, (Scripps Institution of Oceanography). 2018. *Climate, Drought, and Sea-Level Rise Scenarios for the Fourth California Climate Assessment*. California's Fourth Climate Change Assessment, California Energy Commission. Publication Number: CNRA-CEC-2018-006.

Climate change is expected to bring greater variability in precipitation. For example, the annual number of rainy days is expected to decline, but the risk of floods caused by large storms will increase, sometimes occurring in bursts over several weeks. With

305 Dettinger, Michael, Holly Alpert, John Battles, Jonathan Kusel, Hugh Safford, Dorian Fougeres, Clarke Knight, Lauren Miller, and Sarah Sawyer. (United States Geological Survey). 2018. *Sierra Nevada Summary Report. California's Fourth Climate Change Assessment*. Publication Number: SUM-CCCA4-2018-004.

306 Pierce, D. W., J. F. Kalansky, and D. R. Cayan, (Scripps Institution of Oceanography). 2018. *Climate, Drought, and Sea-Level Rise Scenarios for the Fourth California Climate Assessment*. *California's Fourth Climate Change Assessment*, California Energy Commission. Publication Number: CNRA-CEC-2018-006.

potentially larger storms, existing flood management practices and infrastructure will be challenged to meet the higher flows.[307]

Sea-level rise will amplify the impact of winter storms. Under mid to high sea-level rise scenarios, up to 67 percent of Southern California beaches may completely erode by 2100 without large-scale human interventions. Statewide damages could reach nearly $17.9 billion from inundation of residential and commercial buildings if sea-level rise reaches 20 inches, which is within range of midcentury projections. A 100-year coastal flood, on top of this level of sea-level rise, would almost double the cost of damages.[308] A study prepared for *California's Fourth Climate Change Assessment* provides guidance for designing and implementing natural infrastructure, such as vegetated dunes, marsh sills, and native oyster reefs, to adapt coastal communities to sea-level rise.[309]

The number of extreme heat days is expected to grow (Figure 27). Communities in the Central Valley, many of which are already impacted by high emergency room heat-related incidents, are projected to see more heat-health events (such as heat stroke or heat exhaustion) because of climate change.[310] Higher temperatures also mean there will be more extremes in electric energy demand, which will test the resiliency of California's grid.[311]

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307 AghaKouchak, Amir, Elisa Ragno, Charlotte Love, and Hamed Moftakhari. (University of California, Irvine). 2018. *Projected Changes in California's Precipitation Intensity Duration-Frequency Curves. California's Fourth Climate Change Assessment*. California Energy Commission. Publication Number: CCCA4-CEC-2018-005.

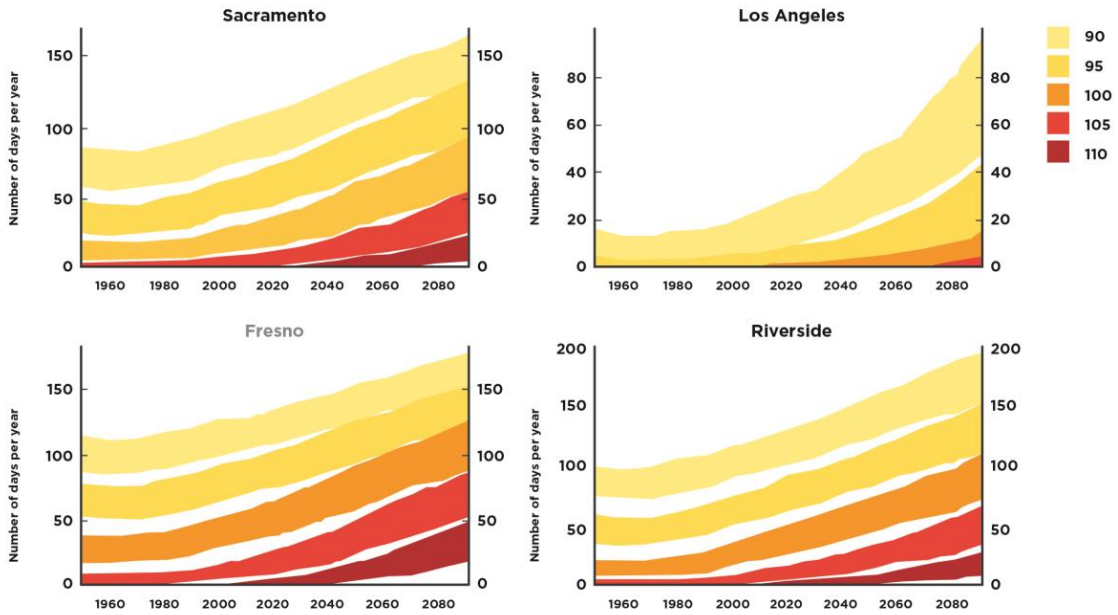
308 Bedsworth, Louise, Dan Cayan, Guido Franco, Leah Fisher, Sonya Ziaja. (California Governor's Office of Planning and Research, Scripps Institution of Oceanography, California Energy Commission, California Public Utilities Commission). 2018. *Statewide Summary Report. California's Fourth Climate Change Assessment.* Publication Number: SUM-8CCCA4-2018-013.

309 Newkirk, Sarah, Sam Veloz, Maya Hayden, Walter Heady, Kelly Leo, Jenna Judge, Robert Battalio, Tiffany Cheng, Tara Ursell, and Mary Small. (The Nature Conservancy and Point Blue Conservation Science). 2018. *Toward Natural Infrastructure to Manage Shoreline Change in California. California's Fourth Climate Change Assessment*. California Natural Resources Agency. Publication Number: CCCA4-CNRA-2018-011.

310 Steinberg, Nik, Emilie Mazzacurati, Josh Turner, Colin Gannon, Robert Dickinson, Mark Snyder, and Bridget Thrasher. (Four Twenty-Seven and Argos Analytics). 2018. *Preparing Public Health Officials for Climate Change: A Decision Support Tool. California's Fourth Climate Change Assessment*. California Natural Resources Agency. Publication Number: CCCA4-CNRA-2018-012.

311 Auffhammer, Maximilian. (University of California, Berkeley and NBER). 2018. *Climate Adaptive Response Estimation: Short- and Long-Run Impacts of Climate Change on Residential Electricity and Natural Gas Consumption Using Big Data. California's Fourth Climate Change Assessment*. Publication Number: CCCA4-EXT-2018-005.

Figure 27: Heat Waves Projected to Increase: Number of Days at Extreme Heat Threshold or Above (Degrees F) for RCP 8.5 Greenhouse Gas Emissions Scenario

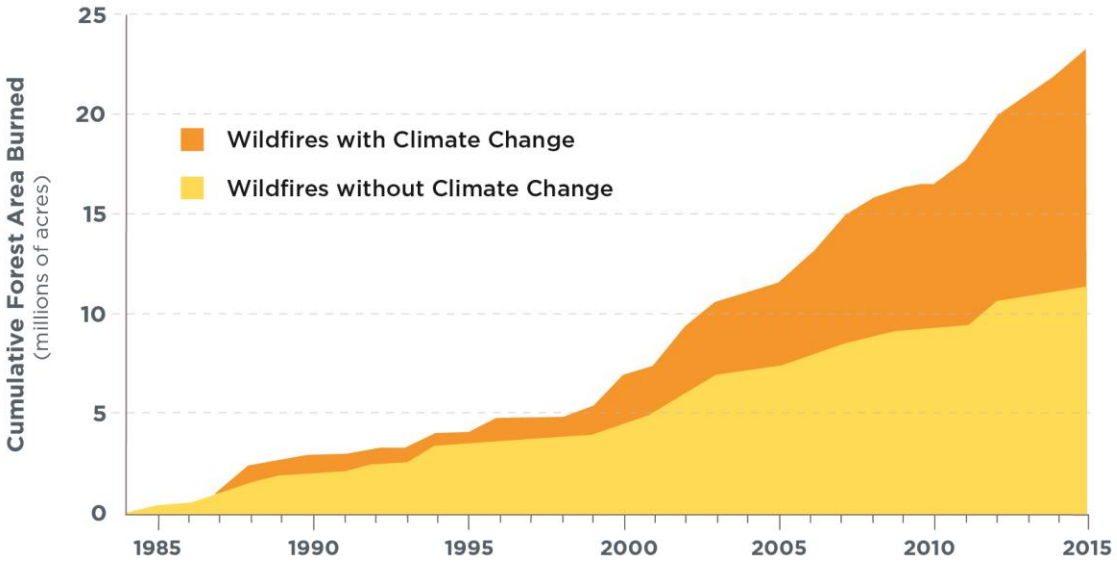


Source: D. Pierce, Scripps Institute of Oceanography

An Update on Science Addressing Climate Change Impacts for Wildfire in California

In November 2018, the U.S. Global Change Research Program released Volume II of the *Fourth National Climate Assessment*. The report includes findings from a scientific study on the impact of climate change on forest fires in the Western United States. The study estimates climate change doubled the cumulative acres burned between 1984 and 2015. (See Figure 28.)

Figure 28: Wildfire in the Western United States (1984–2015): Estimated Impact of Climate Change on Acres Burned



Source: Abatzoglou, J. T. and A. P. Williams, 2016: "Impact of Anthropogenic Climate Change on Wildfire Across Western US Forests." *Proceedings of the National Academy of Sciences of the United States of America,* 113 (42), 1177, as adapted in UGSCRP 2018: *Impacts, Risks, and Adaptation in the United States: Fourth National Climate Assessment, Volume II* (Reidmiller, D.R., C.W. Avery, D.R. Easterling, K.E. Kunkel, K.L.M. Lewis, T. K. Maycock, and B.C. Stewart [eds.]). U.S. Global Change Research Program, Washington, DC, USA, 1515 pp. doi: 10.7930/NCA4.2018.

As discussed below, as part of *California's Fourth Climate Change Assessment*, a 2018 study by Westerling at the University of California, Merced, projects climate change is expected to increase the number and frequency of extreme fires in California.[312] This section summarizes new climate science research to help strengthen preparation for climate change impacts in terms of California wildfires.

Wildfire Scenarios for *California's Fourth Climate Change Assessment*

Multiple factors affect wildfire regimes in California, and they must be considered in developing wildfire projections for the rest of this century. Human activities (for example, sparks from machinery and campfires, smoking, power lines, and arson) are responsible for the vast majority of wildfires in California,[313] but there are regional differences. Anthropogenic, or human-related, activities, account for more than 95 percent of the initiation of wildfires in Southern California and lightning for the rest.[314]

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312 Westerling, Anthony Leroy. (University of California, Merced). 2018. *Wildfire Simulations for California's Fourth Climate Change Assessment: Projecting Changes in Extreme Wildfire Events With a Warming Climate. California's Fourth Climate Change Assessment*. California Energy Commission. Publication Number: CCCA4-CEC-2018- 014.

313 Balch, J. K., B. A. Bradley, J. T. Abatzoglou, R. C. Nagy, E. J. Fusco, and A. L. Mahood. 2017. "Human-Started Wildfires Expand the Fire Niche Across the United States." PNAS. March 14, 2017 114 (11) 2946-2951. https://doi.org/10.1073/pnas.1617394114.

314 Syphard, A. D. and J. E. Keeley. 2015. "Location, Timing, And Extent of Wildfire Vary by Cause of Ignition." *International Journal of Wildland Fire*. Pp. 24, 37-47. January 13, 2015. http://dx.doi.org/10.1071/WF14024.

A recent analysis looking at data over the last 25 years suggests fire initiation by lightning is rare in Southern California, suggesting that human intervention has a major influence on wildfires in this region.[315]

Weather conditions also greatly influence wildfires. For example, high temperatures fuel wildfires and provide the clearest link between wildfire and climate change. Also, the Diablo winds of the San Francisco Bay Area and the Santa Ana winds in Southern California can drive extreme wildfire conditions.[316] Fuel availability is another factor that influences the evolution and intensity of wildfires. The relatively wet conditions in the winter of 2016 resulted in the buildup of vegetation that dried out in the summer and fall in Southern California. Rains came relatively late to wet vegetation during the Santa Ana winds in December 2017. Usually rains start late in October, and Santa Ana winds in December do not result in big wildfires, but, in this case, rains did not appear until January 2018. The result was the catastrophic Thomas Fire in December 2017, the largest fire in California history until the Mendocino Complex Fire in 2018.[317] Accurate wildfire projections must include realistic anthropogenic and natural causes of fires, weather conditions, and availability of fuels.

Wildfire scenarios for the rest of this century are available from several sources, but none were available for the specific land-use and land-cover changes and climate projections used for the Fourth Assessment. Professor Anthony Westerling with the University of California, Merced,[318] used the climate projections developed for the Fourth Assessment[319] and the changes in human footprint estimated by the U.S. Geological Survey[320] to develop a statistical model trained with historical data up to 2013. Westerling's model projects the area burned to increase with warming temperatures, especially in the Sierra Nevada.[321] Westerling assumed no major changes

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315 Bendiz, J. and J. J. Hartnett. 2018. "Asynchronous Lightning and Santa Ana Winds Highlight Human Role in Southern California Fire Regimes." *Environmental Research Letters. Environ. Res. Lett.* 13 (2018) 074024. https://doi.org/10.1088/1748-9326/aace39.

316 Guzman-Morales, J. 2018. "Santa Ana Winds of Southern California: Historical Variability and Future Climate Projections." (Unpublished doctoral dissertation). University of California San Diego, La Jolla, California. https://escholarship.org/uc/item/6hm499nj.

317 Balch, J., K., T. Shoenmagel, A. P. Williams, J. T. Abatzuglu, M. E. Cattau, N. P. Mietkiewicz, and L. A. St. Denis. 2018. "Switching on the Big Burn of 2017." *Fire.* 1,17. https://doi.org/10.3390/fire1010017. Also, see https://www.nytimes.com/2018/08/07/us/mendocino-complex-fire-california.html.

318 Westerling, Anthony Leroy. (University of California, Merced). 2018. *Wildfire Simulations for California's Fourth Climate Change Assessment: Projecting Changes in Extreme Wildfire Events With a Warming Climate. California's Fourth Climate Change Assessment*. California Energy Commission. Publication Number: CCCA4-CEC-2018-014.

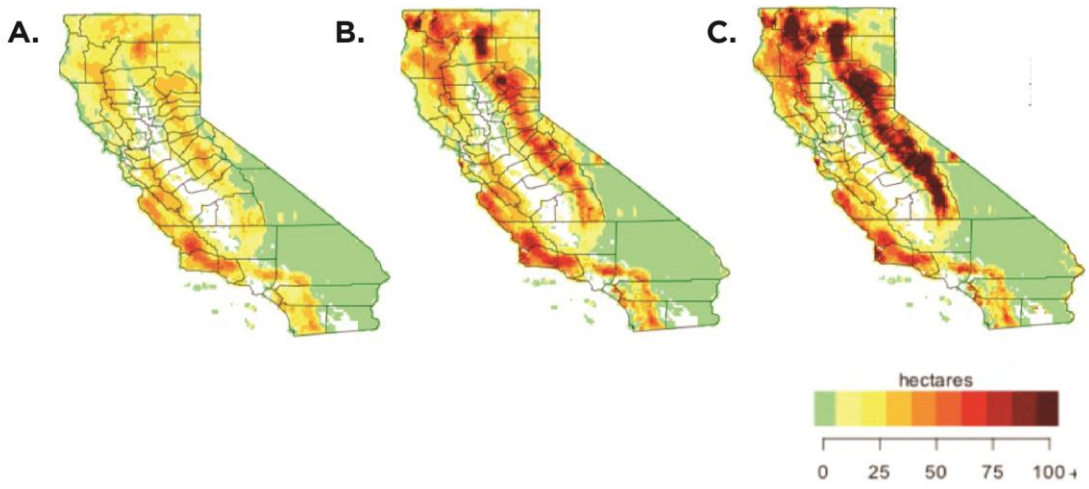
319 Pierce, David W., Daniel R. Cayan, Julie F. Kalansky. (Scripps Institution of Oceanography). 2018. *Climate, Drought, and Sea Level Rise Scenarios for the Fourth California Climate Assessment*. California's Fourth Climate Change Assessment, California Energy Commission. Publication number: CCCA4-CEC-2018-006.

320 Sleeter, B. M., T. S. Wilson, E. Sharygin, and J. T. Sherba. 2017. "Future Scenarios of Land Change Based on Empirical Data and Demographic Trends." *Earth's Future.* Volume 5, Issue 11. DOI:10.1002/2017EF000560.

321 Westerling, Anthony Leroy. (University of California, Merced). 2018. *Wildfire Simulations for California's Fourth Climate Change Assessment: Projecting Changes in Extreme Wildfire Events With a Warming Climate.*

in wind regimes and vegetation, which seems to be a reasonable assumption for the rest of this half century (next 30 years). Swings in extreme weather (from drought, to heavy rain, to extended high Santa Ana winds) can lead to extreme wildfires. Such conditions are expected to become more common, making this an important topic for further climate science research. Figure 29 shows the estimated average annual area burned for 30-year periods representing historical conditions, the situation in the middle of this century, and at the end of this century. As suggested by this figure, California could experience major increases in the amount of area burned —up to 70 percent by the end of this century. Figure 29 presents average results from climate projections for four global climate models.

Figure 29: Estimation of Average Annual Areas Burned for Three 30-Year Periods for RCP 8.5 (Current Trajectory of Global GHG Emissions)



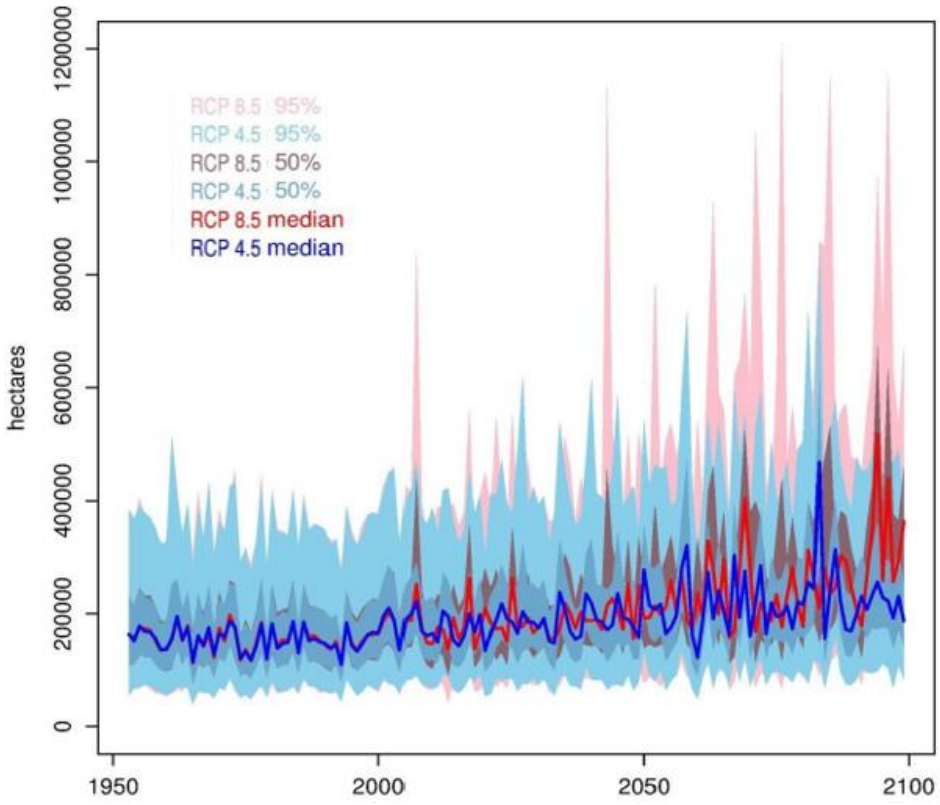
Source: Westerling, a) 1961-1990, b) 2035-2064, c) 2070-2099

The wildfire model used for the Fourth Assessment is a stochastic, or randomly determined, model, so the results must be analyzed using averages for long periods (for example, 30 years) or statistical temporal distribution of estimated outcomes. Figure 31 presents the statistics of the temporal distribution of outcomes per year showing, for example, the 95th percentile of thousands of simulations. It also includes results for RCP 4.5, which is a global GHG emission scenario with relatively moderate increases in global GHG emissions. The Fourth Assessment used RCP 8.5 for studies for this half of this century because actual emissions are above what were assumed for RCP 4.5 and close to the RCP 8.5 emissions.

The model simulates large wildfire years (95th percentile) in this half of this century and predicts even larger and more frequent wildfires in the second half of this century. The specific model years in Figure 30 are not relevant because, as indicated before, the model is stochastic, and a different sample of the available simulations would give different results for a given year, but with similar characteristics and trends.

The consequences of tree mortality experienced mostly in the Sierra Nevada on wildfire are not known because historical observations of tree mortality of this magnitude are not available, and physical laboratory simulations have not been completed. Some hypotheses suggest the possibility of massive wildfires driven by dead trees on the ground, without precedent even in the recent history of large fires in California.[322] Human deaths related to wildfire occur at the rural-urban interface, rather than the High Sierra. Such areas are also at risk for electricity-related wildfires and impacts.

Figure 30: Estimated Area Burned for RCP 8.5 and RCP 4.5 per Year (1950–2100)



Source: Westerling, Anthony Leroy. (University of California, Merced). 2018. *Wildfire Simulations for California's Fourth Climate Change Assessment: Projecting Changes in Extreme Wildfire Events With a Warming Climate. California's Fourth Climate Change Assessment*. California Energy Commission. Publication Number: CCCA4-CEC-2018- 014.

322 Stephen, S. L., B. M. Collins, C. J. Fettig, M. A. Finney, C. M. Hoffman, E. E. Knapp, M. P. North, H. Safford, and R. B. Wayman. 2018. "Drought, Tree Mortality, and Wildfire in Forests Adapted to Frequent Fire." 22*Bioscience*. 68: 77-88. https://doi.org/10.1093/biosci/bix146.

Wildfire, Climate Change, and California's Electricity Grid

One of the technical studies conducted for *California's Fourth Climate Change Assessment* investigated the risk posed by wildfires to 40 transmission "paths" and seven urban "fringe" distribution areas.[323] Over the 2000 to 2016 period, wildfire damages to the transmission and distribution system in selected areas exceeded $700 million. These costs do not represent total costs due to the enormous wildfire impacts in 2017 that included damages to homes, buildings, and other assets. In 2017, wildfires destroyed almost as many structures as were burned in all California wildfires between 2004 and 2016. The report indicates climate change is expected to increase wildfire risk to transmission and distribution assets in Northern California, a risk that would worsen if new transmission paths are developed in the Sierra Nevada Mountains. This study modeled the addition of two new transmission lines across the central Sierra Nevada.[324]

California's Transportation Fuel Sector: Vulnerability to Wildfires

Considering California's transportation fuel sector as an organizationally connected, multisector network, a technical report prepared for *California's Fourth Climate Change Assessment* projects and analyzes climate-change-induced flooding and wildfire exposure.[325] The report indicates many transportation system assets exist in high wildfire-risk areas (Figure 31) although there is an excellent record of response and repair, long-term chronic disturbances due to climate change are only now being discussed. The report also states roads and railroads (which are used to transport transportation fuels) are the assets most exposed and vulnerable to wildfire in this sector.

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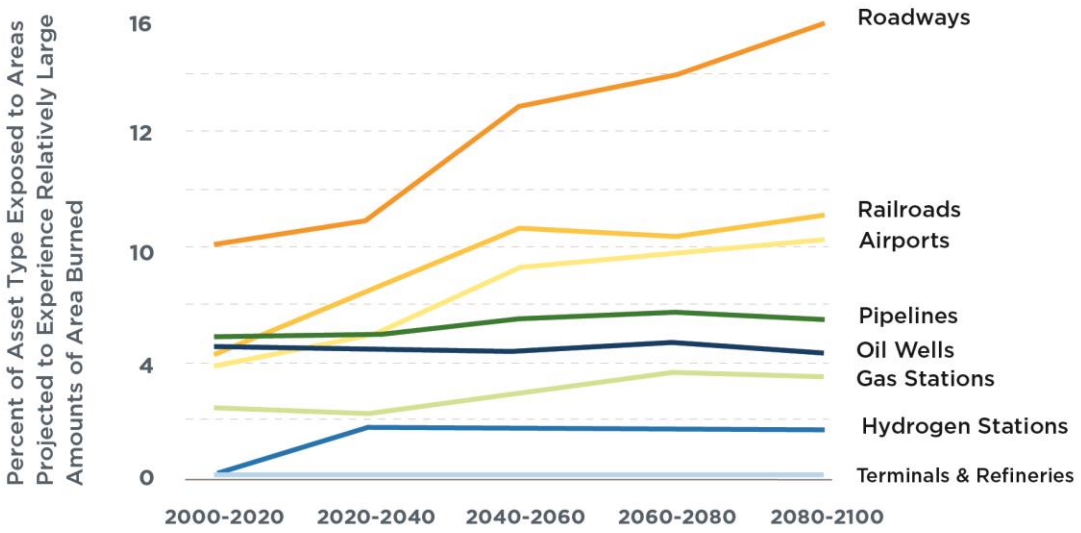
323 Dale, Larry, Michael Carnall, Gary Fitts, Sarah Lewis McDonald, and Max Wei. Lawrence Berkeley National Laboratory. 2018. "Assessing the Impact of Wildfires on the California Electricity Grid." *California's Fourth Climate Change Assessment*. California Energy Commission. Publication Number CCCA4-CEC-2018-002.

324 The two lines used in the study were identified in the following study of the 2050 WECC grid to increase transmission of wind energy from outside California: Nelson, James; Ana Mileva; Josiah Johnston; Max Wei; Jeffery Greenblatt; Daniel Kammen. Renewable and Appropriate Energy Laboratory, Energy and Resources Group, (University of California, Berkeley). 2014. *Scenarios for Deep Carbon Emission Reductions from Electricity by 2050 in Western North America Using the SWITCH Electric Power Sector Planning Model*. California Energy Commission. Publication number: CEC-500-2014-109.

325 Radke, J. D, G. S. Biging, K. Roberts, M. Schmidt-Poolman, H. Foster, E. Roe, Y. Ju, S. Lindbergh, T. Beach, L. Maier, Y. He, M. Ashenfarb, P. Norton, M. Wray, A. Alruheili, S. Yi, R. Rau, J. Collins, D. Radke, M. Coufal, S. Marx, A. Gohar, D. Moanga, V. Ulyashin, and A. Dalal. (University of California, Berkeley) 2018. *Assessing Extreme Weather-Related Vulnerability and Identifying Resilience Options for California's Interdependent Transportation Fuel Sector. California's Fourth Climate Change Assessment,* California Energy Commission. Publication Number: CCCA4-CEC-2018-012

Figure 31: Projected Exposure of Transportation Fuel System to Large Wildfire (2000–2100)



Source: Radke, J. D, G. S. Biging, K. Roberts, M. Schmidt-Poolman, H. Foster, E. Roe, Y. Ju, S. Lindbergh, T. Beach, L. Maier, Y. He, M. Ashenfarb, P. Norton, M. Wray, A. Alruheili, S. Yi, R. Rau, J. Collins, D. Radke, M. Coufal, S. Marx, A. Gohar, D. Moanga, V. Ulyashin, and A. Dalal. (University of California, Berkeley). 2018. *Assessing Extreme Weather-Related Vulnerability and Identifying Resilience Options for California's Interdependent Transportation Fuel Sector. California's Fourth Climate Change Assessment*. California Energy Commission. Publication Number: CCCA4-CEC-2018-012.

Impacts of Changes in Wildfire Risk on the Cost of Insurance

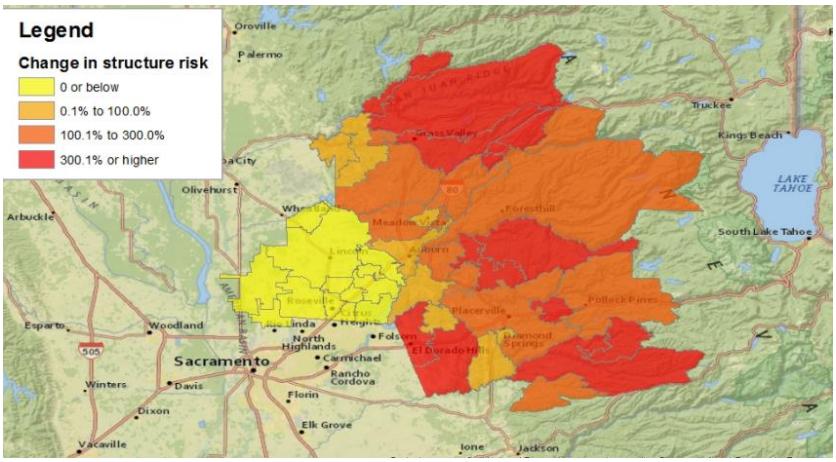
A study prepared for the *California Fourth Climate Change Assessment* uses zip code-level data on insurance policies and wildfire and population projections to explore expected changes in risk and potential implications for residential insurance markets.[326] The study focuses on the Sierra Foothills east of Sacramento (Figure 32) and western San Bernardino County and estimates the impact change in wildfire risk would have on insurance premiums in coming decades. The study found insurance premiums may increase 50 percent or more in about 30 percent of the zip codes in the Sierra Foothills study (Figure 33).

In a November 2018 report, Resources Legacy Fund and University of California, Berkeley's Center for Law, Energy, and the Environment included several recommendations to reduce wildfire risk, including steps to ensure insurance risk models "recognize landscape treatments and other measures" to reduce wildfire risk in California.[327]

326 Dixon, Lloyd, Flavia Tsang, and Gary Fitts. (GreenwareTech and RAND Corporation). 2018. *The Impact of Changing Wildfire Risk on California's Residential Insurance Market. California's Fourth Climate Change Assessment*, California Natural Resources Agency. Publication Number: CCCA4-CNRA-2018-008.

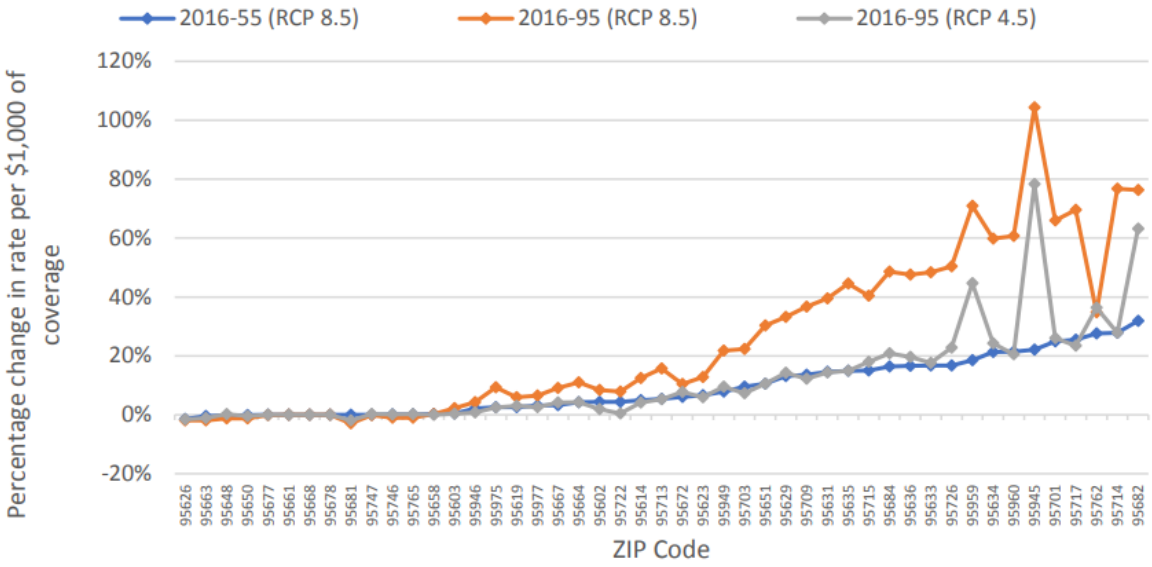
327 https://www.law.berkeley.edu/wp-content/uploads/2018/12/CLEE-RLF-Solutions-for-Californias-Next-Governor.pdf.

Figure 32: Changes in Risk of Fire to Structures in Sierra Foothills (2016–2095, RCP 8.5)



Source: Dixon, Lloyd, Flavia Tsang, and Gary Fitts. (GreenwareTech and RAND Corporation). 2018. *The Impact of Changing Wildfire Risk on California's Residential Insurance Market*. *California's Fourth Climate Change Assessment*, California Natural Resources Agency. Publication Number: CCCA4-CNRA-2018-008.

Figure 33: Projected Percentage Change in Rate per $1,000 of Insurance Coverage for Structures in Sierra Foothills (2016–2095, RCP 8.5)



Source: Dixon, Lloyd, Flavia Tsang, and Gary Fitts. (GreenwareTech and RAND Corporation). 2018. *The Impact of Changing Wildfire Risk on California's Residential Insurance Market*. *California's Fourth Climate Change Assessment*, California Natural Resources Agency. Publication Number: CCCA4-CNRA-2018-008.

Emerging Fire Science and Next Steps

To help identify research needs for climate change research related to wildfire, the Energy Commission held a staff workshop on July 25, 2018. The discussion identified the following research needs: to improve vegetation management, expand capabilities for wildfire risk monitoring, reduce the risk of wildfire ignition, and improve capabilities to estimate the impacts of climate change to wildfires and the electricity system.

The Energy Commission is supporting the development of the next generation of regional climate models, which will be more tailored for wildfire simulations and the energy system. They will be used to downscale the results of the new global climate models being run by different centers around the world for the next IPCC Assessment. This new modeling system will have improved representation of wind regimes, changes in relative humidity, and other factors affecting wildfires.

To strengthen wildfire modeling, additional research is needed for California on vegetation changes related to climate change, the potential for the large number of dead trees to fuel mass fires that burn extremely hot but slowly, changes in relative humidity due to climate change as it relates to wildfire, and greater access to wind data to improve modeling of wildfire dynamics related to high winds and the future of extreme wind events due to climate change.

An EPIC solicitation to address climate science needs on wildfire and the electricity system will be released early in 2019. This research would be foundational work for the next *California Climate Change Assessment*, providing new and more detailed wildfire scenarios that will be used to estimate potential impacts of wildfires to the electricity system for the rest of this century. A second solicitation designed to support research on methods to reduce the initiation of wildfires by the electricity system will be released in late summer 2019.

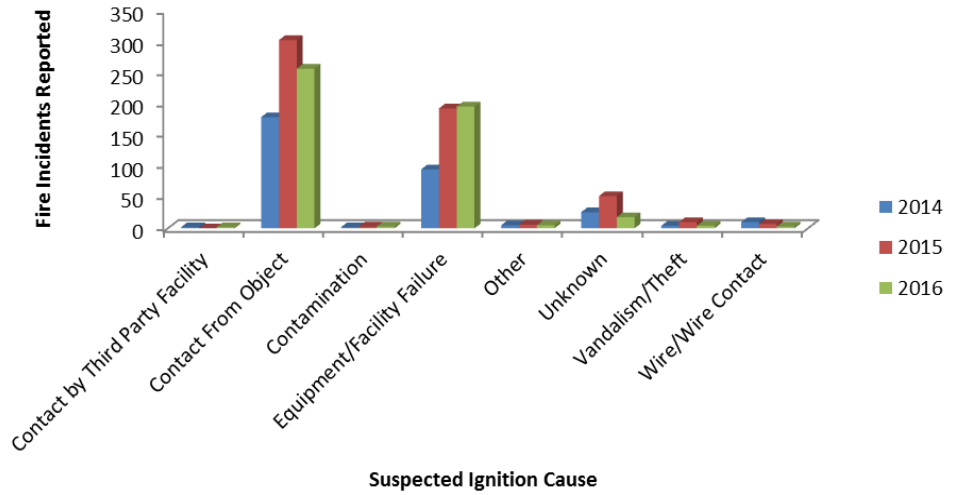
Incorporating Climate Change Impacts Into Planning and Investment Decisions

This section discusses pathways for incorporating climate change impacts into planning and investment decisions related to vegetation management.

Vegetation Management

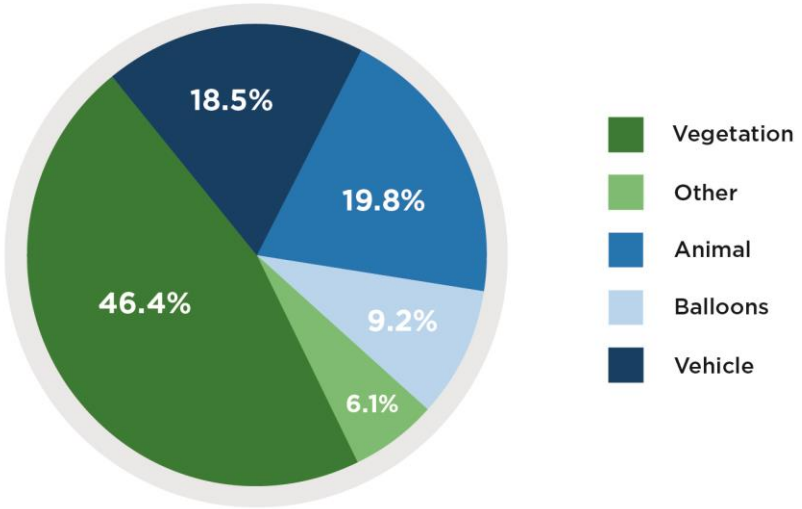
The top suspected ignition cause of utility-related fires in California for 2014–2016 is contact with objects (Figure 34), of which vegetation contact is the leading source (Figure 35).

Figure 34: Utility-Related Fire Incidents by Suspected Ignition Cause (2014–2016)



Source: CPUC, August 2, 2018, joint agency workshop on Climate Adaptation and Resiliency, http://www.energy.ca.gov/2018_energypolicy/documents/#08022018.

Figure 35: Percentage of Reported Fires Suspected to Be Caused by Object Contact (Three-Year Average)



Source: CPUC, August 2, 2018, joint agency workshop on Climate Adaptation and Resiliency, http://www.energy.ca.gov/2018_energypolicy/documents/#08022018.

Vegetation management is required to reduce the risk of contact with transmission and distribution lines; however, in forested areas of Northern California, transmission lines may run through forests with trees as tall as 200 feet. If one of these trees should fall due to high winds, contact with a transmission line is likely unless the corridor

clearance is exceptionally wide. At the distribution level, investor-owned electric utilities spend about $500 million annually for vegetation management.[328]

Vegetation management strategies to reduce the risk of wildfire involve coordination among utilities and federal, state, and private owners of forested land. Interagency measures attempting to address wildfire concerns in California include the former Governor's Executive Order B-52-18,[329] the Forest Management Task Force,[330] the California Forest Carbon Plan,[331] and the extension of prescribed burning from a seasonal to a year-round effort.[332]

Under former Governor Brown's Executive Order B-52-18, the California Air Resources Board (CARB) is collaborating with the CAL FIRE to reduce barriers to forest health and fuel reduction projects.[333] These efforts involve increasing forest restoration thinning and expediting the permitting process for prescribed fire projects. The practice of intensive thinning of highly productive forests creates significant reductions in evapotranspiration,[334] resulting in "increased base flows of up to 10 percent for dry years and 5 percent for all years."[335] Forest restoration thinning and prescribed fire projects are also being pursued on private lands by creating private landowner agreements, called Good Neighbor Authority Agreements, to accelerate these projects on lands outside the state's jurisdiction.[336] Under the executive order, CARB and CAL FIRE

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328 Elizaveta Maleshenko, Director, Safety and Enforcement Division. CPUC. August 2, 2018, Joint Agency Workshop on Climate Adaptation and Resiliency. Transcript. p. 90-95. http://www.energy.ca.gov/2018_energypolicy/documents/#08022018.

329 State of California former Governor Edmund G. Brown Jr. *Executive Order B-52-18*, 10 May 2018. https://www.gov.ca.gov/wp-content/uploads/2018/05/5.10.18-Forest-EO.pdf. The executive order directs agencies to identify forest management threats and needs in support of implementing the Forest Carbon Plan, double forest improvement treatments on nonfederal lands from 250,000 acres per year to 500,000 acres per year, reduce regulatory barriers to prescribed fire and other forest improvement activities, support wood product innovation, and require the California Public Utilities Commission to review and update its procurement program for small renewable bioenergy generators.

330 https://fmtf.fire.ca.gov/.

331 Forest Climate Action Team. 2018. *California Forest Carbon Plan: Managing Our Forest Landscapes in a Changing Climate*. Sacramento, CA. 178p. http://resources.ca.gov/wp-content/uploads/2018/05/California-Forest-Carbon-Plan-Final-Draft-for-Public-Release-May-2018.pdf.

332 Henly, Russ. CNRA. August 2, 2018. "Managing Our Forests in Today's World of Climate Change, Carbon, and Fire." Presentation at the August 2 Joint Agency Workshop on Climate Adaptation and Resiliency. http://www.energy.ca.gov/2018_energypolicy/documents/2018-08-02_workshop/2018-08-02_presentations.php. For further information, see Edmund G. Brown Jr. former Governor, California State Budget 2018-19, p. 99–100. http://www.ebudget.ca.gov/FullBudgetSummary.pdf.

333 State of California former Governor Edmund G. Brown Jr. *Executive Order B-52-18*, May 10, 2018. https://www.gov.ca.gov/wp-content/uploads/2018/05/5.10.18-Forest-EO.pdf.

334 *Evapotranspiration* is the process by which water is transferred from the land to the atmosphere by evaporation from the soil and other surfaces and by transpiration from plants.

335 Roche, J. W., M. L. Goulden, and R. C. Bales. 2018. "Estimating Evapotranspiration Change Due to Forest Treatment and Fire at the Basin Scale in the Sierra Nevada, California: Forest Disturbance and Evapotranspiration Change."*Ecohydrology*, e1978. https://doi.org/10.1002/eco.1978.

336 State of California former Governor Edmund G. Brown Jr. *Executive Order B-52-18*, May 10, 2018. https://www.gov.ca.gov/wp-content/uploads/2018/05/5.10.18-Forest-EO.pdf.

are required to extend education and outreach to enable local governments and tribal, academic, and nongovernmental organizations to organize their own prescribed fire projects.

This work is informed by indicators, such as the fire return interval, that show that a large portion of California's forested lands have not burned as frequently as natural processes would indicate should occur. (See Figure 36.)

Adaptive planning is being used in some parts of California to prepare for impacts of climate change. For example, the Karuk Tribe in Klamath County created a new forest management plan to restore forest health and manage fire called the *Somes Bar Integrated Fire Management Project Draft Environmental Assessment*.[337] The Karuk Tribe aims to restore forest health and manage fire by using traditional ecological knowledge[338] and holistic landscape management. Its "eco-cultural revitalization" uses the historical use of low-intensity prescribed fires to create ecosystems that are resilient to changing conditions and climate.[339]

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337 Karuk Tribe. "Press Release – Karuk Tribe: Klamath Communities Begin a Revolution in Forest Management," March 6, 2018. http://www.karuk.us/index.php/information/62-announcements/504-wkrp-plan-for-forest-health.

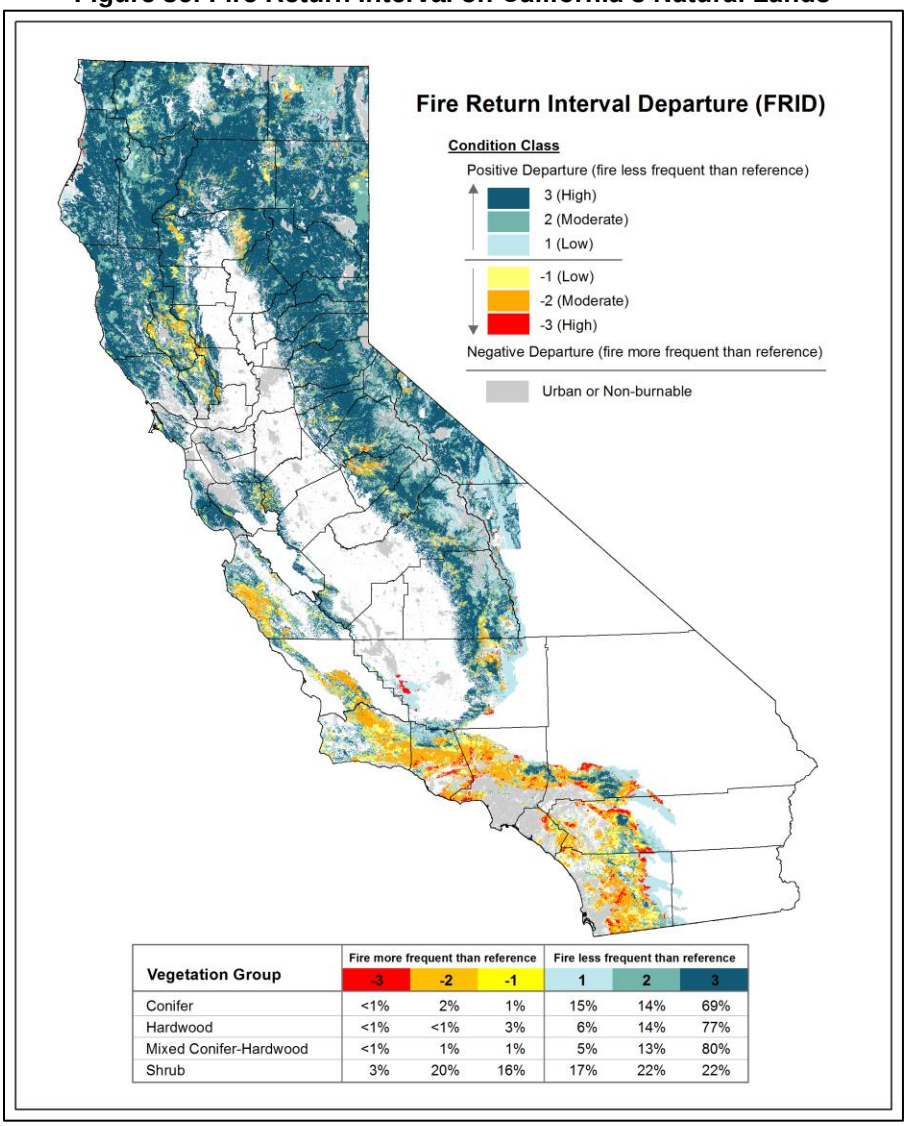
338 *Traditional ecological knowledge* is a body of knowledge, accumulated through multiple generations via cultural transmission, and includes the practices and beliefs developed by indigenous peoples through hundreds or thousands of years of an intense relationship to a specific environment. This includes the relationships among humans, plants, animals, natural phenomenon, landscapes, and timing of events related to traditional lifeways (for example, hunting, fishing, agriculture, forestry, and ceremonies).

Fikret Berkes, Johan Colding, and Carl Folke. "Rediscovery of Traditional Ecological Knowledge as Adaptive Management." *Ecological Applications*, Vol. 10(5), pp. 1251-1262.

United States Fish and Wildlife Service. Traditional Ecological Knowledge for Application by Service Scientists. https://www.fws.gov/nativeamerican/pdf/tek-fact-sheet.pdf (accessed on December 10, 2018).

339 Karuk Tribe. Natural Resources – "Mission Statement," 2018. http://www.karuk.us/index.php/departments/natural-resources.

Figure 36: Fire Return Interval on California's Natural Lands



Vegetation Group	Fire more frequent than reference			Fire less frequent than reference		
	-3	-2	-1	1	2	3
Conifer	<1%	2%	1%	15%	14%	69%
Hardwood	<1%	<1%	3%	6%	14%	77%
Mixed Conifer-Hardwood	<1%	1%	1%	5%	13%	80%
Shrub	3%	20%	16%	17%	22%	22%

Source: "Fire and Resource Assessment Program - California's Forests and Rangelands." Presentation by Chris Keithley, CAL FIRE at the August 2, 2018, joint agency workshop on Climate Adaptation and Resiliency, http://www.energy.ca.gov/2018_energypolicy/documents/#08022018.

Another consideration in vegetation management is the weakened root system that trees may experience after a prolonged drought. If followed by a wet winter, such deciduous trees may develop a full canopy, leaving them vulnerable to high winds. Arborists are not able to predict which trees will fail under winds exceeding 55 miles per hour.[340]

To help address wildfire management on natural and working lands, participants at the July 2018 staff research workshop identified the following potential research areas:

340 August 2, 2018, joint agency workshop on Climate Adaptation and Resiliency, presentation by David Erne, https://efiling.energy.ca.gov/GetDocument.aspx?tn=224355.

- Identify more effective and accurate evaluation methods to assess the condition of existing trees beyond visual inspection.
- Leverage technology (such as augmented visualization) to be able to recognize hazardous conditions that could lead to wildfires.
- Pair LIDAR[341] and other imaging/sensing with data analytics (approaching real-time analysis) to pinpoint vegetation that poses the highest risks.
- Develop best approaches to reducing right-of-way fire risks.

Weather data and modeling are also essential for emergency preparedness and response. Suggested research areas include:

- Developing best strategies for determining locations for using weather sensors or high-definition cameras.
- Leveraging multiple data sources, combined with machine learning or artificial intelligence, to identify time and location of high fire risk.
- Developing equipment sensors to detect the condition of conductors, transformers, along with telemetry to send data back to utilities.
- Using ground-based, aerial, or satellite multispectral imaging or sensors to view topology or the condition of vegetation relative to grid assets.
- Overcoming communication infrastructure challenges, particularly in remote areas.
- Developing strategies for multiple risk response (such as earthquakes and floods) in addition to fires.

Guidelines for Updating Local Government General Plans to Account for Climate Change

Local governments use general plans to regulate land use within their jurisdictions. Senate Bill 379 (Jackson, Chapter 608, Statutes of 2015) requires climate change be taken into account when updating general plans. General plans are infrequently updated, however, so many local governments may still be unprepared for climate change impacts, such as changing wildfire and related risks in California.[342]

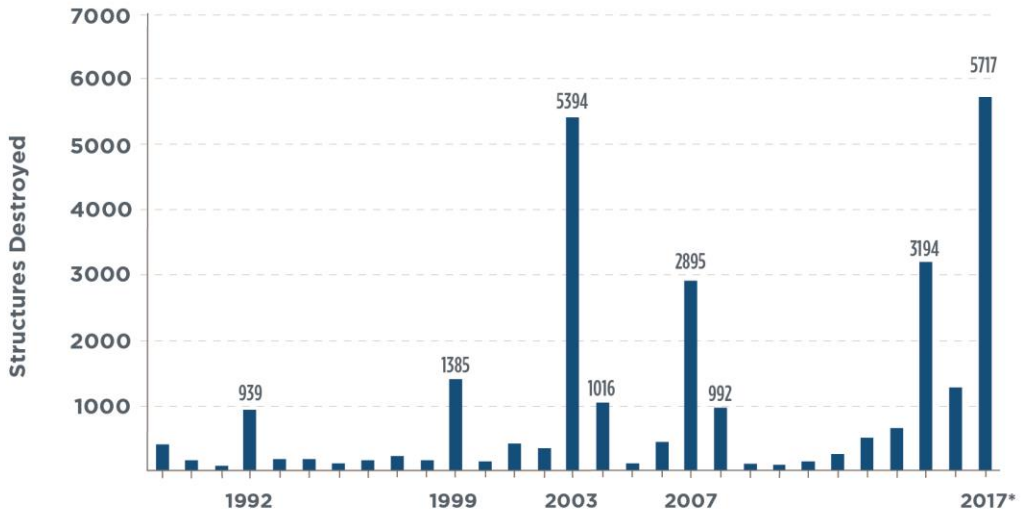
In recent years the number of structures damaged due to wildfire has increased, indicating the importance of timely action to update general plans to incorporate changing wildfire risks and other climate-change impacts. In 2003, Santa Ana winds and

341 *LIDAR*, or light detection and ranging, is a remote sensing method that uses light in the form of a pulsed laser to measure variable distances to the Earth.

342 August 2, 2018, joint agency workshop on Climate Adaptation and Resiliency, Presentation by OPR, https://efiling.energy.ca.gov/GetDocument.aspx?tn=224358.

"insect-riddled eucalyptus bark made explosive by a long drought"[343] fueled the highly damaging Cedar Fire in San Diego County, causing the number of structures destroyed to spike relative to other fire seasons in the early 2000s. (See Figure 37.) The 2018 Camp Fire burned more than 18,800 structures, more than triple the number of structures burned in the most destructive fire of 2017.[344]

Figure 37: Structures Destroyed by Wildfire in CAL FIRE and Contract County Direct Protection Areas (1989–2017)



Source: "Fire and Resource Assessment Program - California's Forests and Rangelands." Presentation by Chris Keithley, CAL FIRE, at the August 2, 2018, joint agency workshop on Climate Adaptation and Resiliency

OPR is statutorily required to adopt and periodically revise the *State General Plan Guidelines*. A general plan serves as a local government's "long-term blueprint for the community's vision of future growth."[345] The General Plan Guidelines serve as a "how-to" resource for drafting general plans, covering mandatory and optional topics. In 2017, OPR updated the guidelines, which now include sections on topics such as community engagement and outreach, equitable and resilient communities, and climate change.[346] The section on climate change combines the efforts of general plans and requirements of the California Environmental Quality Act (CEQA) by including guidelines on reducing GHG emissions, environmental review, and CEQA analysis with total impacts within developing a general plan or a climate action plan. This document

343 CNN. October 29, 2003. "California Wildfires Burn Through 600,000 Acres." http://www.cnn.com/2003/US/West/10/28/california.wildfire/.

344 http://www.fire.ca.gov/communications/downloads/fact_sheets/Top20_Destruction.pdf (Updated as of Dec 4, 2018).

345 Governor's Office of Planning and Research. 2018. *General Plan Guidelines: Update 2017*. http://opr.ca.gov/planning/general-plan/guidelines.html.

346 Ibid.

provides several methods to recommend to local governments for planning for climate change and adaptation, including internal and external links to related elements and considerations, and direct coordination with other resources such as those from the Office of Emergency Services, Cal-Adapt, the Adaptation Planning Guide, and Integrated Climate Adaptation and Resiliency Program (ICARP).

The *California Adaptation Planning Guide– Planning for Adaptive Communities* is another planning document and resource focusing on climate change adaptation. It was developed by the California Emergency Management Agency and the California Natural Resources Agency in 2012 to introduce climate change adaptation and planning and to provide specific details on a step-by-step process that involves "local and regional climate vulnerability assessment and adaptation strategy development."[347]

The guide consists of four complementary documents to help guide and support communities in adapting to the unavoidable consequences of climate change: *Planning for Adaptive Communities*, *Defining Local and Regional Impacts*, *Understanding Regional Characteristics*, and *Identifying Adaptation Strategies*.[348]

The steps listed in climate adaptation strategy development involve a vulnerability assessment and an adaptation strategy development. This step-by-step process couples goals for local adaptation planning and reducing GHG emissions and includes identifying exposure, sensitivity, potential impacts, adaptive capacity, and risk, and evaluating strategies.[349] The document recommends local communities adjust according to their local needs and potential climate-related risks by focusing on flexibility of time, funding, and scope. For example, Southern California counties have more structures in areas of high fire risk than Northern California (Figure 38), but Northern California counties may have a larger proportion of structures in such areas. Figure 39 shows areas within each county that have burned between 1960 and 2015. Figure 40 shows the fire risk in Los Angeles County within the service area of the Los Angeles Department of Water and Power (LADWP).

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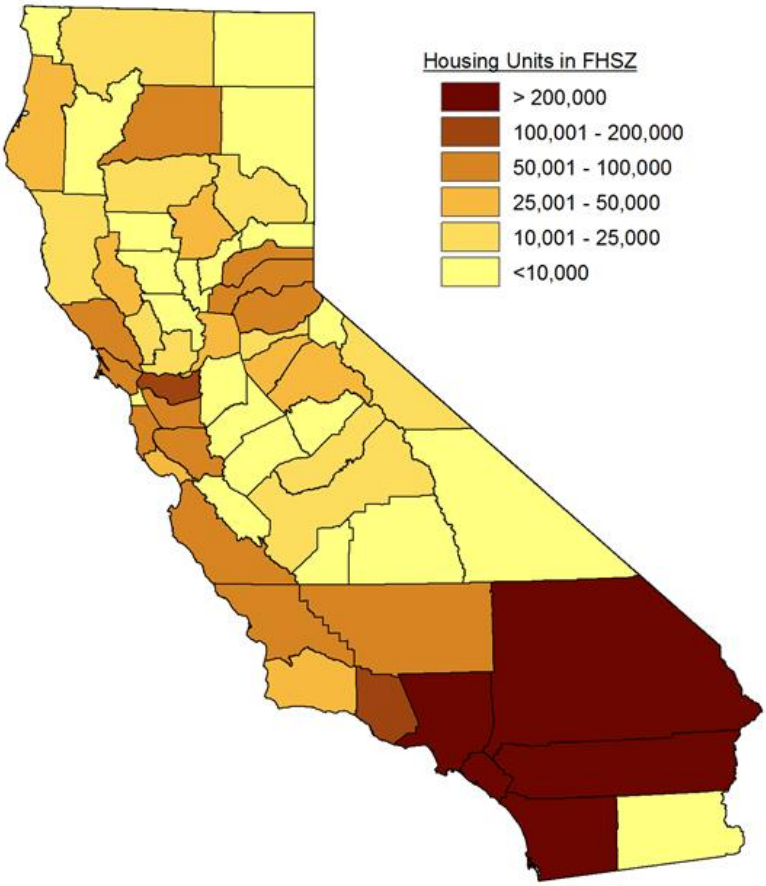
347 California Emergency Management Agency, and California Natural Resources Agency. July 2012. *California Adaptation Planning Guide –Planning for Adaptive Communities.* http://resources.ca.gov/docs/climate/01APG_Planning_for_Adaptive_Communities.pdf.

348 Ibid.

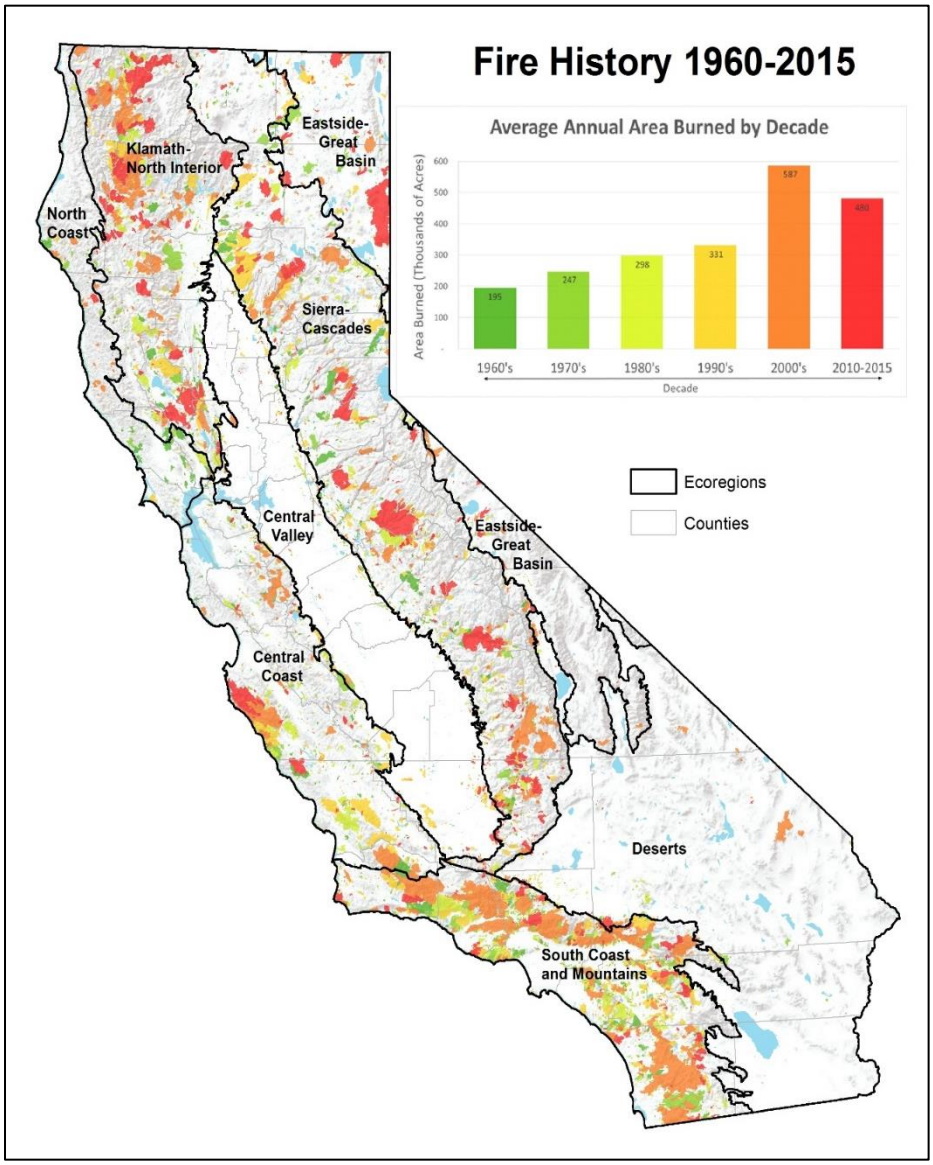
349 Ibid.

Figure 38: Number of Housing Units in Fire Hazard Severity Zones (2010)



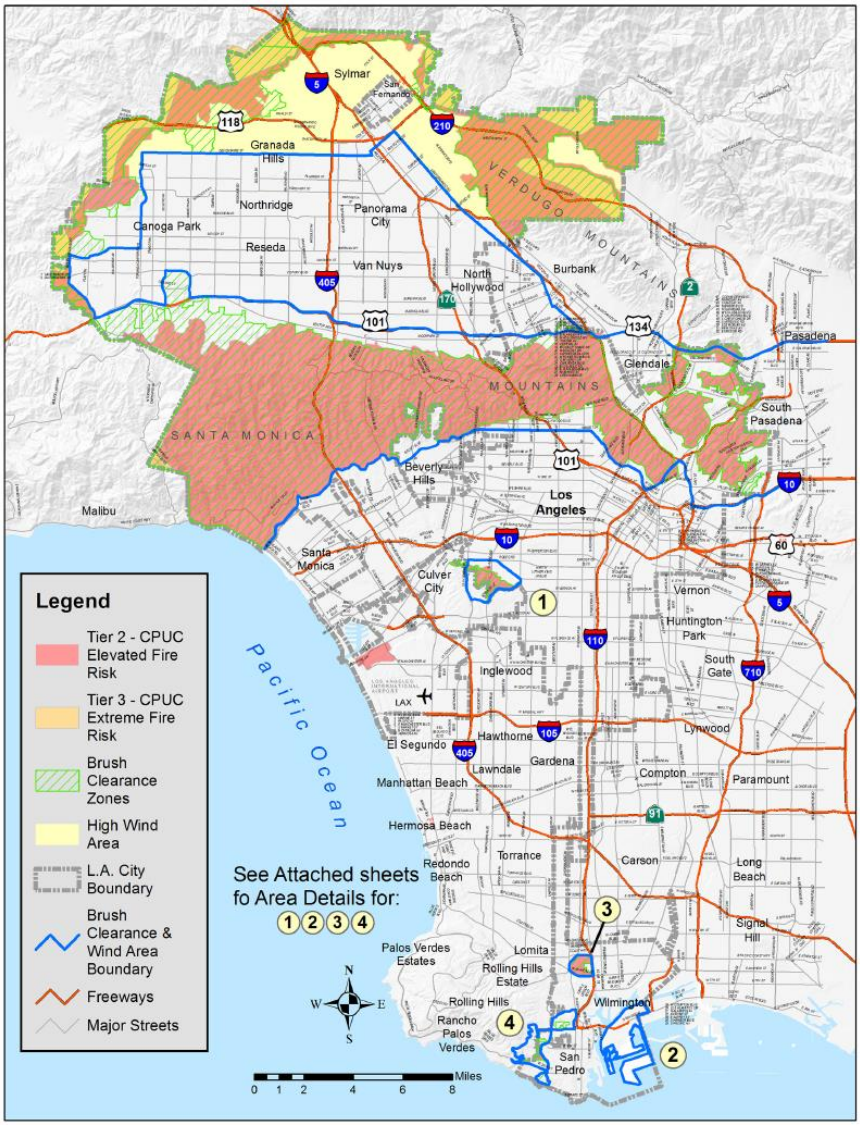
Source: "Fire and Resource Assessment Program - California's Forests and Rangelands." Presentation by Chris Keithley, CAL FIRE, at the August 2, 2018, joint agency workshop on Climate Adaptation and Resiliency, http://www.energy.ca.gov/2018_energypolicy/documents/#08022018

Figure 39: California Fire History (1960–2015)



Source: "Fire and Resource Assessment Program - California's Forests and Rangelands." Presentation by Chris Keithley, CAL FIRE, at the August 2, 2018, joint agency workshop on Climate Adaptation and Resiliency, http://www.energy.ca.gov/2018_energypolicy/documents/#08022018

Figure 40: High-Fire-Risk Areas of Los Angeles County Within LADWP Service Territory



Source: Presentation by Bill Herriott, LADWP, at the August 2, 2018, joint agency workshop on Climate Adaptation and Resiliency, http://www.energy.ca.gov/2018_energypolicy/documents/#08022018

In 2015, then-Governor Brown signed Senate Bill 246 (Wieckowski, Chapter 606, Statutes of 2015), directing the OPR to create the ICARP to develop cohesive, coordinated, and holistic strategies to address the impacts of climate change within all levels of government.[350]

ICARP has two components: the State Adaptation Clearinghouse and the technical advisory council. The clearinghouse acts as a centralized source of trustworthy resources to assist decision makers at the state, regional, and local levels of planning for

350 Governor's Office of Planning and Research. 2018. "Integrated Climate Adaptation and Resiliency Program," http://opr.ca.gov/planning/icarp/.

adaptation and resiliency. The clearinghouse website[351] contains vetted, best-available tools and data meant to assist in climate planning and case study examples of local community efforts to bolster resilience to serve as best practices for interested parties. The website is being developed by OPR and is conducting user outreach to improve functionality, ease of use, and utility of the resources provided.

The advisory council brings together various stakeholders including local governments, practitioners, scientists, and community leaders to aid collaboration among many levels of expertise on preparing California.[352] In 2017, the council developed a vision statement to express the characteristics of a resilient California and the principles to follow in planning actions to achieve this end, and further defined "vulnerable communities" in April 2018. These communities, due to physical, social, political, or economic factors or a combination thereof, experience heightened risk and increased sensitivity to the impacts of climate change and have less capacity to cope with, adapt to, or recover from those impacts.[353] Understanding the unique challenges faced by vulnerable communities is a first step in incorporating environmental justice and equity concerns in proactive climate change adaptation planning. The clearinghouse and advisory council provide information, resources, and communication among various stakeholders involved in planning for adaptation and resiliency in California.

Public Safety Priorities: Vulnerable Populations

To reduce the risk of wildfire, the CPUC has updated several safety regulations (as shown in Figure 41), and additional climate adaptation and fire safety measures are under development. The CPUC has clarified the utilities' authority to de-energize to protect public safety (such as during high-wind conditions) and created rules that utilities must comply with in de-energizing any area.[354] Outreach is underway to strengthen community preparations in the event an area must be de-energized. For example, San Diego Gas & Electric (SDG&E) is working with communities in the backcountry to identify community cooling centers and other resources and plan for contingency electricity services to these areas should the area be de-energized.[355]

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351 https://resilientca.org/.

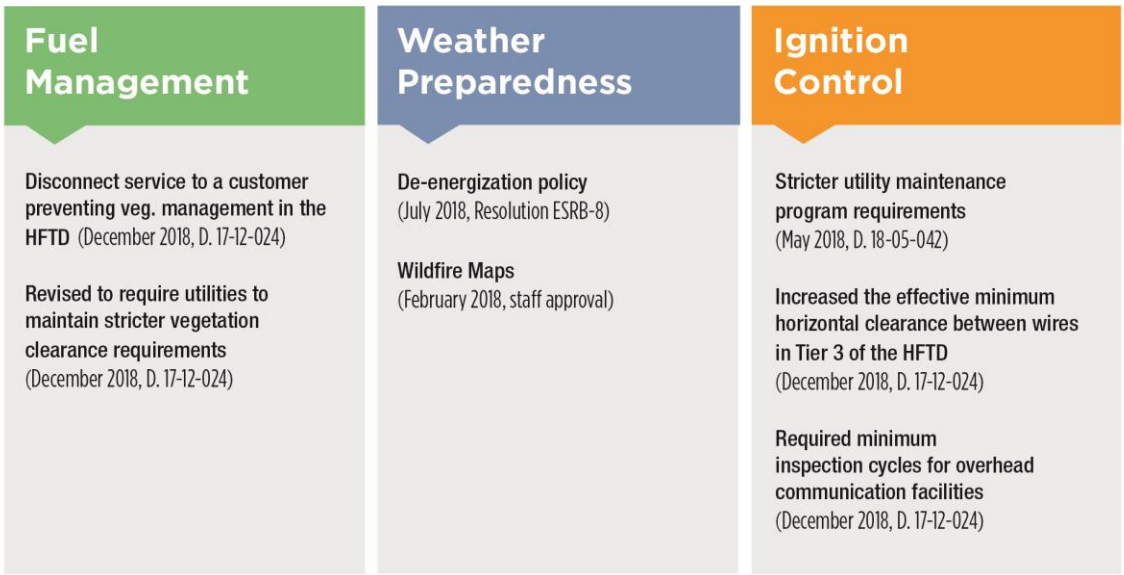
352 Governor's Office of Planning and Research. "Integrated Climate Adaptation and Resiliency Program," 2018. http://opr.ca.gov/planning/icarp/.

353 California Governor's Office of Planning and Research. *Defining Vulnerable Communities in the Context of Climate Adaptation.* July 2018. http://opr.ca.gov/docs/20180723-Vulnerable_Communities.pdf

354 CPUC. July 12, 2018. *Resolution – Resolution Extending De-energization Reasonableness, Notification, Mitigation and Reporting Requirements in Decision 12-04-024 to all Electric Investor-Owned Utilities.* http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M215/K379/215379996.PDF.

355 August 2, 2018, Joint Agency Workshop on Climate Adaptation and Resiliency, Presentation by SDG&E, https://efiling.energy.ca.gov/GetDocument.aspx?tn=224360.

Figure 41: Examples of CPUC Recent Policy Actions



Source: CPUC, August 2, 2018, joint agency workshop on Climate Adaptation and Resiliency, http://www.energy.ca.gov/2018_energypolicy/documents/#08022018.

Utilities are also important stakeholders to include when planning for adaptation and resiliency with consideration of the state's vulnerable populations. SDG&E is a leading example of an investor-owned utility (IOU) that has amended its fire safety standards for de-energization. SDG&E altered its fire safety standards to reduce the risk of wildfires and protect public safety from Santa Ana winds that are strong enough to topple power lines onto dry vegetation. These requirements, which include providing notice to customers and mitigation when de-energizing for public safety reasons, were adopted in CPUC Decision 09-09-030. Building upon its requirements for SDG&E, in 2018, the CPUC in Resolution ESRB-8 strengthened standards for all utilities. The resolution sets forth requirements for notification, mitigation, and reporting to ensure a thoughtful approach to de-energizations.[356] The new standards include a special focus on vulnerable populations, whose electricity needs must be taken into account. For example, customers who rely on electrical life support systems (such as oxygenators) are at a particularly high risk when de-energization is considered. The utilities have made progress in meeting the requirements put forward by the CPUC. PG&E created a Community Wildfire Safety Program with precautionary measures listed to reduce the risk of wildfires, as well as explanations of the phases of notifications in the case of de-energization.[357] This program also includes a public education campaign asking its

356 CPUC. July 12, 2018. *Resolution – Resolution Extending De-energization Reasonableness, Notification, Mitigation and Reporting Requirements in Decision 12-04-024 to All Electric Investor-Owned Utilities,* http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M215/K379/215379996.PDF.

357 PG&E. 2018. "How Public Safety Power Shutoff Notifications Work." https://www.pge.com/en_US/safety/emergency-preparedness/natural-disaster/wildfires/public-safety-power-shutoff-notifications.page.

customers to update their contact information, evaluate their home for emergency preparedness, and create an emergency supply kit.[358] Similarly, SCE has publicized explanation of the phases of a public safety power shutoff regarding planning, monitoring, power shutoff, and power restoration.[359]

The California Department of Public Health can inform efforts to prioritize backup electricity needs for vulnerable populations. It is addressing the health-related risks of climate change within climate adaptation and resilience planning through its program California Building Resilience Against Climate Effects (CalBRACE). CalBRACE developed indicators for climate change and health (such as Figure 42, highlighting counties with a high percent of population currently living in very high wildfire risk areas and a high percentage of population age 65 or older) to help local health departments and others better understand the communities that are particularly susceptible to the adverse health impacts related to climate change, including extreme heat and wildfires.[360] CalBRACE provides resources and promotes partnerships between local and regional needs and local health departments. This work could also assist with implementation of community fire preparedness. In January 2019, Governor Newsom issued an executive order with a call for state agencies to cooperate with Cal FIRE to identify and prioritize the most at-risk communities taking proximity to fire danger and high indicators of social vulnerability into account.[361]

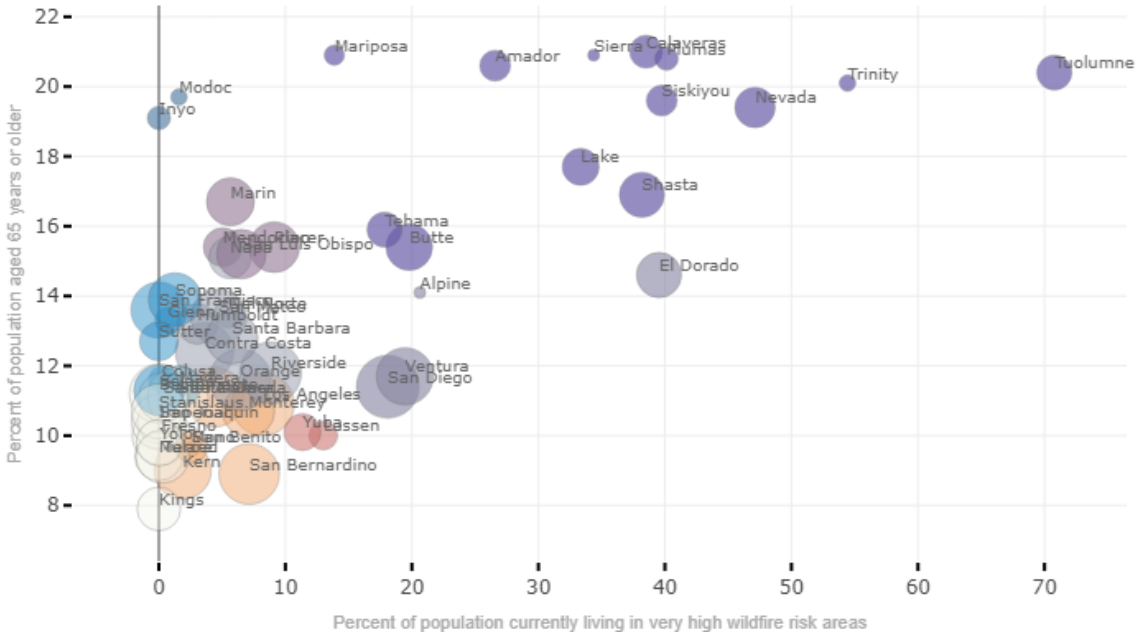
358 PG&E. 2018. "Community Wildfire Safety," https://www.pge.com/en_US/safety/emergency-preparedness/natural-disaster/wildfires/community-wildfire-safety.page

359 SCE. 2018. "Public Safety Power Shutoff," https://www.sce.com/wps/wcm/connect/9ef7f86a-ca79-41c8-b34f-b0dd449baf39/PSPS_Timeline.pdf?MOD=AJPERES.

360 California Department of Public Health. 2018. "CalBRACE: Preparing for Climate Change in California –A Public Health Approach." https://www.cdph.ca.gov/Programs/OHE/Pages/calbrace.aspx.

361 https://www.gov.ca.gov/wp-content/uploads/2019/01/1.8.19-EO-N-05-19.pdf.

Figure 42: California Counties With Combined Vulnerability from Environmental Exposure (Percent of Population Currently Living in Very High Wildfire Risk Areas) and Population Sensitivity (Percent of Population Aged 65 Years or Older)



Source: California Department of Public Health, Office of Health Equity. Climate Change and Health Vulnerability Indicators for California. https://discovery.cdph.ca.gov/ohe/CCHVIz/

Another program focusing on the human health impacts of climate change is the California Environmental Protection Agency's Office of Environmental Health Hazard Assessment (OEHHA). It collaborates with other institutions to perform human health studies and has found correlations between higher temperatures from climate change and adverse health outcomes, specifically heat-related effects from high temperatures and air pollution. These studies have also been used to identify vulnerable populations according to heat-related mortality and illness that include the elderly, pregnant women, children, and those residing in coastal areas.[362]

The Safeguarding California Plan summarizes California's climate adaptation strategy, outlines actions underway, and identifies next steps to prepare for climate impacts in California. Assembly Bill 1482 (Gordon, Chapter 603, Statutes of 2015) directs the California Natural Resources Agency to update the plan every three years. The 2018 update of the Safeguarding California Plan includes chapters with specific topics on policy sections of adaptation strategy including climate justice, emergency management, energy, and natural and managed resource systems. (For discussion of energy equity issues, see Chapter 4.) The Climate Justice section includes specific practices to make progress toward outlined goals including:[363]

362 Office of Environmental Health Hazard Assessment. 2015. "Human Health Impacts of Climate Change." https://oehha.ca.gov/climate-change/general-info/human-health-impacts-climate-change.

363 California Natural Resources Agency. January 2018. *Safeguarding California Plan: 2018 Update – California's Climate Adaptation Strategy.*

- Foster partnerships to address community concerns and make warnings of extreme weather forecasts and related information accessible to diverse communities and in multiple languages.
- Identify and prioritize populations that are low-income and otherwise disproportionately vulnerable to climate impacts with the use of existing climate change projections and datasets to determine impacts.
- Coordinate across policy areas with the promotion of a general plan and guidelines on how to address climate and hazard impacts.

Public Safety Priorities: Critical Facilities

One concern surrounding de-energization is how best to provide necessary power to critical facilities, such as hospitals and fire stations, if an area must be de-energized.

Along with establishing strong lines of communication among utilities, vulnerable communities, and critical facilities, technological strategies such as installing backup generators and storage may be another option to protect critical facilities during extreme weather events that lead to de-energizations or during wildfire-caused outages. Assembly Bill 1014 (Cooper, Chapter 145, Statutes of 2017) requires all critical facilities to maintain and continue to test diesel backup generators to ensure these facilities have power in case of an emergency. In accordance with AB 1014, the California Department of Public Health published an all-facilities letter detailing its plans for diesel backup generators for health care facilities, including general acute care hospitals and skilled nursing care centers.[364] Highway electrical facilities are also critical facilities to consider as they control traffic, including traffic signal systems and highway and sign lighting systems, especially during wildfires.[365]

According to the Center for Retail Compliance, there are requirements for permitting backup generators, including the fuel type, size and type of the generator, and environmental considerations such as air pollutant emissions.[366] These permitting requirements make it difficult for critical facilities to obtain backup generators. Such generators are also powered by carbon-intensive fuels like diesel.

Backup generation systems intended for use during de-energization and other multiday emergencies should prioritize a mix of clean, efficiency technologies, such as renewable energy, storage, and fuel cells, over dirtier, less efficient technologies. The South Coast

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http://resources.ca.gov/docs/climate/safeguarding/update2018/safeguarding-california-plan-2018-update.pdf.

364 California Hospital Association. Jan. 12, 2018. "New Law Clarifies Diesel Backup Generator Testing." https://www.calhospital.org/cha-news-article/new-law-clarifies-diesel-backup-generator-testing.

365 California Department of Transportation. July 2014. *Chapter K: Electrical.* http://www.dot.ca.gov/hq/maint/manual/2014/27_Chpt_K_July_2014.pdf.

366 Center for Retail Compliance. 2017. "Fact Sheet – Emergency Generator Fact Sheet." http://www.retailcrc.org/RegGuidance/Pages/fact-sheet.aspx?s=Emergency%20Generator%20Fact%20Sheet.

Air Quality Management District does not permit emergency backup generators to operate longer than 200 hours a year and allows operation only in the event of an emergency power failure.[367] As wildfires and extreme weather events increase, making de-energizations more possible and frequent, backup generators may operate for longer periods than permitted, emitting additional GHG emissions. Utilities have begun exploring alternatives such as battery storage for communities particularly threatened by de-energization, and these low-GHG approaches should be encouraged.

Many state governments across the country, including Maryland, Florida, and Hawaii, have already incorporated these factors into their emergency management plans. Following Hurricane Sandy, the state of Maryland's Emergency Management Agency launched a grant program to aid fuel stations with installing backup power generation to ensure customers have quick access to energy in case of emergencies or disasters that lead to outages.[368] Similarly, the state of Florida passed a statute requiring each motor fuel terminal facility and wholesaler selling motor fuel in the state to be able to operate its fuel distribution while using an alternate fuel source for at least 72 hours.[369] Hawaii's Department of Transportation implemented a different emergency plan by installing backup generators fueled by biofuels, rather than fossil fuels, for the Daniel K. Inouye International Airport in Honolulu.[370] Additional research is needed on the potential use of renewable gas for similar purposes in California, especially near locations working to reduce fire risk through sustainable forestry.

Other methods for adapting to future impacts of climate change in vulnerable communities could involve the use of microgrids and distributed energy resources. In the event of extreme wildfires, these resources could provide a means of "islanding" a community, where its power from the utilities would be cut off as a safety precaution, while the microgrid and distributed energy resources would support critical facilities and individuals with life support systems. However, if high winds elevate local wildfire risk, distribution lines powering a microgrid and distributed energy resources in the area will need to be turned off as well.

A particularly inspiring example of conditions allowing a microgrid to provide local energy resiliency can be seen in the Blue Lake Rancheria in Humboldt County, as local

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367 South Coast Air Quality Management District. 2018. "Emergency Generators." http://www.aqmd.gov/home/permits/emergency-generators.

368 Maryland Emergency Management Agency. Sept. 23, 2013. "Maryland Launches Grant Program for Backup Power at Fuel Stations." http://news.maryland.gov/mema/2013/09/23/maryland-launches-grant-program-for-backup-power-at-fuel-stations/.

369 The State of Florida Legislature. 2018. *The 2018 Florida Statutes – Title XXXIIII: Regulation of Trade, Commerce, Investments, and Solicitations.* http://www.leg.state.fl.us/statutes/index.cfm?App_mode=Display_Statute&URL=0500-0599/0526/Sections/0526.143.html.

370 State of Hawaii Department of Transportation. June 29, 2017. "Daniel K. Inouye International Airport Emergency Power Facility in Full Operation." http://hidot.hawaii.gov/blog/2017/06/29/daniel-k-inouye-international-airport-emergency-power-facility-in-full-operation/.

leaders and government have developed an array of projects to make progress toward clean energy, GHG emissions reductions, and community resilience.[371]

The Blue Lake Rancheria microgrid, shown in Figure 43, was funded by the Energy Commission's Electric Program Investment Charge (EPIC) program and includes onsite renewable generation of 420 kW solar photovoltaic coupled with 500 kW of energy storage. Benefits of the microgrid include:[372]

- Reducing GHG emissions by about 175 to 200 tons per year.
- Providing energy savings of $200,000 per year.
- Increasing clean energy employment by 10 percent.
- Providing electricity services for a Red Cross safety shelter in the event of an emergency.

During a fire in October 2017, Blue Lake lost its connection to utility power but did not realize it until much later because its microgrid system seamlessly restored power. In addition, Blue Lake is constructing a facility-scale fuel station and convenience store microgrid that relies on solar and battery storage and is partially funded by the EPIC program.[373]

Figure 43: Blue Lake Rancheria Microgrid

Source: Blue Lake Rancheria

At the Energy Commission's July 2018 wildfire research workshop, there was substantial discussion of resilience research. Research needs identified at the workshop included fire science, community solutions (such as creating fire-resilient homes), microgrids (to

371 California Natural Resources Agency. January 2018. *Safeguarding California Plan: 2018 Update – California's Climate Adaptation Strategy.* http://resources.ca.gov/docs/climate/safeguarding/update2018/safeguarding-california-plan-2018-update.pdf.

372 Jana Ganion with Blue Lake Rancheria- Presentation for April 20, 2018, IEPR Workshop, https://efiling.energy.ca.gov/GetDocument.aspx?tn=223237.

373 Ibid.

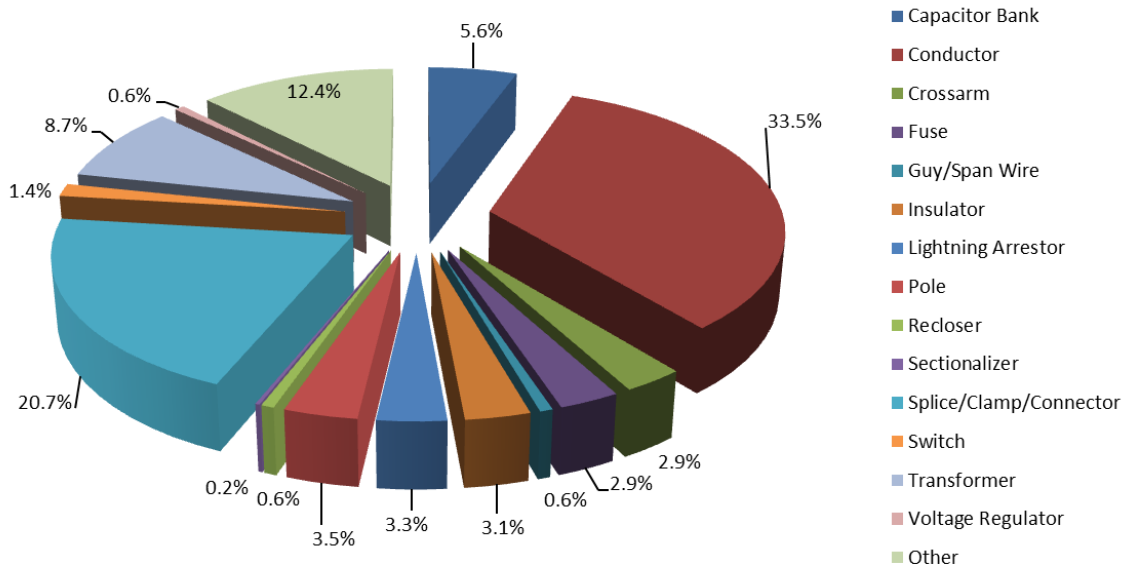
serve as additional backup storage in the event of emergencies), and mobile energy (such as mobile batteries that could be moved to power command centers during an emergency).

Wildfire as an Example of Climate Risks Related to Energy Infrastructure and Operation

The CPUC's Climate Adaptation Order Instituting Rulemaking (OIR) on Strategies and Guidance for Climate Change Adaptation focuses on integrating climate change adaptation into electric and gas IOU planning and operations to ensure safety and reliability; creating guidelines for the use of available data, tools, and resources in climate adaptation efforts; and considering the climate-driven risks facing utilities.[374] Wildfire is an important example of the challenges facing utilities in preparing for climate change impacts.

As shown in Figure 44, the second leading cause of fire ignitions is electric line splice, clamp, or connector failure, accounting for roughly 20 percent of all reported equipment-related ignitions.

Figure 44: Percentage of Reported Fires Suspected to Be Caused by Equipment Failure–Listed by Equipment Type (2014-2016)



Source: CPUC, August 2, 2018, joint agency workshop on Climate Adaptation and Resiliency

Following the fires in Southern California in October 2007, the CPUC created regulations to address the potential fire hazards associated with overhead utility power lines.[375] The CPUC adopted additional regulations regarding the distance between bare-line

374 CPUC. May 2018. *Order Instituting Rulemaking to Consider Strategies and Guidance for Climate Change Adaptation.* http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M213/K511/213511543.PDF.

375 CPUC. 2018. "Fire-Safety Regulations." http://cpuc.ca.gov/general.aspx?id=6442454972.

conductors and vegetation in areas of high fire threat in Southern California.[376] As discussed above, this relates to natural and working lands as the conductors passing through forested lands are required to be a certain distance away from vegetation, and forests are required to be trimmed in a timely manner to avoid the spread of wildfires.

In December 2017, the CPUC adopted a high fire-threat district consisting of three regions:[377]

- Tier 1: High Hazard Zones on the U.S. Forest Service-CAL FIRE joint map of Tree Mortality High Hazard Zones.
- Tier 2: CPUC Fire-Threat Map, where there is an elevated risk of utility-caused wildfires.
- Tier 3: CPUC Fire-Threat Map, where there is an extreme risk for utility-caused wildfires.

This high-fire-threat district was then depicted on the CPUC fire-threat map to identify areas of high fire threat and direct efforts to vulnerable communities in these areas. In addition, the CPUC required increased regular inspections of facilities located near power lines in high fire threat and rural areas of Southern California to ensure that vulnerable locations facing the highest risks are being closely monitored.[378]

Given the increasing frequency of wildfires and the expected cost in transmission- and distribution-related damages, the CPUC has required utilities to create assessments for risk drivers that include climate impacts and plans for wildfire preparedness. Beginning in 2014, the CPUC required IOUs to develop risk assessment and mitigation phase (RAMP) filings that inform decisions about expenditures in the IOUs' general rate cases. PG&E's RAMP identified 22 safety risks, including six climate-related risks and the associated costs and plans for future mitigation.[379] SDG&E and Southern California Gas Company (SoCal Gas) of Sempra Utilities also submitted a RAMP filing that listed climate change as a risk and proposed time and resources to further research associated risks.[380] Both IOUs identified wildfires as their own risk with extensive plans described to mitigate against wildfires.[381] Within Sempra's RAMP filing, the utility described 28 significant risks, analyzing each according to severity and probability.[382] Wildfire risk

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376 Ibid.

377 CPUC. Dec. 14, 2017. *CPUC Adopts New Fire-Safety Regulations.* http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M201/K352/201352402.PDF.

378 CPUC. 2018. "Fire-Safety Regulations." http://cpuc.ca.gov/general.aspx?id=6442454972.

379 CPUC. May 7, 2018. *Order Instituting Rulemaking to Consider Strategies and Guidance for Climate Change Adaptation.* http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M213/K511/213511543.PDF.

380 Ibid.

381 Ibid.

382 CPUC. March 8, 2017. *Risk and Safety Aspects of Risk Assessment and Mitigation Phase Report of San Diego Gas & Electric Company and Southern California Gas Company Investigation 16-10-015 and I. 16-10-016.*

mitigation was the utility's highest scoring risk, with 10 identified drivers of wildfires as a safety risk, including climate change adaptation impacts, lack of internal or external coordinated response, and extreme force-of-nature events.

Sempra's RAMP filing highlighted climate change adaptation as a long-term strategy to deal with extreme changes in weather patterns and ecological conditions.[383] To address fire risk, SDG&E's Fire Science and Climate Adaptation Department is focused on areas such as studying fire science and analytics, developing the Community Fire Safety Program, and establishing innovative weather technology. In addition, SDG&E has developed nine community resource centers in areas of high fire risk, a critical step toward climate change adaptation and emergency preparedness.[384]

SCE has also taken steps to reduce wildfire risk and enhance its infrastructure and procedures.[385] It restricts certain types of work and patrol lines in areas of high fire risk during periods of extreme weather and aims to reduce the occurrence of fires during high risk days by issuing public safety power shutoffs.[386] SCE's infrastructure has been updated with the use of fire-resistant poles, composite cross-arms, and covered conductors. Fire risks have also been addressed with increased trimming and clearing of trees and debris. SCE's wildfire preparedness has expanded to include forecasting and meteorological monitoring with additional weather stations and cameras to better prepare for and respond to fires.[387] In September 2018, SCE submitted a proposal for additional wildfire safety measures.[388]

PG&E has also updated its infrastructure to prepare for the "unprecedented and unanticipated wildfires" that the extreme weather events of climate change are causing.[389] PG&E's Community Wildfire Safety Program created a network of 50 new weather stations to collect data on temperature, wind speeds, and humidity levels to

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http://www.cpuc.ca.gov/uploadedFiles/CPUCWebsite/Content/Safety/Risk_Assessment/RCR/Final%20Sempra%20RAMP%20030717.pdf.

383 Ibid.

384 In June 2018, following Sempra's evident leadership in RAMP filing and enhanced wildfire preparedness, SDG&E was awarded the 2018 Edison Award by Edison Electric for their strategic investments to help strengthen the grid and increase awareness of protocols.

385 SCE. "SCE Has Been Addressing the New Normal," https://www.sce.com/wps/wcm/connect/f3e37cbc-84b2-47c0-b991-c147a3ba4b84/PSPS_NewNormal.pdf?MOD=AJPERES.

386 Ibid.

387 Ibid.

388 SCE. September 10, 2018. "SCE Proposes Grid Safety and Resiliency Program to Address the Growing Risk of Wildfires." Press Release. https://newsroom.edison.com/releases/sce-proposes-grid-safety-and-resiliency-program-to-address-the-growing-risk-of-wildfires.

389 PG&E. July 16, 2018. "PG&E Adds Over 50 New Weather Stations to Advance Forecasting Abilities, Better Predict Extreme Weather and Wildfire Potential." https://www.pge.com/en/about/newsroom/newsdetails/index.page?title=20180716_pge_adds_over_50_new_weather_stations_to_advance_forecasting_abilities_better_predict_extreme_weather_and_wildfire_potential.

predict the occurrence and location of fire threats.[390] This monitoring and forecasting of weather patterns and fire threat projections act as a precautionary measure that allows PG&E to reduce wildfire risks.

Tools are available to incorporate climate change considerations into risk management. For example, private companies can create dynamic models of climate change impacts, including flooding and extreme temperatures, to enable utilities to assess their risks and vulnerabilities and make data-driven decisions on how best to adapt to a changing climate.

To reduce the risk of wildfire, LADWP has adopted construction standards, including requirements to use larger overhead supply conductors, increase conductor spacing (as shown in Figure 45), replace service voltage conductors, and surpass state wind-loading requirements.

Figure 45: Example of Increased Conductor Spacing in LADWP Territory

Source: LADWP, August 2, 2018, joint agency workshop on Climate Adaptation and Resiliency, http://www.energy.ca.gov/2018_energypolicy/documents/#08022018. (Note: LADWP increased minimum conductor spacing on 4.8 kV from 11.5” to 39” to allow for conductor sway in high wind conditions.)

390 Ibid.

California's utilities are structured in a way that allows them to avoid competing with each other; as a result, there is a lot of scope for collaboration to learn from one another, establish best practices, and focus on the safety of their customers.

On May 17, 2018, the CPUC issued an order instituting rulemaking[391] on adaptation and resilience, one of the first public utility commission proceedings to incorporate climate change into utility requirements. The New York Public Utilities Commission looked at strengthening resilience after Hurricane Sandy. The CPUC's proceeding includes a broader scope of climate impacts. This CPUC proceeding has five working groups, one on each of the following topics:[392]

- Definition of adaptation
- Data sources, models, and tools
- Guidelines for assessment and planning
- Vulnerable and disadvantaged communities
- Decision-making framework for adaptation[393]

While there has been promising progress toward resilient and safe energy infrastructure and operation, there are still challenges that lie ahead. One of the most difficult challenges is accessing private land for clearing vegetation. While a utility could undertake the utmost precautions and safety measures on its own land, it has no jurisdiction over private lands, creating potentially dangerous situations. For example, homeowners could refuse to take necessary precautions such as cutting down large trees that pose a threat to power lines. In Resolution E-4932, the CPUC authorized utilities to disconnect service to a customer who will not allow access to trim or remove trees on their property that could fall on electric lines.[394] The CPUC has an ongoing emergency preparedness proceeding (R.15-06-009) to help address these and related safety issues.[395]

At the August 2, 2018, workshop, CPUC staff identified priority future actions to reduce energy-related wildfire risk, as detailed in Figure 46.

391 http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M213/K511/213511543.pdf.

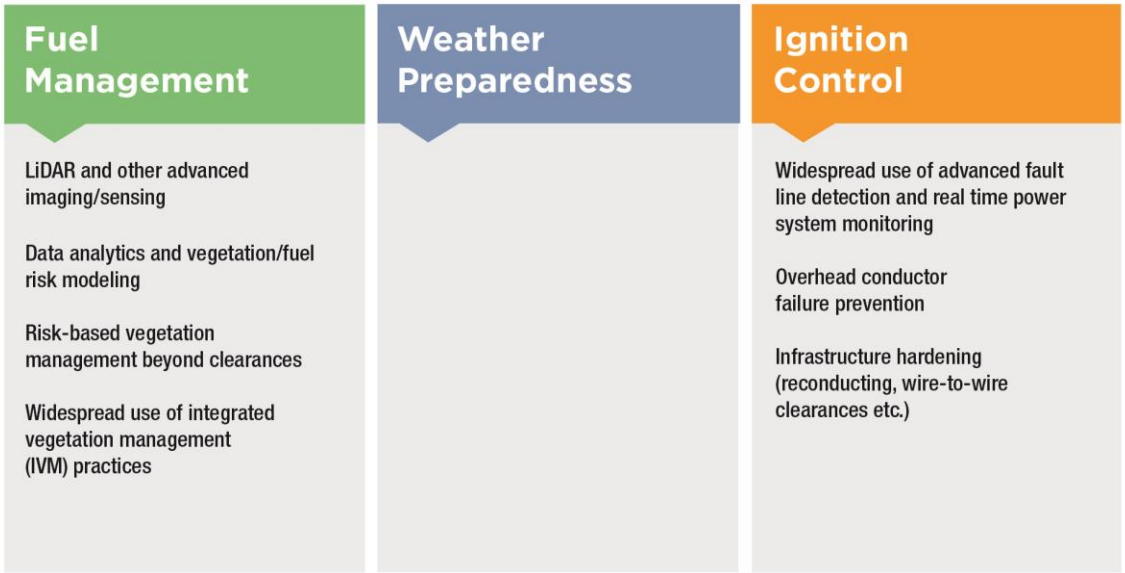
392 CPUC. October 10, 2018. Assigned Commissioner's Scoping Memo and Ruling. Rulemaking 18-04-019.

393 Using input from the other four working groups, this group will develop recommendations on how to make climate-related decisions under a high degree of uncertainty, including a framework for decision-making, additional reporting and accountability, and potential procedural venues.

394 http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M218/K017/218017363.PDF.

395 Further information here: http://www.cpuc.ca.gov/General.aspx?id=6442457399.

Figure 46: CPUC Priority Future Actions to Reduce Energy-Related Wildfire Risk



Source: CPUC, August 2, 2018, joint agency workshop on Climate Adaptation and Resiliency

At the July 25, 2018, staff research workshop on wildfire, the following research areas were suggested to reduce the risk of wildfire caused by utility equipment:

- Develop better information on conductor failure causation and prediction (such as from broken/falling vegetation, flying debris, wire slap, toppling poles, or age and degradation).
- Leverage voltage and phasing data to inform decisions on which circuits to de-energize in an emergency.
- Develop a falling conductor detection scheme (for example, detecting a falling conductor and de-energizing the circuit before it hits the ground).
- Improve methods for assessing the post-installation condition of overhead lines (beyond visual observation).
- Evaluate the effectiveness of infrastructure-hardening methods and fire safety of utility equipment.
- Investigate low-energy automatic reclosers.[396]
- Demonstrate advanced power poles with sensors for fire, wind, downed wire, and real-time loading.
- Decentralize the control of safety equipment (such as automatic response) for faster system response to events.

396 A r*ecloser* is a switch or circuit breaker that establishes an electrical circuit again manually, remotely, or automatically after a service interruption.

Many of these topics are included in the third EPIC investment plans of the IOUS, which are under consideration by the CPUC.

Recommendations

- **Prioritize actions that build climate preparedness and reduce greenhouse gas emissions.**
    - Consider cost-saving opportunities to coordinate energy infrastructure upgrades to reduce fire risks (such as replacing wooden poles and expanding the wind monitoring network), where applicable.
    - Consider trends such as the growing prevalence of distributed generation or zero-emission vehicles when planning multiday low-GHG backup generation strategies.
    - Develop a wildfire prevention and resilience research working group to refine and coordinate research areas. The working group should include a broad set of stakeholders, including community representatives. If the working group is involved in solicitation development outside a public workshop, the members of the group must not disclose information and will not be eligible to bid on the solicitation. The working group should promote efforts to leverage research from other entities.
    - Leverage the multiple cross-sector regional climate collaboratives that exist throughout the state to provide input on regional research and policy priorities, increase awareness of research findings, and assist in identifying local partners for demonstration and implementation projects.
- **Develop flexible and adaptive approaches**. The Energy Commission, California Public Utilities Commission, and the Governor's Office of Planning and Research should develop and share best practices of climate change adaptation, wildfire risk assessment, and energy planning to strengthen resilience to the combined impact of multiple stressors, including combined and sequential climate change impacts on local governments, vulnerable populations, and ecological systems (such as forest health). Stakeholders should also use the best available data, studies, and tools in making their decisions. For example, the data and studies found in the Cal-Adapt tool, which is continually being updated and improved, should be relied upon as vetted and trustworthy sources.
- **Protect the state's most vulnerable populations.**
    - Continue to develop strong lines of communication between utilities and vulnerable communities to ensure that they have accurate and updated information, access to resources during emergencies, and back-up measures set in place for potential local area de-energization.

    - Expand and improve government agency outreach to local communities, particularly those with barriers such as isolation (rural communities) or nontraditional governance (unincorporated areas, tribal lands) that might render traditional outreach ineffective.
    - Improve coordination between government agencies to ensure that the full suite of resources, which may be siloed among different departments, are available to all communities that need them.
    - Work to engage publicly owned utilities, along with the investor-owned utilities, in wildfire prevention discussions.
    - Continue to work with local government agencies in updating general plans to account for climate risks.
- **Continue wildfire and climate adaptation research**. As knowledge is gained in fire science, such as about changes in extreme wind events, the potential role of tree mortality on fire behavior, and land-use effects in the wildland urban interface, these findings should be incorporated into modeling long-term wildfire scenarios. Develop more robust methods of tracking the health and climate impacts of wildfires — both with regard to the destruction of carbon sinks and emissions of pollutants. Continue to develop new technology and strategies to assist with fuel management, ignition control, and weather awareness. Improve the granularity of data to target resilience and prevention actions. More broadly, climate adaptation research should be prioritized. As new adaptation-related data and studies become available, these should be carefully vetted and added to the Cal-Adapt tool, as appropriate, for use in utility planning and operations. Also, conduct demonstration projects to develop collaborative efforts with California Native American Tribes to use and incorporate traditional ecological knowledge into institutional approaches to watershed and forest management, including use of fire for forest thinning.

CHAPTER 6: Southern California Energy Reliability

Southern California has been the focus of major electric reliability concerns beginning with the outage of the two San Onofre Nuclear Generating Station units (San Onofre) in January 2012, followed by the decision to retire San Onofre in June 2013 and the massive gas leak discovered on October 23, 2015, at the Aliso Canyon natural gas storage facility. These events, coupled with the expected compliance-related closure of several Southern California coastal power plants that use ocean water for cooling, as well as the ongoing natural gas pipeline outages on the Southern California Gas (SoCalGas) system, are tightening the region's energy supply. The California Energy Commission, the California Public Utilities Commission (CPUC), and the California Independent System Operator (California ISO) worked together to address reliability issues, first with the closure of San Onofre, and again, with the additional partnership of the Los Angeles Department of Water and Power (LADWP), to respond to reliability issues related to Aliso Canyon. Ongoing work to address reliability issues related to San Onofre and Aliso Canyon is discussed below.

2018 Aliso Canyon Natural Gas Storage Facility Energy Reliability Issues

The SoCalGas system continues to operate at less than full capacity due to a significant number of pipeline outages and continuing restrictions on use of the Aliso Canyon natural gas storage facility. Extensive natural gas pipeline outages increase reliability risk. Challenges stem primarily from continuing outages on four key natural gas pipelines, which will make it difficult for SoCalGas to meet demand through a combination of flowing supplies and stored gas to ensure energy reliability throughout the winter. The reduction in flowing pipeline supplies means more reliance on storage to meet demand. The CPUC authorized SoCalGas to increase inventory at Aliso Canyon from a maximum of 24.6 billion cubic feet (Bcf) to 34 Bcf to prepare for winter. The Energy Commission, CPUC, California ISO, and LADWP (members of the "technical assessment group") have jointly addressed the near-term reliability issues associated with Aliso Canyon through the Energy Commission's Integrated Energy Policy Report (IEPR) proceeding, beginning with the *2016 IEPR Update*. The most recent analysis addresses short-term reliability issues for the summer of 2018 and winter 2018–2019 and provides a look back at winter 2017-2018.[397]

On August 8, 2018, California Attorney General Xavier Becerra, along with the California Air Resources Board (CARB), the County of Los Angeles, and the Los Angeles City

397 Winter is defined as November 1 through March 31, and summer is April 1 to October 31. These dates coincide with the traditional underground gas storage withdrawal and injection seasons for the natural gas industry.

Attorney's Office, announced having reached a settlement to resolve their outstanding claims against SoCalGas from the massive gas well leak at Aliso Canyon.[398]

If approved by the Los Angeles County Superior Court, SoCalGas will take four key actions, in addition to paying $119.5 million:

- Monitor methane at the Aliso Canyon facility fence line and post the data online in near real time for eight years, with certain methane levels triggering new reporting requirements.
- Create a new internal safety committee, which shall remain in place for eight years from approval of the settlement by the court.
- Retain an independent "safety ombudsman" to evaluate the internal safety committee's work and report to the public on safety-related issues at the Aliso Canyon facility for eight years following approval of the settlement by the court.
- Refrain from shifting the cost of this settlement.

The $119.5 million settlement payment is broken down as follows:[399]

- $26.5 million– GHG mitigation program to be invested in dairy biogas-collection infrastructure to fully mitigate the 109,000 metric tons of methane emitted by the leak.
- $7.6 million– GHG mitigation reserve.
- $45.4 million– Supplemental environmental projects, including $25 million for a long-term health study,[400] a local air monitoring network in Porter Ranch, air filtration systems in public schools, electric school buses, mobile asthma clinics, lead paint abatement of homes near the closed Exide battery recycling plant, and a fund to provide grants for other air pollution reduction projects.
- $19 million– Reimbursement for costs incurred by government agencies.
- $21 million– Civil penalties.

CARB gave official notice to the settlement and opened a comment period, which lasted 35 days and ended on September 12, 2018.[401]

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398 See settlement agreement at https://oag.ca.gov/system/files/attachments/press-docs/notice-lodging-and-proposed-cd-full.pdf.

399 https://www.arb.ca.gov/html/aliso-canyon/aliso-canyon-mitigation-agreement.pdf?_ga=2.120101964.557895652.1533753574-568780011.1524768107&utm_medium=email&utm_source=govdelivery.

400 The Porter Ranch Neighborhood Council expressed concerns about the long-term health impacts from exposure to crude oil (a constituent of the gas) from the gas leak, see letter from Issam Najm, president of the Porter Ranch Neighborhood Council to CPUC Commissioners Picker, Peterman, Randolph, Guzman Aceves, and Rechtschaffen, TN#225672, and response from Commissioner Randolph, TN# 225889 at https://efiling.energy.ca.gov/Lists/DocketLog.aspx?docketnumber=18-IEPR-03.

401 https://ww2.arb.ca.gov/our-work/programs/aliso-canyon-natural-gas-leak.

Operating Status of the SoCalGas System as of April 2018

Reliability challenges continue in Southern California despite the increase in allowed/permitted inventory at the Aliso Canyon storage facility. Significant natural gas pipeline outages on the SoCalGas system are the primary reason. Four key pipeline outages continue in 2018, reducing system capacity by more than 1 Bcfd from full system capacity:[402]

- Line 235-2 ruptured on October 1, 2017, and damaged nearby Line 4000.[403] There is no return-to-service date identified yet for Line 235-2.
- Line 4000 has been in and out of service and is operating at reduced pressure such that only an incremental 270 million cubic feet per day (MMcfd) is allowed into the system.
- Line 3000 has been out of service between July 2016 and September 17, 2018. The in-service date of Line 3000 was delayed multiple times. However, the return to service of Line 3000 will not incrementally increase system capacity due to the bottleneck created by losses on Lines 235-2 and 4000.
- Line 2000 has been operating at reduced pressure since 2011 and was reduced further by 30 MMcfd due to the expiration of the right-of-way through federal lands held in trust for the Morongo Band of Mission Indians.

These pipeline outages continued to hamper SoCalGas' ability to meet demand. Available pipeline capacity of 2,655 MMcfd as of April 10, 2018, is significantly lower than the 3,185 MMcfd available in summer 2017 and the full capacity of 3,875 MMcfd. Figure 47 shows the areas impacted by the pipeline outages. Table 16 presents SoCalGas system pipeline capacity for summer 2017; operating conditions as of April 10, 2018; pessimistic and optimistic cases;[404] a combined case with additional outages and mitigations; and SoCalGas nominal[405] system capacity (without outages). In all cases, system pipeline capacity is lower than 2017.

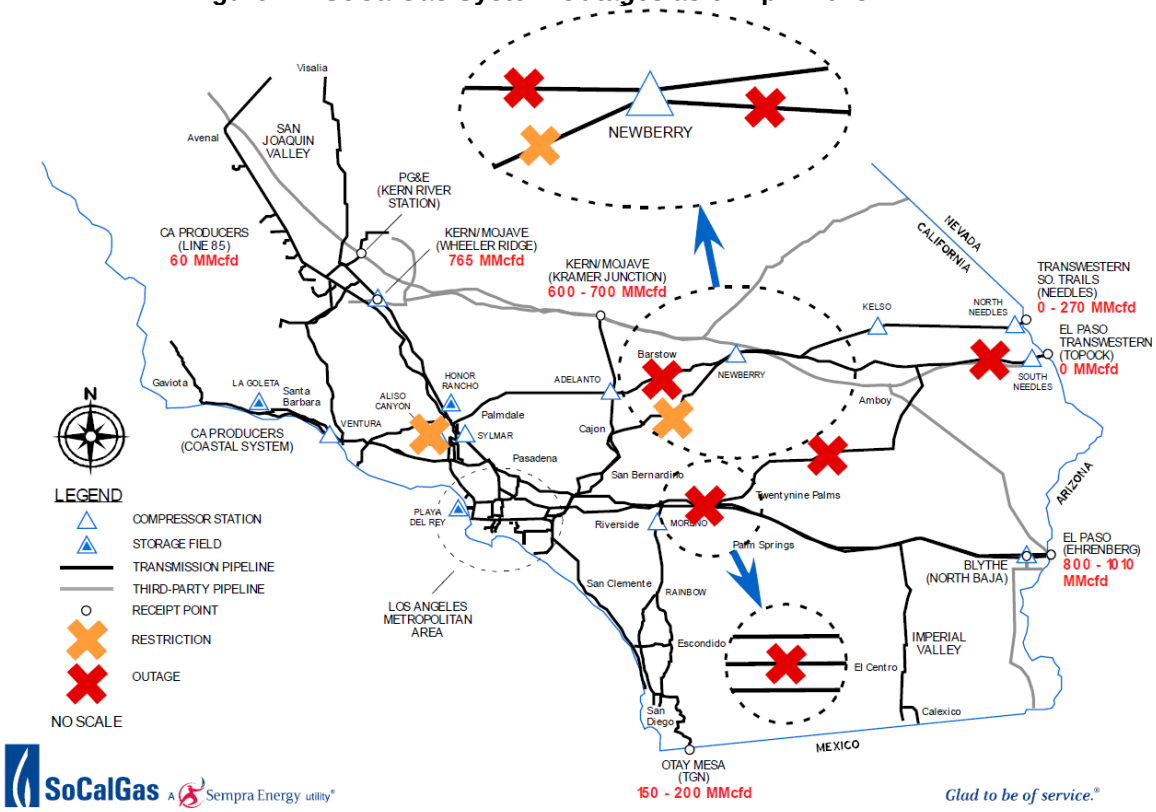
402 Full system capacity of 3.875 Bcfd (revised to 3.775 Bcfd due to derating of pipeline in the Line 85 zone) less 2.655 Bcfd (current operating capacity as of April 10) is 1.220 Bcfd, which is greater than 1.0 Bcfd.

403 SoCalGas commented that "the remediation work for Line 4000, however, was not caused by damage from the rupture of Line 235-2." (See TN# 26490 in Docket 18-IEPR-01, February 8, 2018.)

404 The pessimistic case assumes more outages, while the optimistic case assumes fewer outages.

405 "Nominal" refers to normal maximum stated capacity. The real capacity would be measured with analysis such as hydraulic modeling.

Figure 47: SoCalGas System Outages as of April 2018



Source: SoCalGas presentation at the May 8, 2018, IEPR Joint Agency Workshop on Southern California Energy Reliability in Southern California, May 8, 2018, http://www.energy.ca.gov/2018_energypolicy/documents/#05082018.

Table 16: SoCalGas System Pipeline Capacity (MMcfd)

	Summer 2017	As of April 10, 2018	Summer 2018 Pessimistic	Summer 2018 Optimistic	Summer 2018 Combined	2016 CA Gas Report
Receipt Point						
North Needles[a]	800	270[a]	0	270[a]	0	1,590
Topock*[b]	0	0[b]	0	0[b]	0	
Kramer Junction[c]	550	550	550	625[c]	625	
Ehrenberg	1,010	980	800	980	800	1,210[d]
Otay Mesa[d]	0	30	150	230	230	
Wheeler Ridge	765	765	765	765	765	765
CA production[e]	60	60	60	60	60	310[e]
TOTAL Supply	**3,185**	**2,655**	**2,325**	**2,930**	**2,480**	**3,875[f]**

a) As long as Line 4000 is operating at reduced pressure, receipts at North Needles or Topock are limited to 270 MMcfd. b) The Line 3000 outage limits receipts at the Topock receipt point to zero. c) Firm deliveries at Kramer Junction are limited to 550 MMcfd; Kern River can deliver up to 700 MMcfd under certain system conditions. d) 1,210 MMcfd is the nominal capacity of the southern zone but achieving it requires 200 MMcfd be delivered via Otay Mesa. The Otay Mesa receipt point is rarely used and thus is excluded under "normal" conditions. The right-of-way expiration on Line 2000 means that 30 MMcfd must be delivered at Otay Mesa to keep the southern system total at 1,010 MMcfd. e) California production delivered to SoCalGas in recent years has run far below this nominal capacity value. f) SoCalGas indicates their nominal capacity is 3.775 MMcfd. The difference of 0.10 Bcfd is due to derating of pipeline in the Line 85 zone.

Source: Summer 2018 Technical Assessment

Winter 2017–2018 Look Back

The *Aliso Canyon Winter Risk Assessment Technical Report 2017–18 Supplement* (2017–2018 Winter Assessment)[406] concluded that Southern California faced new challenges and greater uncertainty than in winter 2016–2017. Significant and unprecedented unplanned outages on SoCalGas pipelines, combined with a series of other planned maintenance requirements and delays in returning facilities to service, lead to higher risk of curtailments in winter 2017–2018. The assessment raised the possibility that noncore customer curtailments in December might be needed to preserve gas storage inventory needed for core customers to meet peak demand later in the winter season.[407] The weather was unseasonably warm through much of last winter, enabling SoCalGas to preserve inventory until a cold spell hit in mid-February. The sustained cold snap led to electric generator curtailments that began on February 20 and ended on March 6, 2018. Six and one-half Bcf of gas was withdrawn collectively from storage during this time, most, but not all, from non-Aliso Canyon fields. Withdrawals from Aliso Canyon

406 *Aliso Canyon Winter Risk Assessment Technical Report 2017-18 Supplement*, November 28, 2018, is available at http://www.energy.ca.gov/2017_energypolicy/documents/#05222017.

407 Core customers are the owners of homes and small businesses. Noncore customers are larger commercial customers, some of which burn natural gas to produce electricity.

occurred on six days during that time, totaling about 1.14 Bcf.[408] The CPUC is investigating the nature of the withdrawals and will publish the findings in a report.

Summer 2018

Summer 2018 marks the third summer that the joint agency technical assessment group analyzed the natural gas and electricity systems and released a third summer assessment, *Aliso Canyon Risk Assessment Technical Report Summer 2018* (*2018 Summer Assessment*).[409] Since much of the needed natural gas system data and hydraulic modeling capacity[410] were held by SoCalGas, the technical assessment group asked the gas company to perform the required modeling, as in prior studies.[411]

On May 8, 2018, the Energy Commission, CPUC, California ISO, and LADWP held a joint IEPR workshop in Diamond Bar to present the analysis and outlook. The analysis focused on summer 2018, as well as a look forward to winter 2018–2019. The findings showed a moderate risk to electricity reliability in summer 2018 but suggest a more serious risk ahead. SoCalGas will be challenged to fill storage to a level sufficient to ensure energy reliability throughout the coming winter because of multiple pipeline outages. The continued pipeline outages mean that more reliance on storage will likely be needed to meet demand. Anytime demand exceeds flowing pipeline supplies, storage withdrawals or curtailments will be needed.

The *2018 Summer Assessment* includes a summer electric peak-day analysis and monthly gas balance analysis through the beginning of winter to evaluate possible storage inventory buildouts. The assessment includes several analytical components:

- Hydraulic modeling of summer peak-day demand by SoCalGas for two cases: a base case that assumes current operating conditions and a sensitivity case that assumes additional pipeline outages and mitigations.
- An electric impact analysis, including power-flow analysis, by the California ISO and LADWP using the deliverable gas demand estimates to determine whether electric generator gas demand could be served and whether electricity service interruptions could occur on a summer peak day. The analysis includes

408 *Southern California Gas Company 30-Day Aliso Canyon Withdrawal Report* is available at http://www.cpuc.ca.gov/uploadedFiles/CPUC_Public_Website/Content/Safety/Aliso%20WD%2030_Day%20Report_Public%20Version.pdf.

409 *Aliso Canyon Risk Assessment Technical Report Summer 2018* is available at http://www.energy.ca.gov/2018_energypolicy/documents/#05082018.

410 *Natural gas hydraulic modeling* is a simulation of the natural gas system that withdraws and injects gas into storage, opens and closes valve stations to the interstate pipeline supplies, and turns on and off compressor stations to meet the hourly demand. A successful simulation ensures that the gas system operates between the minimum and maximum operating pressures, operates within the capacities of the gas transmission facilities, and recovers system line pack at the end of each day.

411 The series of joint agency technical assessments includes three summer assessments and two winter assessments.

calculating minimum generation levels to meet reliability and electric import sensitivities.

- Gas balance analysis by the Energy Commission for seven cases through December 31, 2018. The cases are based on normal weather conditions and varying pipeline outages, mitigations, and Aliso Canyon inventory levels.

The assessment finds that the forecast 1-in-10-year electric peak day forecast demand of 3,511 MMcfd can be met under base case results of 3,555 MMcfd supportable demand,[412] but not under sensitivity case results of 3,425 MMcfd supportable demand. If electric generation is curtailed to minimum generation levels, adjusted demand can be met under sensitivity case assumptions. Curtailing to minimum generation levels is an emergency measure that presumes the balancing authorities can procure the necessary electricity imports, and that leads to higher costs. Electric reliability can be maintained on a 1-in-10-year electric peak day without using gas from Aliso Canyon, assuming 100 percent electricity transmission import utilization and the availability of non-gas-fired generation in Southern California. This conclusion changes if electricity transmission import utilization drops below 90 percent.

The gas balance cases were run for normal weather conditions. Cold weather cases were not evaluated for this assessment, but the assessment essentially would look worse with higher demand under cold weather conditions. In general, the cases with lower pipeline capacity assumptions demonstrate lower monthly reserve margins and lower December month-end storage inventory levels. In the pessimistic case, there is not enough flowing supply capacity available throughout the summer to meet customer demand, so net monthly storage withdrawals become necessary in September and October.[413] The return to service of pipelines and additional supplies at Otay Mesa would improve the outlook. The optimistic case shows reasonable reserve margins except later in the year and the highest December month-end inventory levels.

Natural Gas Hydraulic Analysis

The *2018 Summer Assessment* hydraulic analysis simulates the physical operations of the SoCalGas transmission and storage system. The technical assessment group developed two cases for SoCalGas to run: a base case assuming current operating conditions as of April 10, 2018, and a sensitivity case based on additional pipeline outages and mitigation solutions. The base case assumptions did not account for the loss of 30 MMcfd due to the right-of-way expiration of Line 2000.[414] The sensitivity case assumed additional outages on Line 4000 in the northern system and Line 5000 in the

412 *Supported* or *supportable demand* is a term used by SoCalGas to describe how much demand its system can support, but it also can be viewed as system capacity.

413 Traditionally, the storage injection season is April through October, and the storage withdrawal season is November through March.

414 The technical assessment group learned of the loss of 30 MMcfd due to the right-of-way expiration of Line 2000 after developing the base case assumptions and running the hydraulic modeling cases.

southern system and additional supply at Otay Mesa and Kramer Junction. The hydraulic analysis assumed no injection and no withdrawal from Aliso Canyon but assumed full withdrawal capability at the other storage fields.

Table 17[415] compares the results for the 2018 Summer Assessment to the 2017 Summer Assessment.[416] The results show supported demand[417] of 3,555 MMcfd in the base case and 3,425 MMcfd in the sensitivity case, about 100 to 200 MMcfd lower than summer 2017 results. Pipeline supplies were lower by 530 MMcfd, and storage withdrawals were 432 MMcfd higher in the base case compared to the summer 2017 results. This finding demonstrates greater use of gas from storage to meet demand in summer 2018 than summer 2017. Storage is likely to be used more in summer 2018 than last, all else being equal. If the storage depleted during the summer cannot be replaced before higher winter demand sets in, the system ends up being back in the same situation as last winter.

Table 17: Base and Sensitivity Case Results

	Summer 2017		Summer 2018			
	Base Case		Base Case		Sensitivity	
	Day MMcfd	Peak Hour MMcfh	Day MMcfd	Peak Hour MMcfh	Day MMcfd	Peak Hour MMcfh
Pipeline	3185	132.7	2655	110.6	2525	105.2
Storage	468	61.3	900	55	900	55
Supported Demand	3638	221.5	3555	214.7	3425	205.3
Pack(+)/Draft(-)	15	-27.5	0	-49.1	0	-45.1

Source: Summer 2018 Technical Assessment

Electricity Impact Analysis

The California ISO and LADWP balancing authorities performed a complementary joint assessment of electric impacts based on SoCalGas supportable demand of 3,555 MMcfd in the base case and 3,425 MMcfd in the sensitivity case. The balancing authorities performed a power-flow analysis to determine the minimum generation amount needed to meet reliability standards. As noted above, going to the minimum generation amount is an emergency measure that presumes curtailments to the electric generators and

415 In this context, "pack+/draft-" simply compares system capacity versus the sum of pipeline supplies and storage withdrawals. It implies that the system would be over or under capacity limit if the quantities of supply shown were to materialize.

416 *2017 Summer Assessment* available at, http://www.energy.ca.gov/2017_energypolicy/documents/2017-05-22_workshop/2017-05-22_documents.php.

417 *Supported demand* is a term used by SoCalGas to describe how much demand its system can support, but it also can be viewed as system capacity.

leads to increased costs. The minimum generation level also presumes the balancing authorities are able to procure the necessary imports.

The availability of supply from alternative sources may be less in summer 2018 than in summer 2017 due to less-than-average hydroelectric conditions in 2018. Table 18 presents the minimum generation gas requirements, including the qualifying facilities (QFs). The 2017 minimum electric generation requirements of 1,870 MMcfd went down by almost 300 MMcfd in 2018 to 1,574 MMcfd. If electric generation is curtailed to minimum generation levels, the "2018 Projected 1-in-10-Year Electric Peak Day" analysis shows that a 397 MMcfd curtailment is needed for 1,971 MMcfd of demand. Several transmission upgrades that came on-line at the end of 2017 and some gas generation retirements in the SoCalGas service area contributed to the lower minimum generation gas burn requirements. Electric generation can be curtailed by as much as 397 MMcfd below normal on a peak summer day and still maintain electric reliability.

Table 18: California ISO and LADWP Minimum Generation Gas Requirements Including QFs (MMcfd), Assuming a Hotter-Than-Average Summer

California ISO and LADWP Electric Generation Gas Requirements	MMcfd
2017 Actual Peak Load Day, Electric Generation Gas Burn	2,028
2017 Minimum Electric Generation Including N-1 Contingency[418]	1,870
2018 Projected 1-in-10 Year Electric Peak Day, Electric Generation	1,971[419]
2018 Minimum Electric Generation Including N-1 Contingency	1,574
2018 Implied Curtailment if Electric Generation Goes to Minimum Generation	397

Source: Summer 2018 Technical Assessment

Table 19 presents the projected 1-in-10-year summer peak demand for 2018, and the adjusted demand assuming electric generation is curtailed to minimum generation levels. Any outage or change on the gas system that reduces gas system capacity below 3,114 MMcfd minimum generation gas demand level will result in insufficient gas being available to keep the electric system reliable on a summer peak day.

418 An *N-1 contingency event* is an electricity reliability planning criterion by which operators assure facilities are available to operate to maintain reliability for the most severe generation or transmission facility outage.

419 The projected 2018 1-in-10-year electric peak day demand for electric generation is slightly lower than the actual 2017 peak load day electric generation gas burn because of some gas generation retirements.

Table 19: 2018 1-in-10-Year Summer Peak Day Demand at Forecast Versus Minimum Electric Generation Levels

Summer Demand (MMcfd)	1-in-10 Year Peak Day Forecast Electric Generation	1-in-10 Year Peak Day Minimum Electric Generation, N-1 Contingency,
Core	770	770
Noncore, Non-Electric Generation	770	770
Noncore, Electric Generation	1,971	1,574
Total Demand	3,511	3,114
Implied Curtailment if Electric Generation Goes to Minimum Generation	N/A	397

Source: Summer 2018 Technical Assessment

The technical assessment group examined how variations in gas supply and electric import capability could affect California ISO's and the LADWP's ability to meet summer 2018 peak demand, resulting in a shortfall in one of the scenarios. Table 20 presents the results of six scenarios for the base and sensitivity cases under 100, 90, and 85 percent electric import capability. If electric generation is curtailed to minimum generation levels, a surplus results in five of the six cases. This "surplus" capacity could be used to allow generators to burn more than the minimum level. The results show that electric reliability can be maintained unless transmission utilization drops below 90 percent. At 85 percent transmission utilization, Scenario 6 results in a deficit of 67 MMcfd. These results assume 100 percent flowing gas supply. The electric load could be at risk if the electric system is not fully available, electric supplies are limited, or other outages affect the amount of gas delivered to the gas system. In such circumstances, gas supplies from Aliso Canyon storage would be necessary to reduce the shortfall to avoid interruption of electric service.

Table 20: Summary of Results for the Base and Sensitivity Cases Under 100, 90, and 85 Percent Transmission Import Utilization, Assuming Electric Minimum Generation Level and a Hotter-Than-Average Summer in 2018 (1-in-10-Year, 2018 Peak Summer Case)

	Base Case			Sensitivity Case		
	1	2	3	4	5	6
Demand Supportable by SoCalGas (MMcfd)	3,555	3,555	3,555	3,425	3,425	3,425
Implied Curtailment if Electric Generation Goes to Minimum Generation	-397	-397	-397	-397	-397	-397
Transmission Import Utilization	100%	90%	85%	100%	90%	85%
Gas System Surplus/Deficit After Moving Electric Generation to Minimum	441	164	63	311	34	-67

Source: California Energy Commission

Gas Balance Analysis and Look Forward Toward Winter 2018-2019

The Energy Commission's gas balance analysis provides an assessment independent of SoCalGas and tests additional sensitivity cases with alternate assumptions. The gas balance cases looked at monthly supply and demand, including injections and withdrawals from storage inventory. The cases look ahead through December 31, 2018, and demonstrate the summer challenges with a look toward winter 2018–2019 beginning inventory. The cases were developed for normal weather demand and represented average daily demand for each month, recognizing that some days will be higher or lower than the average. Cold weather demand cases were not run but would likely be worse, given higher gas demand.

The Energy Commission developed seven cases for the gas balance analysis with varying supply assumptions and target inventory levels at Aliso Canyon. Table 21 contains the varying SoCalGas system pipeline capacity and supply assumptions used in the gas balance analysis, ranging from a low of 2,325 MMcfd to a high of 2,930 MMcfd pipeline capacity, depending on the pipeline outages and gas system mitigations in place. The range was designed to capture plausible outages and mitigations since there is uncertainty surrounding which pipelines will remain out of service, whether additional outages will occur, and which gas system mitigations will be in place. The cases also tested varying inventory levels at Aliso Canyon. As of April 10, 2018, the maximum allowable inventory level at Aliso Canyon was 24.6 Bcf. SoCalGas prepared its own technical assessment and requested an increase of inventory at Aliso Canyon to 30 Bcf in an advice letter to the CPUC.[420] Several gas balance cases aimed to determine whether SoCalGas could achieve this higher inventory level. In addition, one case tested the

420 Supplemental Advice Letter 5275 A, which superseded Advice Letter 5275 in its entirety, Requesting Approval of the Proposed Second Injection Enhancement Plan and Second Injection Enhancement Memorandum between the System Operator and the Gas Acquisition Department for Services to Maintain Summer Reliability Pursuant to the March 13, 2018 "Injection Required for SoCalGas Summer Reliability and Storage Inventories" Letter from CPUC Executive Director Alice Stebbins available at https://www.socalgas.com/regulatory/tariffs/tm2/pdf/5275-A.pdf.

maximum achievable inventory level at Aliso Canyon, given a certain set of supply assumptions.

The technical assessment team assumptions differed from those made by SoCalGas and did not discount pipeline capacity to 85 percent, but the assessments generally drew similar conclusions. Table 21 presents the seven cases and associated December 2018 month-end inventory level. Figure 48 presents the planning reserve margins for the bookend cases and the conditions case with 30 Bcf at Aliso Canyon to show the range in reserve margins. The planning reserve margins indicate the amount of excess capacity beyond expected demand that is available to deal with unplanned outages or higher demand than forecast. Natural gas planners do not have an explicit monthly planning reserve margin requirement, but 15 percent is a desirable target. Planners must meet a peak-day design criterion and curtail noncore load to bring the system back to balance. The results show that the planning reserve margins are tight and generally below 10 percent for all cases except the optimistic case. Across the months, margins could be zero percent in some cases, and all cases decline to zero percent by the end of December.

Table 21: Gas Balance Cases

Gas Balance Cases		Aliso Canyon Target Inventory (Bcf)	Sept. 2018 Projected Pipeline Supply (MMcfd)	Dec. 2018 Month-End Inventory (Bcf)		
				Aliso Canyon	Other Storage Fields	Total Storage Inventory
1	Current Conditions as of April 10, 24.6 Bcf	24.6	2,655	17	37	54
2	Current Conditions as of April 10, 30 Bcf	30	2,655	22	37	59
3	Pessimistic, 30 Bcf	30	2,325	16	14	30
4	Optimistic, 30 Bcf	30	2,930	30	37	67
5	Combined Outage & Mitigation, 24.6 Bcf	24.6	2,480	14	30	44
6	Combined Outage & Mitigation, 30 Bcf	30	2,480	15	33	48
7	Combined Outage & Mitigation, Max 51 Bcf	51	2,578	36	33	69

Source: California Energy Commission

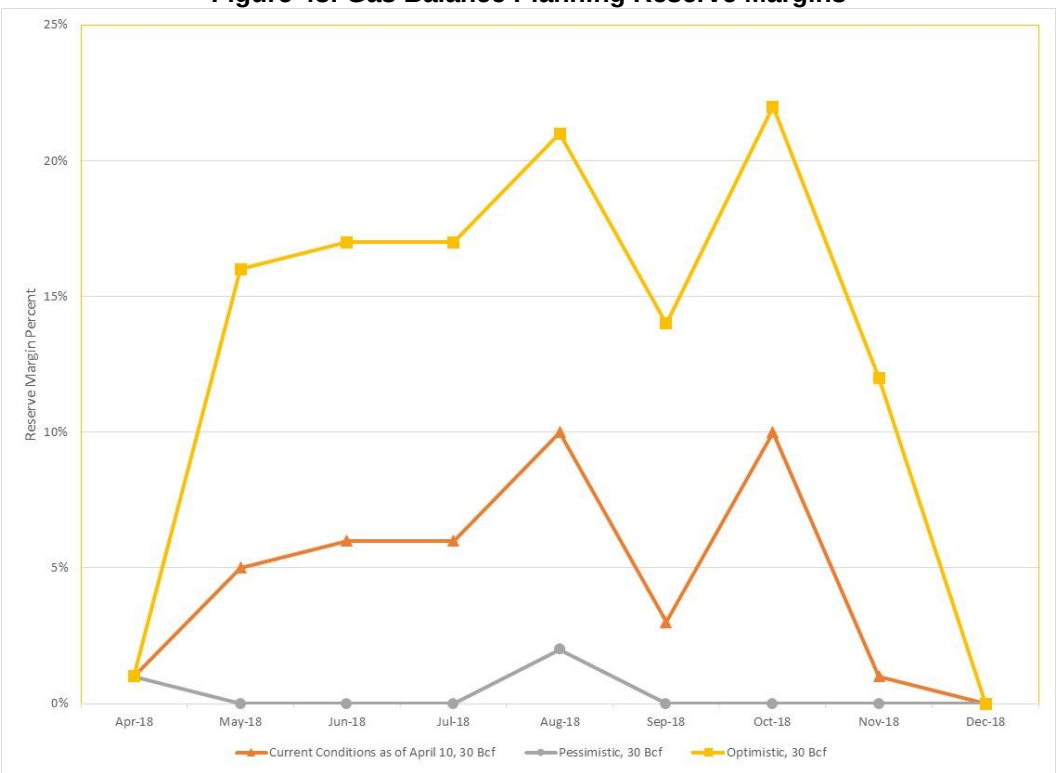
The assessment concludes that there is a moderate risk to reliability during the summer but a more serious risk for winter. There may not be enough flowing supply throughout the summer to meet demand and inject gas into storage. The December month-end storage inventory levels could be so low that the withdrawal capability is insufficient to maintain reliability in winter.[421] The results highlight the critical need to fix the pipelines and safely return them to service.

421 SoCalGas has stated it needs 43 Bcf in the non-Aliso Canyon storage fields to support the maximum withdrawals needed should an extreme peak-day event occur. The technical assessment team knows of no

Concerns over attaining the storage inventories needed to preserve winter reliability were raised in the 2017–2018 Winter Assessment. On June 18, 2018, the CPUC issued a draft 715 report, *Aliso Canyon Working Gas Inventory, Production Capacity, Injection Capacity, and Well Availability for Reliability*,[422] that recommended the maximum allowable Aliso inventory be increased from 24.6 Bcf to 34 Bcf to help meet winter reliability.

In summary, SoCalGas will be challenged to meet demand with flowing supply and fill storage to a level sufficient to ensure energy reliability throughout the coming winter because of all the pipeline outages. Pipeline outages are likely to prevent injection of much more than 30 Bcf into Aliso Canyon, regardless of the approved inventory level.

Figure 48: Gas Balance Planning Reserve Margins



Source: California Energy Commission

publicly vetted analysis that verifies the 43 Bcf or the relationship between storage withdrawal capability and inventory.

422 In the aftermath of the 2015 gas leak at the Aliso Canyon natural gas storage facility, Senate Bill 380 added Section 715 to the Public Utilities Code, which requires the CPUC to determine the range of Aliso inventory necessary to ensure safety, reliability, and just and reasonable rates.

CPUC draft 715 report, *Aliso Canyon Working Gas Inventory, Production Capacity, Injection Capacity, and Well Availability for Reliability*, is available at http://www.cpuc.ca.gov/uploadedFiles/CPUC_Public_Website/Content/News_Room/Draft715Report_Summer2018.pdf.

Mitigation Measures

Energy reliability remains challenging due to the numerous pipeline outages on the SoCalGas system. The technical assessment group recommends continuing most of the mitigation measures implemented over the past three years and exploring several others. More than 40 mitigation measures are in place or proposed, ranging from changing the gas balance rules to implementing new demand response programs to authorizing supply at Otay Mesa. Appendix B of the 2018 Summer Assessment contains the full list of mitigation measures, including five new ones listed below:

- Buy LNG to assure that up to 230 MMcfd can reach the Otay Mesa receipt point on a firm basis.
- Coordinate with gas customers to ensure they are prepared to respond to high and low gas operational flow orders.
- Give the SoCalGas operational hub permission to buy gas to fill the receipt points to capacity when capacity would otherwise go unused.
- Expedite any pending transmission upgrades that would reduce the electric generation minimum generation requirement.
- Monitor the federal "Energy Infrastructure Demand Response Act of 2018" to ensure California is considered as a region for any Department of Energy-sponsored demand response pilot programs.

The mitigation measures focus on short-term reliability concerns, but looking further ahead, other ideas are being explored to develop a plan to phase out Aliso Canyon within 10 years, as former California Governor Edmund G. Brown, Jr. has directed Energy Commission Chair Robert B. Weisenmiller.[423] (See sidebar on "Opposition to Reopening Oil and Gas Drilling Along Coastal and Public Lands.") Chair Weisenmiller and CPUC President Michael Picker requested California ISO President and Chief Executive Officer Stephen Berberich to evaluate expanded transmission capability of low-carbon supplies to and from the Northwest to support phasing out Aliso Canyon.[424]

Opposition to Reopening Oil and Gas Drilling Along Coast and Public Lands

On September 8, 2018, then-Governor Brown signed SB 834 (Hannah-Beth Jackson, Chapter 309) and AB 1775 (Al Muratsuchi, Chapter 310) to block new federal offshore oil drilling along California's coast, and announced the state's opposition to the federal government's plan to expand oil drilling on public lands in California. While this does not affect energy reliability in Southern California, this step is consistent with California's efforts to move away from fossil fuels and develop environmentally sound energy sources.

Source: https://www.gov.ca.gov/2018/09/08/trump-offshore-oil-drilling-expansion/

423 July 19, 2017, letter from Robert B. Weisenmiller to Michael Picker, TN 220299 in https://efiling.energy.ca.gov/Lists/DocketLog.aspx?docketnumber=17-IEPR-11.

424 February 15, 2018, letter from Robert B. Weisenmiller and Michael Picker. https://efiling.energy.ca.gov/GetDocument.aspx?tn=222907.

The study is underway as part of the California ISO 2018-19 Transmission Planning Process and includes stakeholders, such as LADWP, Bonneville Power Administration, and Southern California Edison. In addition, Gill Ranch Storage proposes use of its independent storage field in Northern California to improve reliability to Southern California.[425] The Gill Ranch idea would require greater connectivity and infrastructure investment between PG&E and SoCalGas natural gas systems. SoCalGas has provided comments[426] that significant investment in new pipeline and compressor infrastructure would be required. The Energy Commission encourages SoCalGas to provide the details and documentation of these infrastructure investments in next year's *IEPR*.

Winter 2018–2019

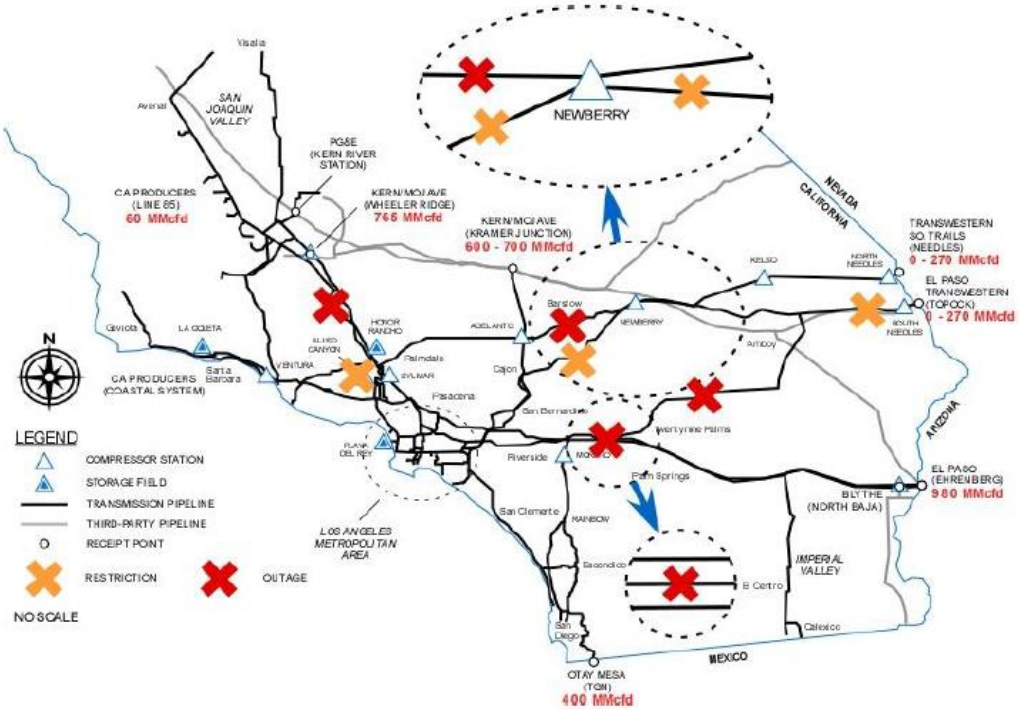
Winter 2018–2019 marks the third winter that the joint agency technical assessment group released a winter assessment (*2018–2019 Winter Assessment*).[427] Southern California continues to face reliability challenges to its energy system in winter 2018–2019, primarily due to continuing outages and reduced capacity on key natural gas pipelines. The current operating status of the SoCalGas system is mostly unchanged from last winter, as described in the section "Current Operating Status of the SoCalGas System," except for the extra gas stored at Aliso Canyon and Line 3000, which returned to service September 17, 2018, at reduced operating pressure, in theory allowing receipts from the Topock area. (See Figure 49.)

425 Presentation by Dave Weber and Justin Palfreyman at May 7, 2017, Joint Agency Workshop. Found at https://efiling.energy.ca.gov/GetDocument.aspx?tn=223367.

426 https://efiling.energy.ca.gov/GetDocument.aspx?tn=225796.

427 *Aliso Canyon Risk Assessment Technical Report Winter 2018-19 Supplement, October 10, 2018.* https://www.energy.ca.gov/2018_energypolicy/documents/#05082018.

Figure 49: Southern California Gas System Outages



Source: SoCalGas

As mentioned, the return to service of Line 3000 does not incrementally increase supply due to the bottleneck created by losses on Line 235-2 and Line 4000. Table 22 presents feasible sendout from the SoCalGas system for winter 2018–2019 with and without gas system mitigations.

Table 22: SoCalGas Feasible System Sendout for Winter 2018–2019

	Winter 2018–2019 Outage on Line 235-2 and Reduced Operating Pressure on Lines 4000 and 3000*
Maximum Feasible System Sendout Without Gas System Mitigations	3,807
Maximum Feasible System Sendout With Gas System Mitigations	4,057

Source: *Aliso Canyon Risk Assessment Technical Report Winter 2018-19 Supplement, October 10, 2018.* https://www.energy.ca.gov/2018_energypolicy/documents/#05082018, Note: Includes flowing pipeline supplies and non-Aliso Canyon storage. Mitigations include 50 MMcfd at Kramer Junction and 200 MMcfd at Otay Mesa. * Maximum feasible sendout varies according to which pipeline assets are in versus out of service. The combination of outages this winter is slightly different than those evaluated in the winter assessment for 2017–2018. Staff's "Period 3: Post 12/31/2017" case projected a maximum feasible sendout (with mitigations) of 4,117 MMcfd, some 60 MMcfd higher than the 4,057 MMcfd shown for this winter.

SoCalGas remains unable to meet its 1-in-10-year peak cold day forecast gas demand of 4.965 Bcf. System sendout of 4,057 MMcfd is similar to last winter's post December 31, 2017, projection of 4,117 MMcfd with gas system mitigations. Last winter, LADWP postponed necessary maintenance and upgrades on its electric transmission lines to

reduce reliability risks caused by outages on the SoCalGas system. LADWP plans to move forward with this work to meet impending Renewables Portfolio Standard requirements. The minimum electric generation requirement for this winter is similar to last winter's post-February 1, 2018, amount, when LADWP planned to begin its maintenance and upgrade work. Under 1-in-10-year peak day demand, a shortfall exists even when the balancing authorities reduce generation to the minimum levels needed to meet reliability. The options to resolve the shortfall would be to withdraw gas from Aliso Canyon, curtail other noncore customers, or interrupt electricity service.

SoCalGas will begin winter with higher levels of natural gas in storage than projected. Mild summer conditions enabled SoCalGas to reach 80.5 Bcf of gas in storage by November 1, 2018, which includes the increase in natural gas storage volume at Aliso Canyon of 34 Bcf. The additional 9.4 Bcf of storage inventory at Aliso Canyon will help meet seasonal winter demand; however, Aliso Canyon is a resource of last resort and is subject to the withdrawal protocol established by the CPUC.

The largest risk to the system is not from a single day of high gas demand — it is from multiple days that draw storage inventories down to capacity levels that are insufficient to meet gas demand later in the winter. With no reduced risk from last winter, all mitigation measures established last year will need to continue, including extension of the tighter gas balance rules and renewed funding for winter conservation messaging. LADWP, the California ISO, and other noncore users should be prepared to respond to operational flow orders and gas service curtailments. New mitigation measures include an SCE request for 20 MW of energy storage to help address electrical system operational limitations, and SoCalGas' demand response program expansion from 9,000 to 50,000 thermostats (pending CPUC approval). Reliability challenges continue in Southern California despite the increase in authorized inventory at Aliso Canyon.

SoCalGas submitted the *Southern California Gas Company Winter 2018-19 Technical Assessment,*[428] which estimates a maximum system wide capacity range of 3.75 to 4.15 Bcfd, including use of Aliso Canyon. This range contrasts with the technical assessment team's range in Table 21 of 3.81 to 4.06 Bcfd, as Table 21 does not include the use of Aliso Canyon. The range depends on the outage assumptions for Line 235 and Line 400 and additional supply at Kramer and Otay Mesa. SoCalGas hydraulic analysis also assumes discounting pipeline supply to 90 percent utilization, which the technical assessment team does not support. Its assessment finds that noncore winter curtailments will be likely under all but the most optimistic conditions (warm temperature conditions with minimal facility outages) and that it would not be able to meet 1-in-10-year winter peak day demand even with the use of Aliso Canyon, or have sufficient storage inventory to meet demand over the entire winter in most scenarios. The report also raised the possibility of curtailing noncore customers to maintain minimum inventory requirements and withdrawal capacity for core customers. SoCalGas

428 SoCalGas Comments, *Aliso Canyon Risk Assessment Technical Report Winter 2018-19 Supplement*, TN#225785, https://efiling.energy.ca.gov/Lists/DocketLog.aspx?docketnumber=18-IEPR-03.

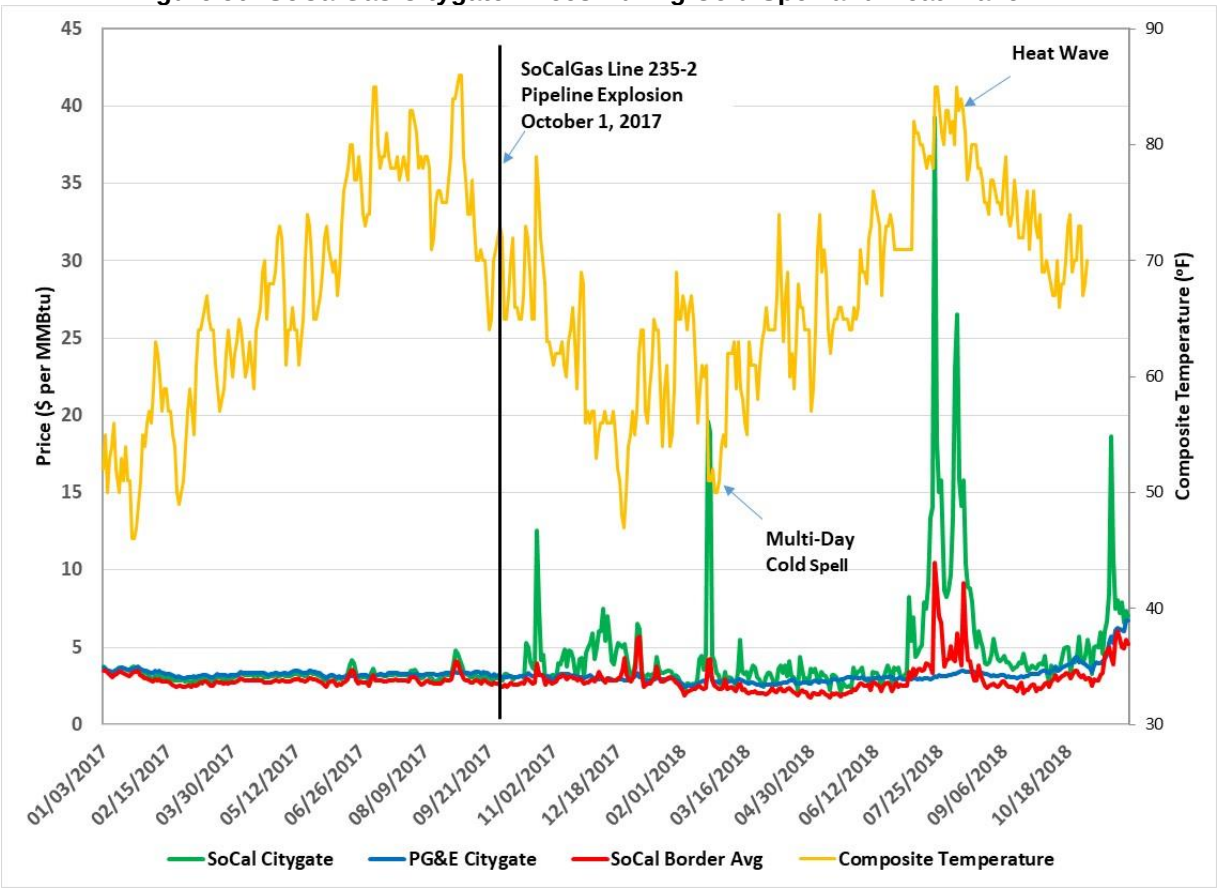
estimates Aliso Canyon maximum withdrawal capacity of 1,317 MMcfd based on an inventory level of 34 Bcf and plans to preemptively use supply from Aliso Canyon and SoCalGas Rule 23 curtailment procedures as necessary to preserve these minimum levels.

Winter 2017–2018 and Summer 2018 Look Back at Natural Gas Prices

Natural gas prices have been impacted by the outages on the SoCalGas system. Figure 50 presents natural gas prices and SoCalGas composite temperature from January 2017 to November 2018. Before the explosion on Line 235-2 on October 1, 2017, natural gas prices remained in the $3 per MMBtu range for much of 2017. After the explosion, price spikes and price volatility increased at SoCalGas Citygate, with prices reaching the $20 per MMBtu range during the winter cold snap in late February 2018 and nearly $40 per MMBtu during a summer heat wave in late July 2018, while those at SoCalGas Border and PG&E Citygate did not. Increased volatility at the SoCalGas Citygate since the rupture of Line 235-2 and the maintenance outage on Line 4000 has been observed and noted in the Energy Commission's *2017 Integrated Energy Policy Report*.[429] The data clearly show that natural gas prices have been impacted from the natural gas pipeline outages, rather than restricted use of Aliso Canyon. The highest price increases occurred on the days that the system composite temperature was at the lowest during the winter and highest during the summer. As long as the pipeline outages exist, natural gas price volatility may likely continue this winter.

429 California Energy Commission staff. 2017. *2017 Integrated Energy Policy Report*. California Energy Commission. Publication Number: CEC-100-2017-001-CMF. p. 220.

Figure 50: SoCalGas Citygate Prices During Cold Spell and Heat Wave



Source: California Energy Commission

The Energy Commission, together with the CPUC, held a joint agency workshop on January 11, 2019, to discuss the cause of the price spikes and to solicit input on actions they should take to mitigate the spikes. A number of stakeholders provided their views and suggestions. Commissioners asked SoCalGas to provide more detail about why the pipelines have not yet been fixed and may consider taking additional action after stakeholders submit written comments in late January.

Update on Southern California Electricity Reliability

Much of the transmission system in Southern California was built around the assumed operation of the San Onofre Nuclear Generating Station, which provided not just 2,200 MW of capacity, but voltage support and reactive power to maintain grid stability, as well as capacity to balance flows and keep transmission lines from overloading. Preserving reliability means replacing all those services, as well as the services for the various coastal power plants that use ocean water for once-through-cooling (OTC), as mandated by SWRCB. Since 2013, the joint agencies, along with representatives from the investor-owned utilities and local air districts in the South Coast Air Basin, have conducted public workshops at least annually to discuss these intertwined issues.

Using the action plan developed in 2013 at the direction of former Governor Brown as a guideline, the energy agencies put in place a multipronged plan of preferred resources, transmission upgrades, and conventional generation to meet the reliability needs of Southern California.[430] The agencies also developed a backup plan of two contingency mitigation measures in case any of the solutions are delayed or do not come to fruition. The contingency mitigation measures consist of an OTC compliance date deferral process and new gas-fired generation options and are available to be triggered if needed to meet reliability concerns.[431] The agencies, as part of the Southern California Reliability Project (SCRP) team, periodically review progress in securing preferred resources, transmission projects, and conventional generation to determine whether further actions need to be taken. As uncertainties become clear, the agencies will seek mitigation solutions that maintain Southern California grid reliability and promote the state's policy goals.

The workshop on May 8, 2018, provided an update on overall reliability and the status of projects. The suggested direction of the 2013 action plan was that the shuttered capacity of San Onofre and OTC generation retirements be replaced with roughly 50 percent preferred resources, 50 percent conventional generation, and transmission infrastructure improvements that could provide voltage support. The information below updates progress documented in the *2017 IEPR*.

Preferred Resources

The joint agency team continues to track procurement of preferred resources[432] identified in the CPUC's Long-Term Procurement Plan (LTPP) proceeding,[433] which are designated in specific CPUC decisions, as well as procurement assumed to occur through ongoing programs. The CPUC is implementing a new Integrated Resource Planning (IRP) proceeding in response to the legislative requirements of Senate Bill 350 (De León, Chapter 547, Statutes of 2015),[434] which will serve as a successor to LTPP and will include periodically evaluating generation resources in the California ISO system

430 Southern California Reliability Plan for the greater Los Angeles area and San Diego. See TN 71933, https://efiling.energy.ca.gov/GetDocument.aspx?tn=71933.

431 The *2016 IEPR* and *2017 IEPR* provide details of these two options.

432 *Preferred resources* were defined in the Preliminary Reliability Plan for the Greater Los Angeles Area and San Diego as local energy efficiency, demand response, renewable generation, storage, and combined heat and power.

433 The CPUC's Long-Term Procurement Plan (LTPP) proceeding evaluated generation resources in the California ISO system every two years. The intent was to evaluate whether existing and projected resources are sufficient to meet future demand, and to authorize procurement of additional resources in the event that they are insufficient. OTC retirement schedules were incorporated into this analysis and updated according to progress toward or changes in retirement deadlines. In addition to systemwide analyses, the LTPP also evaluated capacity requirements in localized, high-demand areas.

434 Similarly, SB 350 requires specific publicly owned utilities to adopt IRPs and submit them to the Energy Commission. Parties are welcome to participate in the Energy Commission's proceeding for reviewing the publicly owned utilities' IRPs. For more information on how to participate, see https://www.energy.ca.gov/sb350/IRPs/.

and local areas, as well as out-of-state renewables, hydro, and other imports.[435] (See Chapter 2 for information on implementation of increased energy efficiency in response to SB 350.) Table 23 presents the preferred resources that have been procured in the San Onofre area to meet reliability requirements necessitated by retirement of the nuclear plant and pending closures of OTC facilities.

Table 23: Preferred Resources in the San Onofre Area

Preferred Resource Projects	PTO	Procurement Source	Capacity MW	Status
Energy Efficiency	SCE	LCR/D. 15-11-041	101	Approved
Energy Efficiency	SCE	LCR/D. 15-11-041	23	Approved
Demand Response	SCE	LCR/D. 15-11-041	5	Approved
Distributed Solar Generation	SCE	LCR/D. 15-11-041	28	Approved
Distributed Solar Generation	SCE	LCR/D. 15-11-041	10	Approved
Energy Storage	SCE	LCR/D. 15-11-041	100	Approved
Energy Storage	SCE	LCR/D. 15-11-041	46	Approved
Energy Storage	SCE	LCR/D. 15-11-041	118	Approved
Demand Response	SCE	PRP RFO2	45	Approved
Energy Storage	SCE	PRP RFO2	60	Approved
Energy Storage	SCE	Aliso Canyon	61	Approved
Willdan Energy Efficiency	SDG&E	LCR/D. 16-12-041	18.5	Approved
Escondido/El Cajon Energy Storage	SDG&E	Aliso Canyon	37.5	Approved
Energy Storage	SDG&E	LCR/D. 18-05-024	83.5	Approved
OhmConnect Demand Response	SDG&E	LCR/D. 18-05-024	4.5	Approved

Source: California Energy Commission (Note: LCR = Local Capacity Requirement, PRP = Preferred Resources Pilot)

Southern California Edison

The CPUC approved preferred resource and energy storage procurement for SCE in the San Onofre area through D.13-02-015[436] and D.14- 03-004[437] for a minimum of 600 MW up to 1,000 MW (as well as an additional 300–500 MW that could be from any resource). CPUC D.15-11-041[438] approved SCE's application for 500.6 MW of preferred resources in the Greater Los Angeles area on November 19, 2015. Six demand response (DR) contracts totaling 70 MW in this application were denied, resulting in a net of 430.6 MW. The basis for denial was listed as not meeting the definition for "preferred resources" and excessive costs. This decision also relieved SCE from procuring the minimum preferred resource requirement of 600 MW, but it left the remaining unused

435 The combined IRP-LTPP proceeding is R.16-02-007.

436 CPUC D.13-02-015 also approved resources in the Big Creek/Ventura local capacity area for a minimum of 215 MW to a maximum of 290 MW from any source. CPUC D.13-02-015 is available at http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M050/K374/50374520.PDF.

437 CPUC D.14-03-014, http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M050/K374/50374520.PDF.

438 CPUC D.15-11-041, http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M156/K064/156064924.PDF.

authorization in place in the event SCE chooses to procure additional preferred resources. CPUC D.16-05-053[439] later modified CPUC D.15-11-041 to require SCE to procure the minimum of 600 MW preferred resources. This modification effectively required SCE to procure an additional 169 MW of preferred resources or file a petition to change the underlying requirement if additional procurement is not necessary.

SCE's Preferred Resources Pilot, a multiyear clean energy study, is investigating if, and how, preferred resources will allow SCE to meet local needs at the distribution level and manage or offset projected electricity demand growth from 2013–2022 in the Johanna and Santiago substation areas of Orange County. If successful, the pilot will allow SCE to meet demand growth with less conventional generation. At the May 8, 2018, workshop, SCE described the deployment challenges, which include developers/aggregators targeting the same market segments and building owners/tenants unwilling to commit to contracts and installations. Due to the lagging deployment, SCE has not yet been able to validate preferred resource performance as planned.

SCE's second Preferred Resources Pilot request for offers (RFO) resulted in contracts for 125 MW of preferred resources (55 MW of demand response, 60 MW of in-front-of-the-meter energy storage, and 10 MW of hybrid behind-the-meter solar PV and energy storage), which are pending CPUC approval. The target in-service date for these resources is 2019 to 2020. A proposed decision[440] to deny the contracts was issued on February 23, 2018, and an alternate decision[441] to approve the contracts was issued on May 31, 2018. CPUC Decision 18-07-023, approving the second Preferred Resources Pilot, was issued on July 20, 2018.[442] Contracts totaling 20 MW have been canceled due to delays in approval.

Most of SCE's procured resources are storage-based, with a portion accelerated due to Aliso Canyon reliability concerns. The resources approved in D.15-11-041 to meet local capacity requirements need to be on-line by December 31, 2020, the critical year when several OTC facilities are scheduled to retire. The joint agencies will continue to monitor progress and ensure that resources are on track to meet reliability needs. Any further delays will need to be addressed promptly before the scheduled retirement of the OTC facilities.

San Diego Gas & Electric

The CPUC authorized SDG&E to procure between 500 MW and 800 MW of resources (a minimum of 200 MW from preferred resources with at least 25 MW from energy storage) through D.14-03-004 and another 100 MW of preferred resources through D.15-05-

439 CPUC D.16-05-053, http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M162/K888/162888503.pdf.

440 CPUC proposed decision of Administrative Law Judge Patricia Miles is available at http://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M210/K041/210041124.PDF.

441 CPUC President Picker's alternate decision is available at http://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M215/K367/215367276.PDF.

442 CPUC D.18-07-023, http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M218/K198/218198816.PDF.

051.[443] CPUC D.16-12-041[444] approved an 18.5 MW energy efficiency contract with Willdan Energy Solutions for deliveries between 2018 and 2024. SDG&E accelerated procurement of 37.5 MW of storage resources in response to Aliso Canyon reliability concerns. These resources were approved in CPUC Resolution E-4798[445] and came on-line in early 2017.

SDG&E launched a 2016 preferred resources local capacity requirement request for offer and on April 19, 2017, filed an application seeking approval of 83.5 MW of energy storage and 4.5 MW of demand response resources, which CPUC approved in D.18-05-024[446] on May 31, 2018. The target in-service date for these resources is late 2019 to 2021. SDG&E is on its way to meeting its minimum preferred resources procurement target, but it still needs to procure another 56 MW.

Conventional Generation

The joint agency team continues to track conventional generation projects in the San Onofre area. Table 24 presents the status for five projects in the area. All five projects have power purchase agreements that were approved by the CPUC. Legal challenges surfaced for the Carlsbad, Alamitos, and Huntington Beach projects, but they have been resolved, and construction is underway for each. Licensing/permitting is underway for the Stanton project. SDG&E's Pio Pico became operational in October 2016.

The Carlsbad Energy Center is replacing the Encina OTC facility for SDG&E. In 2017, the SWRCB approved an OTC compliance date deferral for Encina Units 2–5[447] until December 31, 2018, to allow for the construction of the Carlsbad Energy Center. The California ISO entered into capacity procurement mechanism contracts for 272 MW of Encina Unit 4 and 273 MW of Encina 5 capacity, effective January 1, 2018. Encina Units 2 and 3 remain uncontracted but available to the market. Carlsbad came on-line December 3, 2018.

Alamitos, Huntington Beach, and Stanton Energy Reliability Center are in the western Los Angeles area. The Energy Commission approved the Alamitos Energy Center application for certification and the Huntington Beach Energy Project license amendment on April 12, 2017, and construction began shortly thereafter. As of November 30, 2018, construction is roughly 50 percent complete, and the plants are on track to be on-line in 2020. The Stanton Reliability Energy Center is a 98 MW natural gas-fired facility with 10 MW battery storage and synchronous condenser operation, and the application for certification for the facility was approved November 7, 2018.

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443 CPUC D.15-05-051, http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M152/K058/152058431.PDF.

444 CPUC D.16-12-041 http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M171/K492/171492830.PDF.

445 CPUC Resolution E-4798, http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M166/K269/166269958.PDF.

446 CPUC D.18-05-024, http://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M215/K724/215724114.PDF.

447 Encina Unit 1 retired on April 18, 2017, to make way for the Carlsbad construction.

Table 24: Conventional Generation Projects in San Onofre Area

Conventional Generation Projects	Capacity	Sponsor	Target In-Service Date
Pio Pico	305	SDG&E	Operational 10/20/2016
Carlsbad Energy Center	500	SDG&E	Operational 12/3/2018
AES Alamitos	640	SCE	6/1/2020
AES Huntington Beach	644	SCE	5/1/2020
Stanton Energy Reliability Center	98	SCE	7/1/2020

Source: California Energy Commission

Transmission Projects

The joint agency team continues to track three active transmission projects out of nine projects approved in the San Onofre area, and the other six projects were completed and placed in service as of 2017. The three projects being tracked include two critical transmission lines and up to 1,800 mega volt ampere reactive (MVAR) of reactive support identified in the *2017 IEPR*.[448] The transmission projects being tracked, the sponsor, and expected in-service dates are shown in Table 25, with further discussion provided below. Two of the projects came on-line in 2018, with the in-service date for the last project in 2022. Two large transmission line projects are encountering delays; a mitigation measure was implemented for the Sycamore Canyon–Peñasquitos line to maintain reliability for summer 2018.

448 Reactive power is measured in volt ampere reactive (VAR), and an over- or undersupply of reactive power causes voltages to climb or fall. The San Onofre Nuclear Generating Station provided crucial voltage support in the southern Orange County region, and California ISO approved several transmission projects to replace the voltage support lost with the retirement of San Onofre.

Table 25: Transmission Projects in San Onofre Area

	Transmission Projects	Sponsor	Target In-Service Dates
1	Talega Synchronous Condensers (2x225 MVAR)	SDG&E	In-service 8/7/2015
2	Extension of Huntington Beach Synchronous Condensers (280 MVAR)	SCE	Retired 12/31/2017
3	Imperial Valley Phase Shifting Transformers (2x400 MVAR)	SDG&E	In-service 5/1/2017
4	Sycamore Canyon–Peñasquitos 230kV Line	SDG&E	In service 8/29/2018
5	Miguel Synchronous Condensers (450/-242 MVAR)	SDG&E	In-service 4/28/2017
6	San Luis Rey Synchronous Condensers (2x225 MVAR)	SDG&E	In-service 12/29/2017
7	San Onofre Synchronous Condensers (1x225 MVAR)	SDG&E	In service 10/16/2018
8	Santiago Synchronous Condensers (1x225 MVAR)	SCE	In-service 12/31/2017
9	Mesa Loop-In Project and South of Mesa 230kV Line Upgrades	SCE	**Delayed until 3/1/2022**

Source: California Energy Commission

The California ISO Board of Governors extended the reliability-must-run contract for the Huntington Beach synchronous condensers through 2017, at which time they were retired to make way for the new Huntington Beach Energy Center.

The San Onofre Synchronous Condensers project is one of three projects being tracked. The California ISO board approved the project on March 20, 2014, as part of the California ISO's 2013–2014 Transmission Planning Process (TPP). SDG&E is the project sponsor. This project is within the existing facility boundary, which is already permitted for this purpose and voltage. The facility was permitted August 13, 2015, and construction started on May 2, 2016. The target in-service date was delayed to August 2018 and then again to October 15, 2018. There are multiple reasons for the delay, including weather impacts to the 2017 project schedule. The project came on-line October 16, 2018.

The Sycamore Canyon-Peñasquitos 230 kV transmission project received approval by the California ISO Board of Governors on March 20, 2013, as part of the California ISO 2012–2013 TPP. On March 14, 2014, the California ISO selected SDG&E, in conjunction with Citizens Energy Corporation, as project sponsor through a competitive solicitation. On October 13, 2016, the CPUC approved (in Decision D.16-10-005) the environmentally superior alternative with additional undergrounding identified in the final environmental impact report for this project with a cost cap of $260 million. The project encountered difficulties with undergrounding, but the line was energized August 29, 2018.

The California ISO 2018 Local Capacity Technical Analyses[449] show that a delay of the Sycamore-Peñasquitos transmission line beyond June 2018 causes overloading concerns of transmission lines in the Mission and Old Town areas in San Diego and increases the local capacity requirements in the San Diego-Imperial Valley local area. The transmission line overloads depend partially on the amount of Encina generation available. The power flow studies indicate, however, that even with all Encina generation available and with no other mitigations, overload conditions still exist. The CPUC did not adopt the higher local capacity requirements from this sensitivity in its resource adequacy proceeding. To address the loading concern for summer 2018, the California ISO prepared an interim measure, including load shed that would be implemented as part of the system adjustment between the loss of the first transmission element and loss of a second transmission element.

The Mesa Loop-In is the second of the delayed large transmission projects. The California ISO Board of Governors approved the Mesa Loop-In 500 kV project March 20, 2014, as part of the California ISO's 2013–2014 TPP and subsequently approved the South of Mesa 230 kV line upgrades in conjunction with the Mesa Loop-In project as part of the California ISO's 2014–2015 TPP. The CPUC approved the Mesa Loop-in 500 kV project and South of Mesa 230 kV line upgrades on February 9, 2017. The CPUC's final decision approving the Mesa Loop-in project was largely consistent with SCE's proposed project and rejected alternative project configurations proposed by CPUC staff in the environmental impact report. Timing of the CPUC approval and preconstruction requirements for obtaining other permits and approvals have delayed the start of construction. As a result, SCE has revised the projected in-service date to 2022, which was reported in its Securities and Exchange Commission Form 10-Q filing March 31, 2017.

Construction of the Mesa Loop-In began October 2, 2017. SCE preliminarily estimates that the project will be complete in March 2022, a nine-month delay from the originally scheduled on-line date of June 1, 2021. An SCE representative indicated at the May 8, 2018, IEPR workshop that this is the last project to address San Onofre and OTC generation retirements. SCE continues to evaluate options to accelerate the on-line date to June 2021. The SCE representative indicated that the lower-voltage work (220 kilovolt (kV), 66 kV, and 16 kV) will be completed before the higher-voltage 500 kV work and should be completed around third quarter of 2019. SCE plans to evaluate whether the 500 kV work can be accelerated to reach the 2021 completion date, but a complete evaluation depends on completion of the lower-voltage work. The California ISO noted at the workshop that in the event of a delay beyond the second quarter of 2021, Alamitos (or Redondo Beach) generation OTC compliance dates of December 31, 2020, may need to be extended until the Mesa Loop-in project is placed in service if other

449 California ISO 2018 Local Capacity Technical Analysis is available at http://www.caiso.com/Documents/Final2018LocalCapacityTechnicalReport.pdf.

interim solutions are infeasible. Further study will be needed before making a determination.

The California ISO Board of Governors approved Imperial Irrigation District's S-Line Upgrade on March 22, 2018, as part of the 2017–2018 TPP. The project includes rebuilding the roughly 18-mile wood pole 230 kV single circuit to double-circuit steel tower construction to alleviate power delivery issues. The project provides economic benefits, as well as reliability benefits in reducing local capacity requirements. It is projected to reduce in-basin generation requirements materially for the combined San Diego-Imperial Valley area in the range of 250 MW to 500 MW.

Assessing Progress

As evident from workshops in previous IEPR cycles and from the most recent workshop held May 8, 2018, the Energy Commission and the collaborating agencies in the SCRP are committed to assuring electrical reliability for the region. The agencies are reviewing progress of preferred resources, conventional generation, and transmission projects periodically to determine whether actions need to be taken to assure reliability of the electricity system in Southern California. Significant progress has been made in implementing the plan developed in 2013 to address San Onofre and OTC generation retirements. One of the contingency mitigation measures, the Encina OTC deferral request, was implemented in 2017 because of the delay of Carlsbad, but no actions were needed in 2018. The Alamitos, Huntington Beach, and Carlsbad generation projects are under construction and on track to allow the OTC plants to retire by the State Water Resources Control Board OTC compliance dates. The Mesa Loop-In project bears watching, and mitigation solutions continue to be evaluated to determine the best course of action for 2019. The agencies will continue to monitor project milestones, and as uncertainties become clear, the agencies will seek mitigation solutions that maintain grid reliability and promote the state's policy goals, such as the OTC policy.

Recommendations

Aliso Canyon

- **Require Southern California Gas (SoCalGas) to explore all options available to safely expedite repair of the natural gas pipelines.** The California Public Utilities Commission (CPUC) should require SoCalGas to provide detailed reports of the options and identify areas where agency assistance is needed. The CPUC should continue to evaluate removing nonoperational pipelines from the rate base.[450]

- **Continue coordinated efforts to address the energy reliability risks related to natural gas pipeline outages and the limited use of the Aliso Canyon natural**

450 *Rate base* is the value of property on which a utility is allowed to earn a specified rate of return, in accordance with rules set by the CPUC.

gas storage facility in the near term. The Energy Commission, the CPUC, the California Independent System Operator (California ISO), and the Los Angeles Department of Water and Power (LADWP) should continue to work together to assess the energy reliability impacts of the pipeline outages and limited operations at Aliso Canyon and take appropriate actions to address those risks.

- **Identify and explore the steps needed to implement the new mitigation measures.** The Energy Commission, the CPUC, the California ISO, and the LADWP should determine the viability of the new mitigation measures and the steps needed to implement them.
- **Monitor, evaluate, refine, and extend as needed the existing mitigation measures, including tariff and market changes, needed to reduce daily imbalances in gas scheduling, for the Greater Los Angeles Area.** The Energy Commission, the CPUC, the California ISO, and the LADWP should determine the effectiveness of mitigation measures and whether tighter gas balancing rules and the California ISO market changes should be extended or made permanent, or whether any tariff changes are necessary.
- **Assist in developing a long-term strategy that would lead to the eventual closure of the Aliso Canyon natural gas storage field.** The Energy Commission must continue to provide support to the CPUC as both agencies work to develop strategies for replacement energy resources that ensure electricity reliability in Southern California. These strategies will be led by advances in energy efficiency and distributed energy resources such as demand response and storage of electricity or heat. Incorporate the findings from the Pacific Northwest study into a long-term plan. Suggestions such as Gill Ranch's proposal of better connecting the Pacific Gas and Electric and SoCalGas systems need additional detail and further evaluation.[451]

San Onofre Shutdown and Once-Through Cooling Compliance

- **Assure local reliability in the Greater Los Angeles Area and San Diego.** The California ISO should study the delay of the Mesa Loop-In project beyond summer 2021 to determine whether any mitigation measures are needed. If the California ISO determines further mitigation is needed, it should consider whether a temporary extension of the Redondo Beach or Alamitos facilities, if electrically feasible, could be a potential mitigation option. The joint agencies should work with Southern California Edison to determine whether any of their

451 SoCalGas disagrees with the Energy Commission recommendation to develop a long-term strategy to close Aliso Canyon and points to the California Council on Science and Technology report *Long-Term Viability of Underground Natural Gas Storage in California: An Independent Review of Scientific and Technical Information* as validating the need for underground storage. (SoCalGas comments dated November 2, 2018, Docket 18-IEPR-01, TN# 225796.) This study is a general review concerning storage statewide and is not about whether any specific storage field can or cannot be closed. See the *2017 Integrated Energy Policy Report* for further discussion of this study.

mitigation options are viable solutions to accelerate construction or to address reliability concerns.

- **Continue focus on implementing the Southern California reliability action plan.** The preferred resources, transmission upgrades, and conventional generation identified in the 2013 report are crucial to continuing electric reliability.
- **Continue the Southern California Reliability Project agency team.** The multiagency team should continue the timely monitoring and information sharing now in place.
- **Clarify contracting rules for a utility contracting with a once-through cooling (OTC) power plant that has a deferred compliance date.** In the event the State Water Resources Control Board approves an OTC compliance date deferral request, the CPUC should clarify its interpretation of D.12-04-046 to allow a contract between a utility and an OTC generator, subject to completion of the OTC compliance date deferral.

CHAPTER 7: Energy Demand Forecast Update

Background

The California Energy Commission provides new forecasts for electricity and natural gas demand every two years as part of the *Integrated Energy Policy Report* (*IEPR*) and updates in alternate years, such as for this *2018 IEPR Update*. The forecasts are used in various proceedings, including the California Public Utilities Commission's (CPUC's) Integrated Resource Plan process and the California Independent System Operator's (California ISO's) Transmission Planning Process. Also, projected adoption of behind-the-meter distributed energy resources (DERs) embedded within the Energy Commission's demand forecast form the basis for DER growth scenarios used within the investor-owned utilities' (IOUs) distribution planning process. The Energy Commission also provides annual year-ahead peak demand forecasts for resource adequacy in coordination with the California ISO and the CPUC.

In 2014, the Energy Commission began providing updates to the IEPR forecast in even-numbered years to help meet the process alignment needs and schedules of the CPUC and California ISO planning studies. The update consists of revising economic and demographic drivers used in the previous IEPR forecast with the most current projections. Furthermore, the update adds one more year of historical electricity consumption and peak demand data, and self-generation technology adoptions and pending adoptions, which are used to recalibrate the forecast to the last historical year. Typically, other factors that affect the forecast are not updated; however, the *2018 IEPR Update* is the first to include refreshed projections of solar photovoltaic (PV) system adoptions, plug-in electric vehicle (PEV) adoptions, community choice aggregators (CCAs), and time-of-use (TOU) rate impacts. As with previous forecast updates, projections for additional achievable energy efficiency (AAEE), which measure estimated savings from future efficiency initiatives, remain unchanged until the next forecast.

As in previous forecasts, updates include three demand cases designed to capture a reasonable range of outcomes over the next 10 years. The *high energy demand* case incorporates relatively high economic/demographic growth, relatively low electricity and natural gas rates, and relatively low committed efficiency program, self-generation, and climate change impacts. The *low energy demand* case includes lower economic/demographic growth, higher assumed electricity rates, and higher committed efficiency program and self-generation impacts. The *mid* case uses input assumptions at levels between the *high* and *low* cases.

California Energy Demand Updated Forecast, 2018–2030

Updated Economic and Demographic Drivers

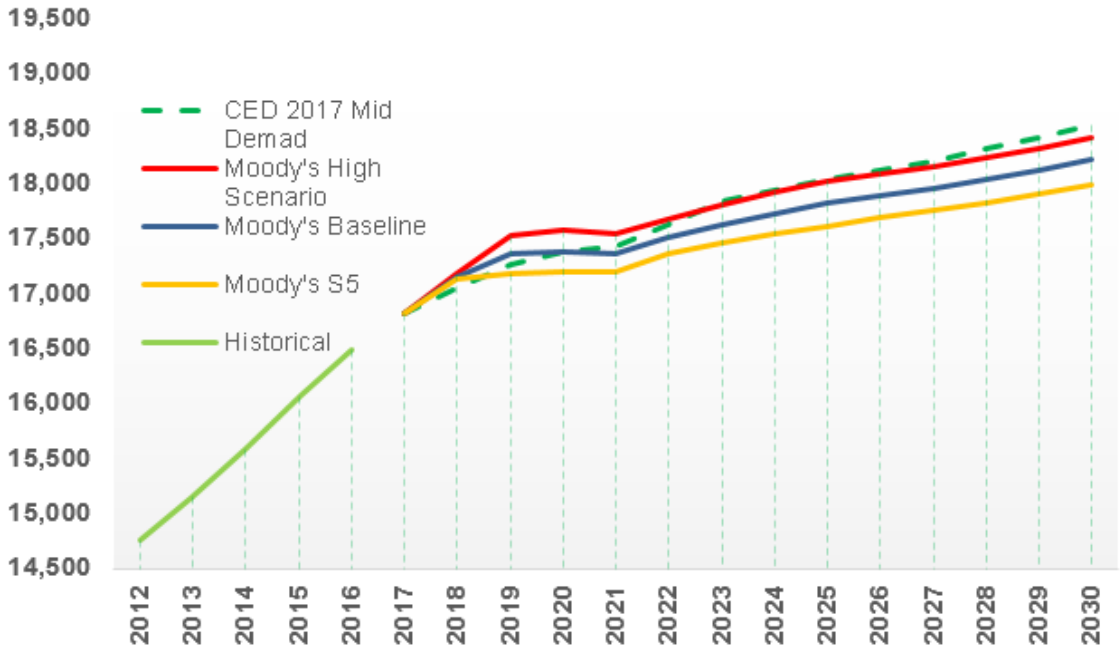
Consistent with the *California Energy Demand (CED) 2017* forecast, staff used data from Moody's Analytics to develop scenarios for key economic drivers for the *California Energy Demand Update (CEDU) 2018*. These scenarios reflect Moody's baseline and pessimistic assumptions about economic growth in the mid and low demand cases, respectively. For the high demand case, Energy Commission staff worked with Moody's to develop a custom set of optimistic assumptions intended to produce a greater spread between the mid and high demand cases.

As shown in Figure 51, the projection for statewide commercial employment[452] in the *CEDU 2018* mid case is slightly lower than in *CED 2017*. By 2030, commercial employment is around 1.47 percent lower in the new mid case compared to *CED 2017*, resulting from Moody's assumption of less migration into California. Annual growth rates from 2017-2030 average 0.70 percent, 0.61 percent, and 0.52 percent in the *CEDU 2018* high, mid, and low scenarios, respectively, compared to 0.75 percent in the *CED 2017* mid case.

Figure 52 shows historical and projected personal income at the statewide level for the three *CEDU 2018* scenarios and the *CED 2017* mid demand case. Moody's projections for income are driven primarily by employment, since the two indicators are closely intertwined. By 2030, income is around 3 percent lower in the *CEDU 2018* mid case compared to *CED 2017*. Annual growth rates from 2017-2030 average 2.73 percent, 2.51 percent, and 2.22 percent in the *CEDU 2018* high, mid, and low scenarios, respectively, compared to 2.72 percent in the *CED 2017* mid case.

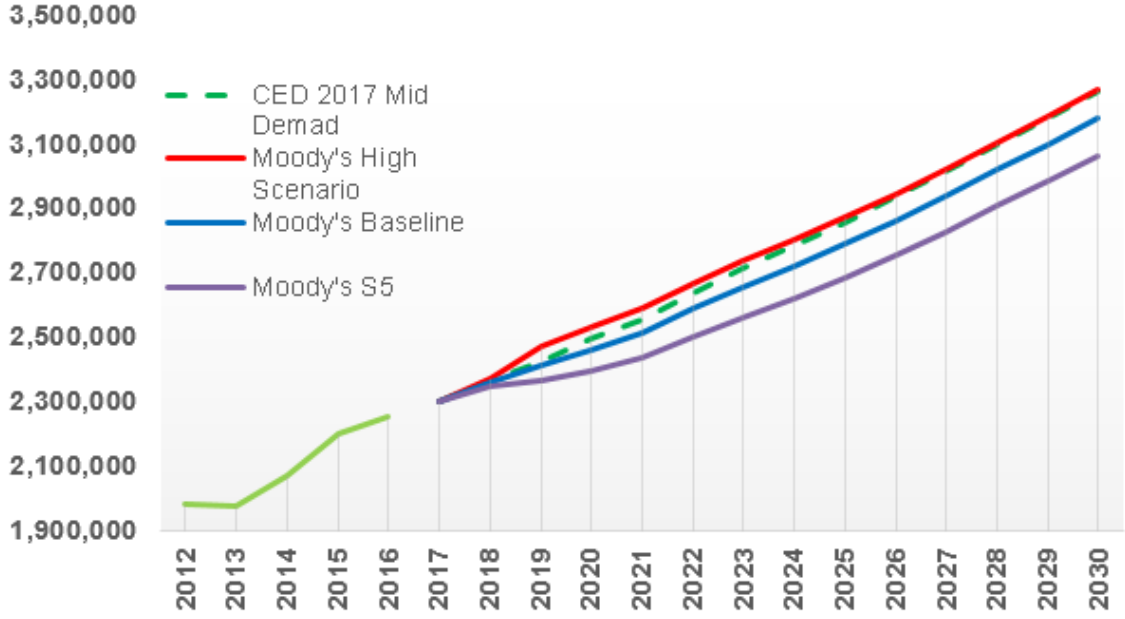
452 Total employment minus employment in the industrial and agricultural sectors.

Figure 51: Statewide Commercial Employment



Source: Moody's Analytics

Figure 52: Statewide Personal Income



Source: Moody's Analytics

Method

The Energy Commission uses detailed models for each economic sector (including residential, commercial, industrial, and transportation) to project electricity consumption and peak demand for each new *IEPR* energy demand forecast (as for the *2017 IEPR*). In addition to the more complex sector models, staff also uses single-equation econometric models by sector, which typically yield similar results at the aggregate level. For *CEDU 2018*, staff relied on these econometric models, reestimated to incorporate historical data for 2017. The variables and estimation results for each econometric model will be provided in an Energy Commission report, which is expected to be available in February 2019.

To ensure a proper comparison to *CED 2017*,[453] staff benchmarks the results from the econometric models to the earlier energy demand forecast to isolate the effects from the revised set of economic and demographic drivers. Percentage changes in electricity demand caused by the updated drivers as estimated by the econometric models are then applied to *CED 2017* results. Finally, staff updates critical demand modifiers such as charging for PEVs, behind-the-meter PV system generation, and load impacts resulting from wide-scale deployment of time-of-use (TOU) electricity rates.

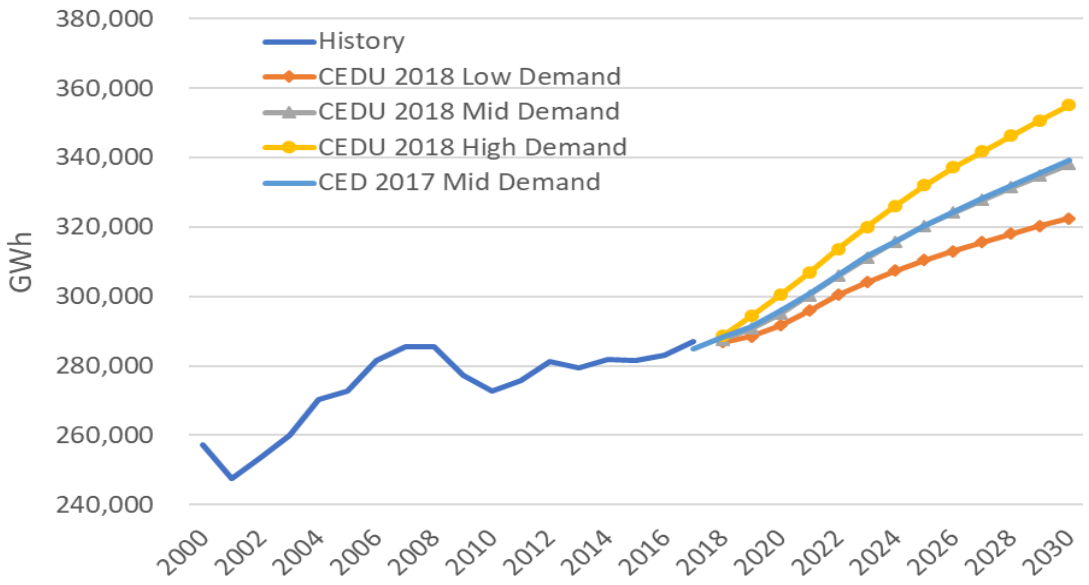
California Energy Demand Forecast Results

This section describes *CEDU 2018* forecast results and component demand modifiers. Energy Commission staff presented these results at an *IEPR* workshop on December 6, 2018. After considering public comments, staff finalized the updated forecast. The Energy Commission formally adopted *CEDU 2018* at the January 9, 2019, Business Meeting.

Figure 53 shows projected electricity consumption for the *CEDU 2018* low, mid, and high baseline demand scenarios. The *CED 2017* mid demand scenario is shown for comparison. Decreases in commercial and agricultural demand relative to *CED 2017* are counterbalanced by growth in residential and resource extraction sectors. As a result, by 2030, the *CEDU 2018* mid demand scenario is relatively unchanged from *CED 2017* — only 0.31 percent lower. Statewide electricity consumption is projected to reach 322,506 GWh, 338,112 GWh, and 355,051 GWh in the low, mid, and high demand scenarios, respectively, by 2030.

453 Kavalec, Chris, Asish Gautam, Mike Jaske, Lynn Marshall, Nahid Movassagh, and Ravinderpal Vaid. 2018. *California Energy Demand 2018—2030 Revised Forecast*. California Energy Commission, Energy Assessments Division. Publication Number: CEC-200-20-18-002-CMF.

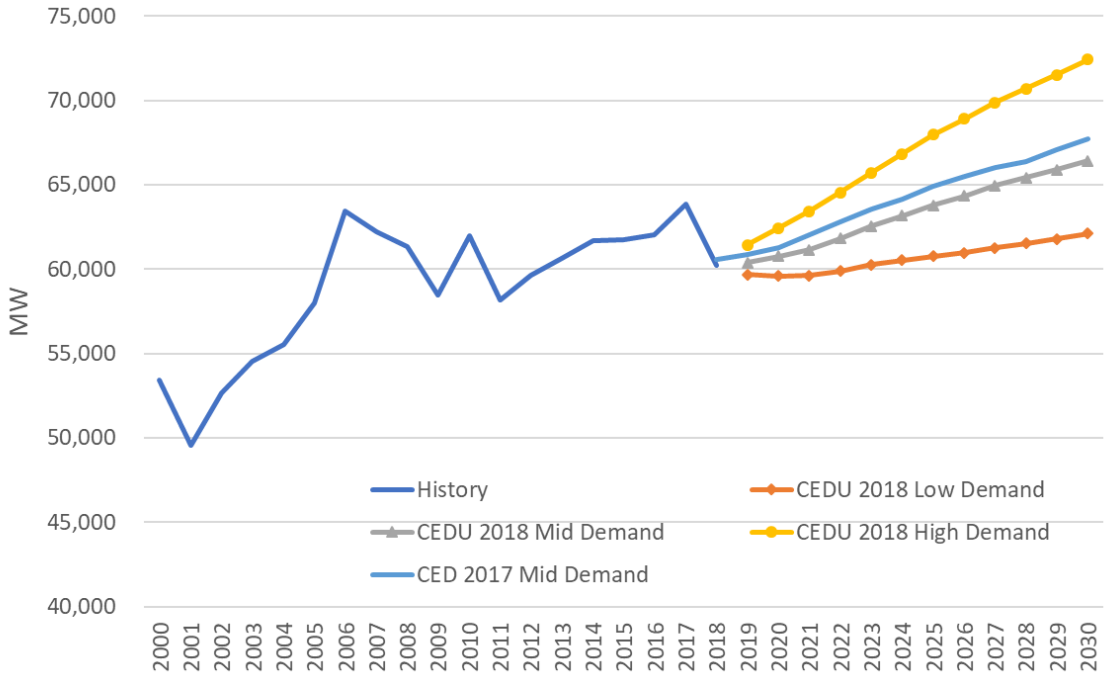
Figure 53: Statewide Electricity Consumption



Source: California Energy Commission

Figure 54 shows updated forecasts of statewide net peak demand for *CEDU 2018* low, mid, and high demand scenarios. The mid case grows at an average annual rate of 0.87 percent — slightly lower than the *CED 2017* mid case. By 2030, the low, mid, and high baseline scenarios reach 62,096 MW, 66,423 MW and 72,413 MW, respectively.

Figure 54: Statewide Net Peak Demand

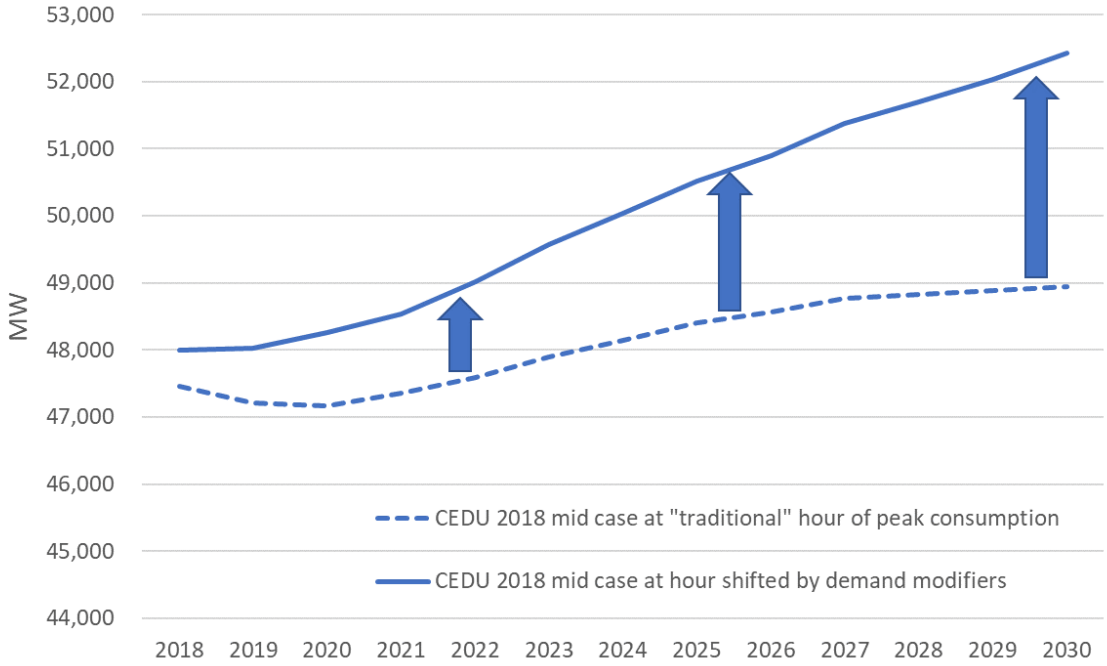


Source: California Energy Commission

Staff used an hourly load model—discussed further in a later section—to estimate

impacts from "peak shift" occurring for each IOU, reflecting changes in utility peak hours and load resulting from increasing penetrations of demand modifiers, most notably PV. Figure 55 shows the impact of peak shift on total noncoincident net peak demand for the California ISO control area. In the mid baseline scenario, peak shift impacts reach 3,484 MW by 2030, increasing the average annual growth rate by about half a percent.

Figure 55: Impact of Peak Shift on Baseline Net Peak Demand (California ISO)



Source: California Energy Commission

Additional Achievable Energy Efficiency

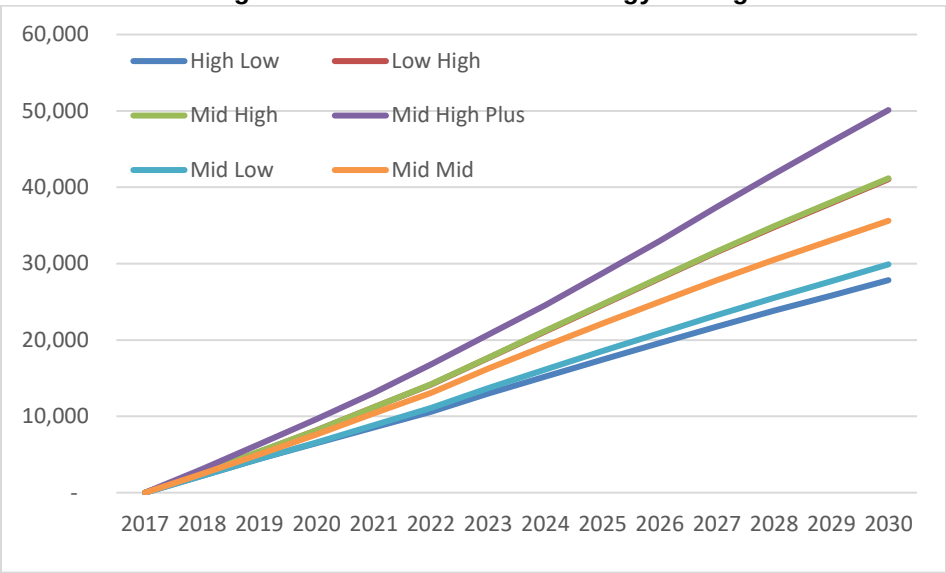
For *CEDU 2018*, AAEE estimates remain the same as in *CED 2017*. However, as applied to *CEDU 2018*, staff calculated estimated impacts as incremental to 2017 for energy and 2018 for peak since any AAEE savings in these two years would be embedded in the historical data.[454] Total estimates include impacts from utility programs, building and appliance standards updates, and Senate Bill 350 (De León, Chapter 547, Statutes of 2015) related activities. *CED 2017* included for the first time a single scenario for POU program efforts. Energy Commission staff is working to expand this analysis to reflect multiple scenarios.

Figure 56 and Figure 57 show incremental AAEE savings projections adjusted to reflect the *CEDU 2018* base year. The scenarios combine savings projections for PG&E, SCE, SMUD, LADWP, and two groupings for small utilities within the California ISO control

454 Since peak system load occurs during the summer, historical peak load data are available before the end of the year. Historical consumption data for a given year are not available until the start of the subsequent year.

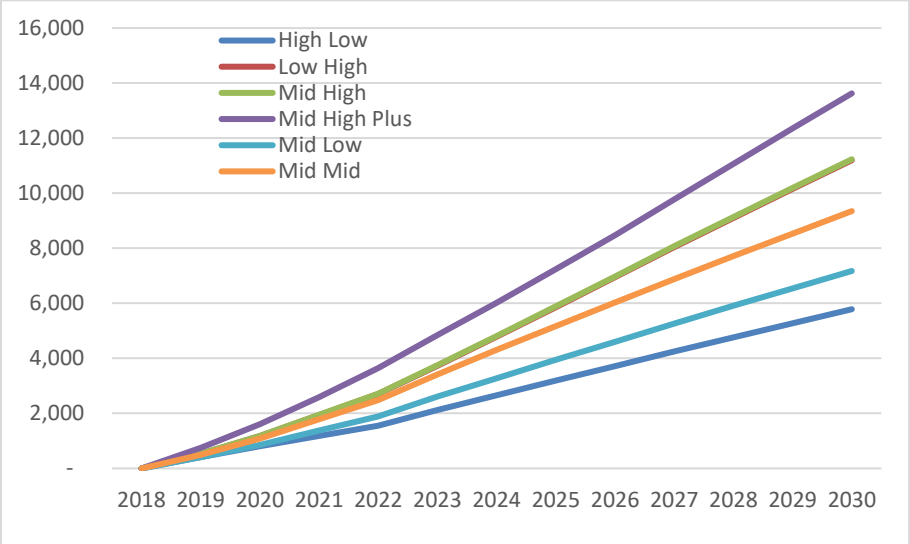
area. The peak savings shown in Figure 57 are derived from the database of energy efficient resources and do not reflect potential impacts from a shifting peak hour.

Figure 56: Combined AAEE Energy Savings



Source: California Energy Commission

Figure 57: Combined AAEE Peak Savings



Source: California Energy Commission

Managed Single Forecast Set

The *CEDU 2018* baseline forecasts combine with AAEE and additional achievable photovoltaic (AAPV) scenarios to form managed forecasts. While the AAEE scenarios described above do not reflect any substantive changes from those adopted as part of *CED 2017*, updates to baseline demand and AAPV scenarios carry through to the *single forecast set* used for planning purposes in the Energy Commission, CPUC, and California

ISO proceedings. Leadership at these agencies have agreed that a single set of forecasts will form the basis of procurement and other planning decisions within the California ISO's Transmission Planning Process (TPP) and the CPUC's Integrated Resource Planning (IRP) and resource adequacy programs.

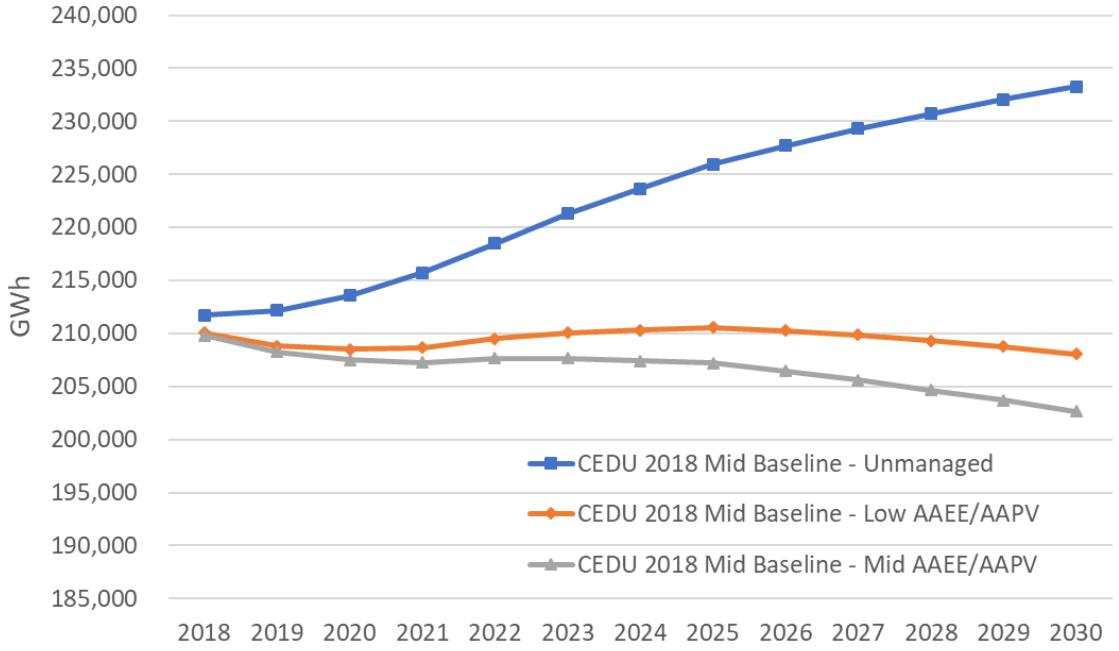
The single forecast set is comprised of the mid demand baseline case for the California ISO control area — with its weather variants — and two scenarios each for AAEE and AAPV, the combination of which depends on the purpose of their use. The mid baseline weather variants have been applied consistently by the CPUC and California ISO as follows:

- 1-year-in-2 weather conditions – Used for system flexibility studies performed by the California ISO, for input into the CPUC's IRP, and for economic studies in the California ISO TPP.
- 1-year-in-5 weather conditions – Used for public-policy transmission assessments and bulk system studies in the California ISO TPP.
- 1-year-in-10 weather conditions – Used for local capacity requirements and California ISO TPP local reliability studies.

The Energy Commission, CPUC, and California ISO leadership agree, in principle, that the same AAEE and AAPV forecast scenarios should be applied to the uses described above; however, due to the local nature of reliability needs and the difficulty of assigning AAEE, AAPV, or demand to specific locations, the agencies' leadership agrees to use the mid-low AAEE and AAPV forecast for local studies and the mid-mid AAEE and AAPV forecast for other system-level studies.

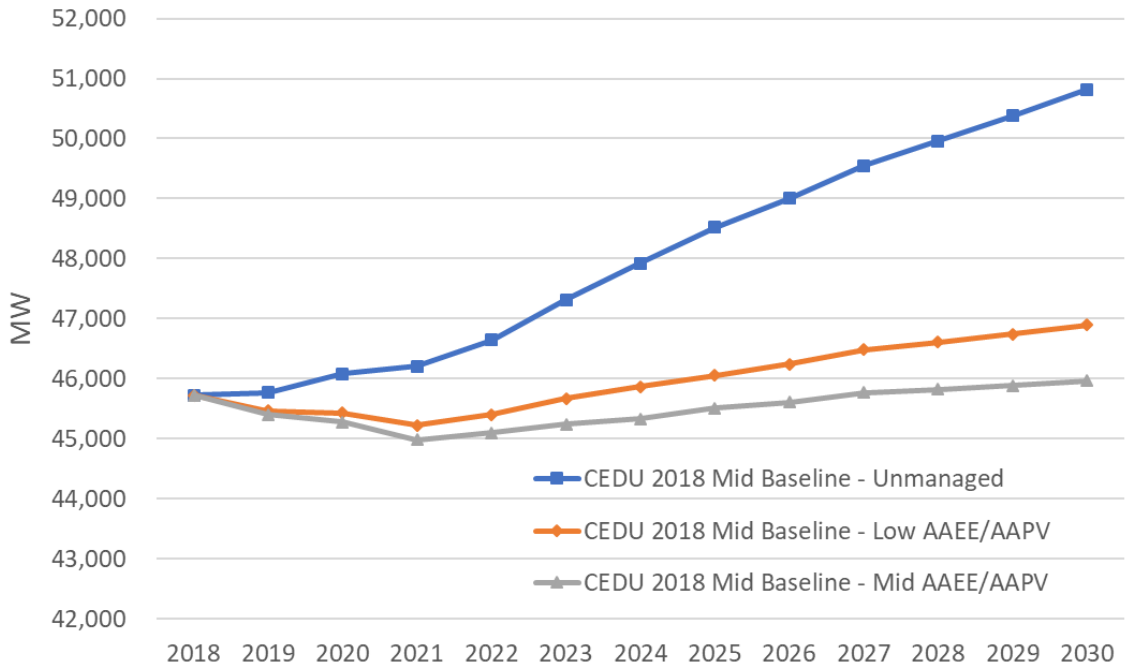
Figures 58 and 59 show the managed scenarios comprising the single forecast set, updated to reflect changes to both the baseline demand forecast and the AAPV scenarios adopted as part of CEDU 2018. Growth in the mid baseline, mid-mid AAEE/AAPV managed sales forecast declines at an average annual rate of 0.29 percent to reach 202,653 GWh by 2030. The similarly managed net peak forecast stays relatively flat, however, as a shifting peak hour drives peak demand up in the latter half of the forecast period. By 2030, managed net peak reaches 45,770 MW.

Figure 58: Managed Electricity Sales (California ISO)



Source: California Energy Commission

Figure 59: Managed Net Peak Demand (California ISO)



Source: California Energy Commission

Updates to Demand Modifiers

As discussed in Chapter 3 (see "Transportation Electrification"), in January 2018, former Governor Edmund G. Brown Jr. signed Executive Order B-48-18, which calls for 5 million zero-emission vehicles (ZEVs) on the road by 2030, 250,000 charging stations, and 200 hydrogen refueling stations by 2025. At the national level, policy changes under the Trump administration include proposed revisions to federal Corporate Average Fuel Economy standards, as well as tariffs on steel and aluminum. To accommodate these changes, *CEDU 2018* held fuel economy inputs constant at 2021 levels in the low case and increased total vehicle cost by about 1 percent to reflect the impact of tariffs. The forecast assumes there is no income criteria for receiving state rebates, and all ZEV buyers in the residential and commercial sectors qualify for rebates. Table 27 summarizes the assumptions used to develop each of the PEV scenarios and the resulting forecast. While results show that the state will surpass the 2030 goal of 4.2 million ZEVs in CARB's S*coping Plan Update*,[455] the 2030 ZEV goal in the executive order falls between the high and aggressive scenarios.

455 https://www.arb.ca.gov/cc/scopingplan/scoping_plan_2017.pdf.

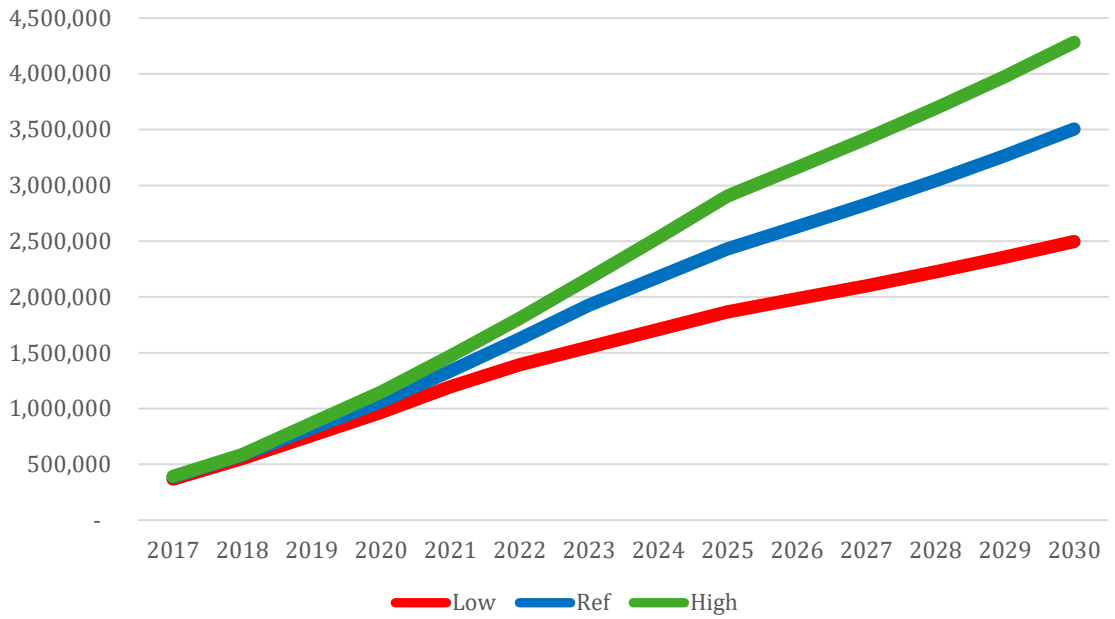
Table 26: Summary of PEV Scenario Assumptions

		PEV SCENARIOS, 2018 UPDATE			
INPUTS	**Very Low**	**Low**	**Reference**	**High**	**Aggressive**
PREFERENCES					
Consumers' PEV Preference	Constant at 2017 Level	Constant at 2017 Level	Increase with PEV market growth	Increase with PEV market growth	Increase with PEV market growth
INCENTIVES					
Federal Tax Credit	Decreasing starting 2019, Eliminated after 2022	Decreasing starting 2019, Eliminated after 2022	Decreasing starting 2019	Decreasing starting 2019	Decreasing starting 2019
State Rebate	To 2025	To 2025	To 2025	To 2025	To 2030 for BEV/FCV
HOV Lane Access	To 2021	To 2021	To 2023	To 2025	To 2025 for PHEV, to 2030 for BEV/FCV
ATTRIBUTES					
Availability of PEVs (in 2030)	PEV models available in 14 of 15 CEC LDV classes	PEV models available in **14** of 15 CEC LDV classes	PEV models available in **14** of 15 CEC LDV classes	PEV models available in **15** of 15 CEC LDV classes	PEV models available in 15 of 15 CEC LDV classes
Vehicle / Battery Price (by 2030)	PEV prices based on initially constrained battery supply	PEV prices based on battery price declining to **~$120/kWh**	PEV prices based on battery price declining to **~$100/kWh**	PEV prices based on battery price declining to **~$80/kWh**	PEV prices based on battery price declining to **~$70/kWh**
Avg. Range (2030)	~255 miles	~255 miles	~260 miles	~280 miles	~280 miles
Refuel Time (2030)	15 -21 min	15 -21 min	15 -21 min	10-16 min	10-16 min
Time to Station (2030)	7-8 min	7-8 min	Same as gasoline	Same as gasoline	Same as gasoline by 2025
FORECAST RESULTS					
2030 ZEV Population	2.59 million	2.60 million	3.64 million	4.44 million	5.47 million

Source: California Energy Commission

Figure 60 shows the statewide PEV forecast in the low, mid, and high scenarios. The statewide PEV forecast in 2030 range from 2.5 million in the low case to 4.3 million in the high case.

Figure 60: Statewide PEV Forecast

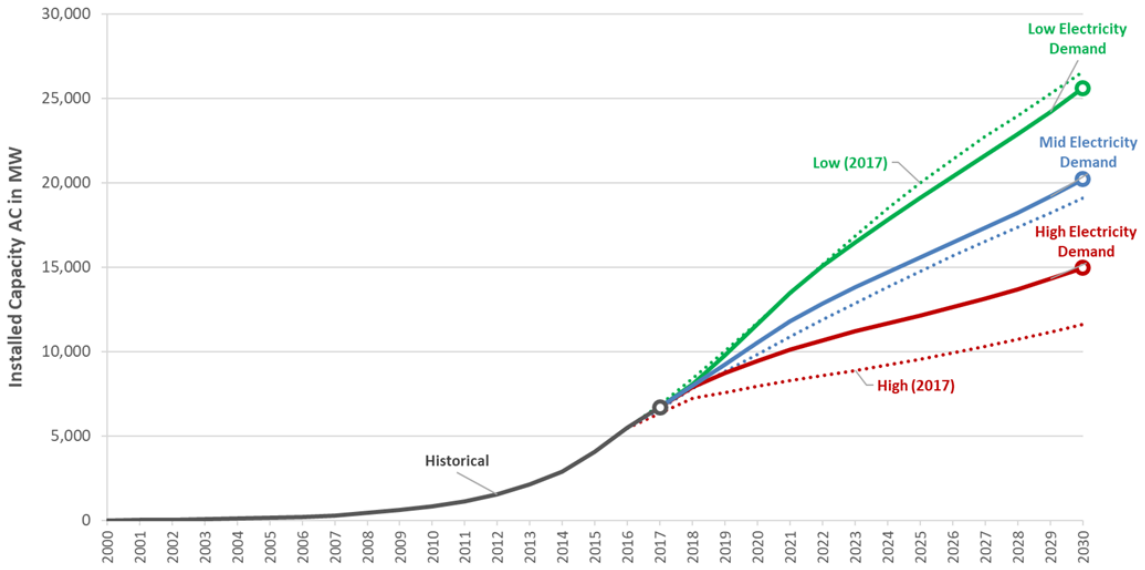


Source: California Energy Commission

CEDU 2018 PV adoption scenario definitions remain unchanged relative to *CED 2017*. However, *CEDU 2018* projections were updated to reflect 2017 system installation data, revised new and total housing stock projections, and updated system cost information, including expected impacts from a new federal tariff on imported PV modules. Figure 61 shows the *CEDU 2018* projections (solid lines) for installed behind-the-meter PV capacity relative to *CED 2017* scenarios (dashed lines). By 2030, installed capacity is projected to reach 14,954 MW and 25,613 MW in the low and high demand scenarios, respectively.[456]

456 *CEDU 2018* demand scenarios are net of self-generation. Therefore, the low demand scenario is assumed to have high penetrations of behind-the-meter PV, and vice versa.

Figure 61: Statewide Behind-the-Meter PV Capacity



Source: California Energy Commission, 2016.

CED 2017 included impacts resulting from additional achievable photovoltaic (AAPV) system adoptions expected to result from the passage of new Title 24 building standards updates, which would require, for the first time, PV installations on new homes. (See Appendix A.) While these standards have since been adopted by the Energy Commission and approved by the California Building Standards Commission, to maintain consistency with the treatment of AAEE, CEDU 2018 retains the AAPV distinction. The efficiency and PV components of the 2019 Title 24 building standards will be incorporated into the baseline forecast beginning with the *2019 IEPR*.

For *CEDU 2018*, staff adjusted AAPV projections from *CED 2017*, accounting for revised projections of PV adoption included in the *CEDU 2018* baseline forecasts. These scenarios project an additional 1,607 MW, 1,949 MW, and 2,290 MW of behind-the-meter PV to be installed on newly constructed homes in the low, mid, and high demand scenarios, respectively.

CED 2017 included impacts from default TOU rates expected to take effect for IOU customers beginning in 2020. (For more discussion of TOU rates see Chapter 3, *Update on Flexible Loads and Resources*.) These impacts were estimated using an assumed opt-out rate of 10 percent. For CEDU 2018, staff reestimated these impacts using data from the first summer of default TOU pilot programs. IOU reports show initial opt-out rates ranging from 12 to 19 percent. Staff also adjusted participation rates to account for load served by CCAs within each IOU territory. Moreover, for this forecast update, staff reassessed hourly TOU load impacts, assuring that for each month, the largest TOU impact occurs on the same day as the forecasted monthly consumption peak

Load served by new and expanding CCAs continues to be an important consideration for the forecast update, as 2018 saw the launch of nine new CCAs — including significant

expansion of service offerings in the Los Angeles, San Francisco Bay, and Monterey Bay areas. Solana Energy Alliance began serving customers in June 2018 — the first CCA to operate within SDG&E's distribution service territory. Growth is expected to continue into next year, with resource adequacy filings indicating that CCAs might serve more than 10,000 MW of peak system load in 2019. Energy Commission forecasters face the challenge of capturing realistic assumptions around long-term expansion of CCAs and reflecting their implications in AAEE, TOU rate impact, PV adoption, and electric vehicle penetration analysis in the *IEPR* forecast.

Process and Methodological Improvements

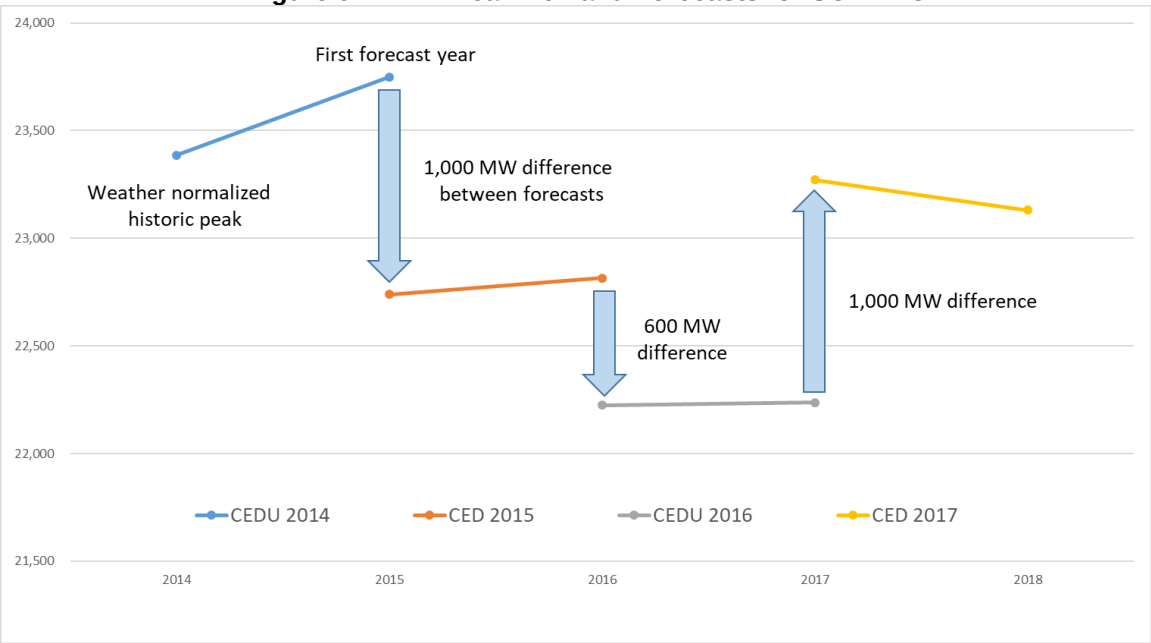
On July 10, 2018, the Energy Commission hosted an *IEPR* workshop on the *2018 California Energy Demand Forecast Update* to present and discuss the scope of the *IEPR* forecast update and outline additional considerations that will be important for the 2019 *IEPR* forecast. Subsequently, the Energy Commission held a series of meetings of the Demand Analysis Working Group (DAWG) to discuss in detail Energy Commission staff's proposed process and methodological improvements to the demand forecast. These discussions placed particular emphasis on two important issues around the Energy Commission's hourly load forecast and weather normalization processes.[457]

Peak-Load Weather Normalization

An issue with the Energy Commission's peak-load weather normalization process was first raised by the Joint Agency Steering Committee and then discussed further at the July 10, 2018, *IEPR* workshop and an August 2, 2018, DAWG meeting. Stakeholders were concerned that an apparent year-to-year "bounce," or the difference between one forecast and the weather normalized starting point of the next forecast, in weather normalized peak load was significantly impacting the CPUC's and California ISO's technical studies. Figure 62 shows that the bounce can be rather large, reaching up to 1,000 MW for Southern California Edison's (SCE's) transmission access charge (TAC) area in recent years.

457 The peak-load forecast begins with a weather-normalized base-year. Rather than starting the forecast from the most recent observed historical peak, the forecast begins from a counterfactual estimate of what peak demand would have been in that year under "average" weather conditions.

Figure 62: *IEPR* Peak Demand Forecasts for SCE TAC



Source: California Energy Commission

To weather normalize peak demand for a particular year, staff first models the load response to temperature exhibited during the months in that year for which a peak event is likely to occur. Using that estimated model, staff then simulates annual peaks using 30 years of historical weather. The median value from this distribution of simulated peak events is taken to be "weather-normal."

Energy Commission staff reviewed its weather-normalization method with stakeholders and identified possible factors that could contribute to the apparent "bounce" effect, the most significant being changes to model specification. Attempting to improve model performance each year, staff changed the regression equations used to predict load. These changes improved model fit but introduced variability into the simulation step, which carried through to the weather-normalized peaks.

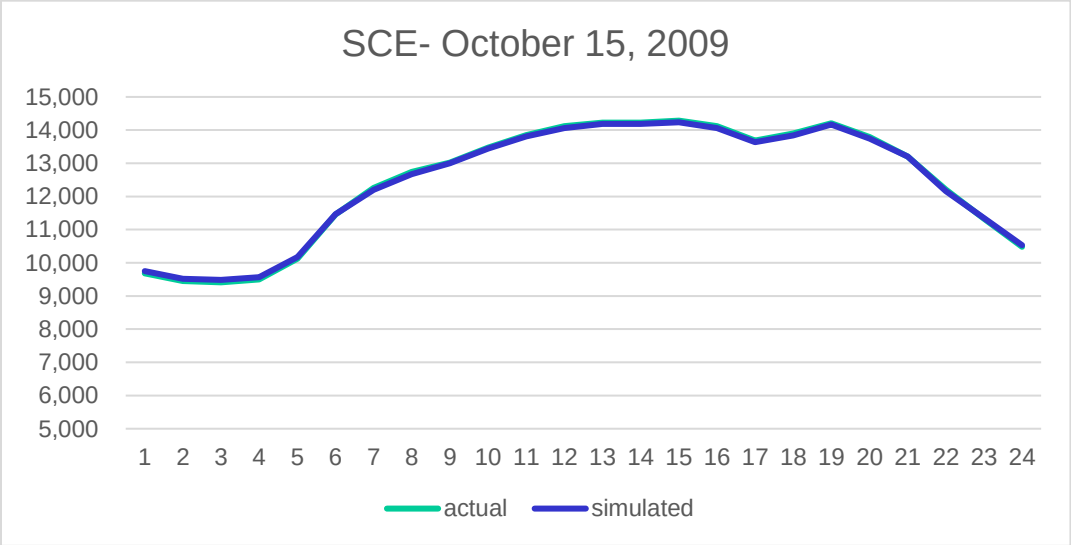
To weather-normalize peak load for *CEDU 2018*, Energy Commission staff selected a set of robust temperature-load models that perform well over several recent historical years. To resolve the "bounce" issue, staff proposes to use these models consistently to weather-normalize peak demand in future *IEPR* cycles. Staff will continue to evaluate model performance as part of every *IEPR* forecast, but any proposed changes to the model specification or to the weather-normalization in general will be reviewed with stakeholders.

Hourly Load Analysis

To provide system planners with a more useful forecast — one capable of assessing the impacts of efficiency and distributed resources on the timing and magnitude of peak load and periods of system ramp — staff developed an hourly load model and included a long-term hourly demand forecast as part of *CED 2017*.

The model estimates the ratio of hourly loads to annual average load for each hour of the day and for each IOU TAC area as a function of weather and calendar variables. Figure 63 illustrates the performance of the model relative to actual load on SCE's system for a randomly chosen day in 2009. The fit to historical data is quite good at the system level, where perturbations in weather and load tend to cancel each other out.

Figure 63: Comparison of Hourly Model Output to Historical Load



Source: California Energy Commission

Using the model, staff simulated load ratios for every hour of the year using 17 years of historical weather data. The median value for each of 8,760 rank-ordered load ratios served as the weather-normalized load ratio for a single hour of the year. For forecasting purposes, those ratios were assigned to specific hours of the year according to a pattern established by an actual historical year, one that was determined to be relatively "average" in terms of heating- and cooling-degree days.[458] This was done to preserve the actual correlations that exist between hours and days.

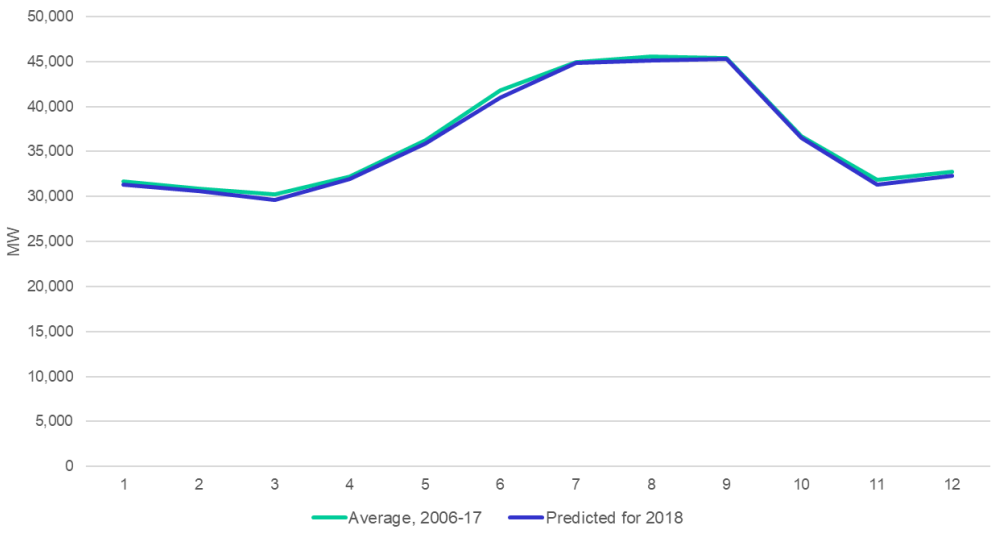
At the July 10 workshop, Energy Commission staff formally presented an issue with this hourly weather-normalization process that had been raised by stakeholders. The choice of a specific year — even one that was relatively "average" — meant that any peculiarities that happened within that year are necessarily carried through the forecast. For *CED 2017*, staff chose 2009 for SCE and San Diego Gas & Electric (SDG&E) — a year characterized by unusually low monthly peak load in May and June. Consequently, the resulting hourly forecast was also characterized by low peaks for those months. And because PG&E was patterned after another year (2012), the sum of hourly loads across

458 The number of heating- and cooling-degree days indicates how often local temperatures reach below or above 65 degrees and by how many degrees. For example, if the average temperature is 10 degrees above 65 degrees for one day in a year, there are 10 cooling degree days for that year for that location.

the distinct TAC area forecasts did not represent a reasonable hourly forecast of California ISO coincident load.

At an August 2 meeting of the DAWG, Energy Commission staff discussed with stakeholders alternative methods for establishing an "average weather year." In testing these methods, staff sought to preserve the expected temperature patterns and extremes within each given month without introducing peculiar discontinuities between months and while preserving correlation across the California ISO footprint. At an *IEPR* workshop on December 6, 2018, staff presented a revised method that accomplishes these objectives. Figure 64 shows predicted California ISO monthly peaks for 2018 taken from the hourly model output and compared against average historical monthly peak loads for the last 12 years.

Figure 64: Comparison of Monthly Peaks—California ISO History vs. Hourly Models



Source: California Energy Commission

Resource Adequacy

Before the development of its hourly load model, the Energy Commission routinely created monthly peak forecasts in support of the CPUC's resource adequacy program by assigning each month a percentage of annual peak load taken from the most recently adopted IEPR forecast. Though not the initially intended purpose, the hourly load analysis developed for *CED 2017* generated monthly peaks that were not aligned with the Energy Commission's resource adequacy forecast. During the 2018 resource adequacy program cycle, the discrepancy between these two monthly peak forecasts inserted a new dimension of uncertainty into stakeholder considerations.

The clearest example of this uncertainty occurred on July 26, 2018, when the California ISO announced its intention to procure emergency capacity for system reliability using

its Capacity Procurement Mechanism authority.[459] The California ISO explained that this procurement was intended to cover the difference between monthly peak forecasts established independently for resource adequacy and the *IEPR*.

The Energy Commission is committed to supporting the joint agency steering committee's *single forecast set* agreement that resource planning and related activities should be based on one consistent set of forecasts.[460] To that end, beginning with the *CEDU 2018*, the Energy Commission intends to adopt a single set of monthly peaks as part of every *IEPR* forecast. Energy Commission staff propose to use these adopted peaks to assess the reasonableness of year-ahead forecasts submitted by load-serving entities (LSEs) in the CPUC's resource adequacy program. Specifically, *IEPR* monthly peaks can serve as a benchmark for determining whether the sum of LSE forecasts sufficiently represents expected peak load at the system level. (See Chapter 3 for more information on resource adequacy.)

Recommendations

- **Continue development of the hourly load model.** New regulations allowing the collection of interval meter data will allow Energy Commission staff to estimate hourly models for other additional geographies and for customer sectors. Scripps Institute of Oceanography may also be able to provide estimates of climate change impacts on temperature at an hourly level for inclusion in the hourly forecast.
- **Develop and adopt a monthly peak forecast as part of the *IEPR* and to inform the California Public Utilities Commission's (CPUC's) resource adequacy program.** Energy Commission staff will continue working with stakeholders to ensure that its hourly load model produces reasonable 1-in-2 monthly peaks suitable for use in system and resource planning and can be presented for adoption alongside the Energy Commission's annual consumption and peak forecasts. Staff may use monthly peak loads adopted as part of the *2018 California Energy Demand Forecast Update* as a system-level benchmark when evaluating the reasonableness of year-ahead forecasts submitted by load-serving entities during the CPUC's 2020 resource adequacy cycle.
- **Continue to develop robust knowledge of and data sets for zero-emission vehicles.** To ensure its vehicle adoption models reflect the most recent trends in consumer preferences, Energy Commission staff will conduct a California Vehicle Survey in 2019. This survey will complement an updated vehicle attribute forecast covering both plug-in and fuel cell electric vehicles.
- **Expand end-use and distributed energy resource load profile analysis to include publicly owned utilities.** Energy Commission staff expects to complete

459 http://www.caiso.com/Documents/CapacityProcurementMechanismSignificantEventCall080218.html.

460 See http://www.cpuc.ca.gov/WorkArea/DownloadAsset.aspx?id=11891.

an analysis of end-use and distributed energy resource load profiles for the investor-owned utilities (IOU) service territories in early 2019. Energy Commission staff will use a similar method to update load profiles for additional forecast zones.

- **Enhance consideration of community choice aggregators (CCA) in the demand forecast.** Energy Commission staff should engage with IOU analysts, CCA analysts, and other stakeholders to vet the reasonableness and accuracy of methods for projecting CCA load growth in the very near term, as well as new CCA formation, load growth, and load migration within existing CCA, and efficiency, self-generation, and rate impacts resulting from CCA programs and tariffs.
- **Refine committed and additional achievable energy efficiency analysis to reflect recent policy updates.** Energy Commission staff will collaborate with California Public Utilities Commission's (CPUC's) Energy Division staff to properly assess committed energy efficiency program savings within the context of the CPUC's 10-year rolling portfolio framework. Additional achievable energy efficiency analysis should be updated to include the CPUC's newest potential and goals study (expected 2019) for IOUs and expanded to reflect a broader set of scenarios for publicly owned utility programs.
- **Expand data collection to improve estimates of behind-the-meter photovoltaic generation.** Phase 2 of Energy Commission Title 20 data collection regulations should be updated to allow the collection of system generation data or to allow the collection of system design specifications that would improve Energy Commission staff's ability to estimate behind-the-meter generation.
- **Refine and incorporate incremental load impacts resulting from cannabis consumption.** *California Energy Demand 2017* included a preliminary projection of increased load resulting from cannabis cultivation following the passage of Proposition 64 in November 2016. Energy Commission staff should reassess those projections, taking into account 2017 and 2018 load data, and incorporate the load impacts into the next full *IEPR* forecast.
- **Continue collaborative efforts with the CPUC and the California Independent System Operator to align interdependent processes.** The Energy Commission's demand forecast serves as a common thread relating transmission studies, resource adequacy, integrated resource planning, and distribution planning. Energy Commission staff will continue to engage with the Joint Agency Steering Committee to promote clear and consistent expectations among agencies and stakeholders about the inputs, assumptions, methods, and timing of these interdependent processes.

Acronyms

AAEE	—	additional achievable energy efficiency
AAPV	—	additional achievable photovoltaic
AB	—	Assembly Bill
AC	—	alternating current
AMI	—	advanced metering infrastructure
BAAQMD	—	Bay Area Air Quality Management District
Bcf	—	billion cubic feet
Btu	—	British thermal unit
CAEATFA	—	California Alternative Energy and Advanced Transportation Financing Authority
CAL FIRE	—	California Department of Forestry and Fire Protection
CalBRACE	—	California Building Resilience Against Climate Effects
California ISO	—	California Independent System Operator
Caltrans	—	California Department of Transportation
CARB	—	California Air Resources Board
CCA	—	community choice aggregator
CED	—	*California Energy Demand Forecast*
CEDU	—	*California Energy Demand Updated Forecast*
CEQA	—	California Environmental Quality Act
CLIMB	—	Clean Energy in Low-Income Multifamily Buildings
CO_2	—	carbon dioxide
CO_2e	—	carbon dioxide equivalent
COPs	—	Conferences of the Parties
CPUC	—	California Public Utilities Commission
CSD	—	California Department of Community Services and Development
CSI	—	California Solar Initiative
CSGT	—	Community Solar Green Tariff Program
CVR	—	conservation voltage reduction
DAC-GT	—	Disadvantaged Community Green Tariff Program
DAC-SASH	—	Disadvantaged Community Single-Family Affordable Solar Homes Program
DAWG	—	Demand Analysis Working Group
DC	—	direct current
DCFC	—	direct current fast charging
DER	—	distributed energy resources
DR	—	demand response
DRAM	—	Demand Response Auction Mechanism
E3	—	Energy and Environmental Economics
EIM	—	energy imbalance market
EPIC	—	Electric Program Investment Charge
FERC	—	Federal Energy Regulatory Commission
GHG	—	greenhouse gas
GWh	—	gigawatt hours

GWP	—	global warming potential
HERS	—	Home Energy Rating System
HFC	—	hydrofluorocarbon
HSPF	—	heating season performance factor
HVAC	—	heating, ventilation, and air conditioning
ICARP	—	Integrated Climate Adaptation and Resiliency Program
IEPR	—	*Integrated Energy Policy Report*
IOU	—	investor-owned utility
IRP	—	integrated resource plan
kV	—	kilovolt
kW	—	kilowatt
LADWP	—	Los Angeles Department of Water and Power
LBNL	—	Lawrence Berkeley National Laboratory
LCFS	—	Low-Carbon Fuel Standard
LED	—	Light-emitting diode
LTPP	—	Long-Term Procurement Plan
MMcf	—	million cubic feet
MMcfd	—	million cubic feet per day
MT	—	metric ton
MVAR	—	megavolt of reactive power
MW	—	megawatt
MWh	—	megawatt hour
NERC	—	North American Electric Reliability Corporation
NMEC	—	normalized metered energy consumption
NO_x	—	oxides of nitrogen
NREL	—	National Renewable Energy Laboratory
OEHHA	—	Office of Environmental Health Hazard Assessment
OIR	—	order instituting rulemaking
OPR	—	Governor's Office of Planning and Research
OTC	—	once-through cooling
PCC	—	Pacific Coast Collaborative
PEV	—	plug-in electric vehicle
PG&E	—	Pacific Gas and Electric
POU	—	publicly owned utility
PPA	—	power purchase agreement
PV	—	photovoltaic
Quad Btus	—	quadrillion British thermal units
QF	—	qualifying facility
RA	—	resource adequacy
RAMP	—	risk assessment and mitigation phase
RD&D	—	research, development, and demonstration
REN	—	regional energy network
RFO	—	request for offers
RFS2	—	Renewable Fuel Standard
RG	—	renewable gas
RPS	—	Renewables Portfolio Standard
San Onofre	—	San Onofre Nuclear Generating Station

SB	—	Senate Bill
SCE	—	Southern California Edison
SCPPA	—	Southern California Public Power Authority
SCP	—	Sonoma Clean Power
SCRP	—	Southern California Reliability Project
SDG&E	—	San Diego Gas & Electric
SEER	—	Seasonal Energy Efficiency Ratio
SEM	—	Strategic Energy Management
SMUD	—	Sacramento Municipal Utility District
SoCalGas	—	Southern California Gas Company
SOMAH	—	Solar on Multifamily Affordable Housing
TAC	—	transmission access charges
TD&D	—	technology demonstration and deployment
TOU	—	time-of-use
TPP	—	Transmission Planning Process
U.S. DOE	—	United States Department of Energy
U.S. EPA	—	United States Environmental Protection Agency
var	—	volt amp reactive
VER	—	variable energy resources
VVO	—	volt/var optimization
WECC	—	Western Electricity Coordinating Council
ZEV	—	zero-emission vehicle

Glossary

Additional achievable energy efficiency

Additional achievable energy efficiency savings include incremental savings from the future market potential identified in utility potential studies not included in the baseline demand forecast, but reasonably expected to occur, including future updates of building codes, appliance regulations, and new or expanded investor-owned utility or publicly owned utility efficiency programs.

Advanced metering infrastructure

Refers to the full measurement and collection system that includes meters at the customer site; communication networks between the customer and a service provider, such as electric, gas, or water utility; and data reception and management systems that make the information available to the service provider (Source: Electric Power Research Institute [EPRI]).

Beneficial electrification

The fundamental premise is that to be beneficial, electrification must meet one or more of the following conditions without adversely affecting the other two:

- Saves consumers money over the long run.
- Enables better grid management.
- Reduces negative environmental impacts.

Bid curve

Bid curves are sets of offers (or bids) to buy or sell an amount of energy at a given price.

Built environment

The *built environment* refers to the buildings in which people live and work and conduct the activities that make up their daily lives. There are broader definitions that include the infrastructure people rely on.

CalTRACK

CalTRACK is a set of methods for calculating site-based, weather-normalized, metered energy savings from an existing baseline and applied to single-family home retrofits using data from utility meters. http://www.caltrack.org/.

Climate adaptation

A growing body of new policies—referred to as *climate adaptation*—is intended to grapple with what is known from climate science and incorporate planning for climate

change into the routine business of governance, infrastructure management, and administration.

Community choice aggregation

Community choice aggregation (or CCA) lets local jurisdictions aggregate, or combine, their electricity load to purchase power on behalf of their residents. In California, CCAs are legally defined by state law as electric service providers and work together with the region's existing utility, which continues to provide customer services (for example, grid maintenance and power delivery). (For more information see http://www.leanenergyus.org/what-is-cca/ and/or http://newsroom.ucla.edu/releases/community-choice-is-transforming-the-california-energy-industry.)

Compressed air energy storage

Compressed air energy storage systems compress and store air under pressure in an underground formation or large storage tanks. When electricity is needed, the pressurized air is heated and expanded to drive a generator for power production. Such systems have not been widely developed, with only two systems operational worldwide.

Conservation voltage reduction

Conservation voltage reduction is a proven technology that reduces energy use and peak demand by optimizing voltages on the distribution system. The basic premise of this technology is that the standard voltage band between 114 and 126 volts can be compressed via regulation to the lower half (114–120 volts) instead of the upper half (120–126 volts). This results in substantial energy savings to the customer at low cost to the utility, with no adverse effects on consumer appliances. Distribution utilities implement CVR and gain savings from decreased losses on their systems. Although end users are not required to take any action, they benefit through reduced energy usage.

Demand charges

Demand charges are electric bill charges that are based on the peak electricity usage of a customer.

Distributed energy resources

Distributed energy resources include:

- *Demand response*, which has been used traditionally to shed load in emergencies. It also has the potential to be used as a low-greenhouse gas, low-cost, price-responsive option to help integrate renewable energy and provide grid-stabilizing services, especially when multiple distributed energy resources are used in combination and opportunities to earn income make the investment worthwhile.

- Distributed renewable energy generation, primarily rooftop photovoltaic energy systems.
- "Vehicle grid integration," or all the ways plug-in electric vehicles can provide services to the grid, including coordinating the timing of vehicle charging with grid conditions
- Energy storage in the electric power sector to capture electricity or heat for use at a later time to help manage fluctuations in supply and demand

Evapotranspiration

Evapotranspiration is the process by which water is transferred from the land to the atmosphere by evaporation from the soil and other surfaces and by transpiration from plants.

Flywheels

Flywheels are heavy wheels used for storing kinetic energy.

Frequency regulation

Frequency regulation refers to maintaining the alternating current frequency in the electricity grid within tight tolerance bounds. This is necessary for reliable operation of the electricity grid.

Fuel substitution

Senate Bill 350 defines *fuel substitution* as "programs that save energy in final end uses by using cleaner fuels to reduce greenhouse gases as measured on a life-cycle basis."

Greenhouse Gas Emission Profile

A *greenhouse gas emission profile* offers detailed information about the energy use of a building and levels of greenhouse gas emissions and identifies initiatives that could reduce energy use and cost.

Global warming potential

Global warming potential is a common measure of how much energy the emissions of 1 ton of greenhouse gas will absorb over a given period, relative to the emissions of 1 ton of CO_2. The larger the global warming potential, the more that a given gas warms the Earth compared to CO_2 over a period, usually 100 years.

Heating season performance factor

The *heating season performance* metric measures the total space heating required during the heating season, expressed in British thermal units, divided by the total electrical energy consumed by the heat pump system during the same season, expressed in watt-hours.

Hydrofluoroolefins

Hydrofluoroolefins are unsaturated organic compounds composed of hydrogen, fluorine, and carbon.

Interval meter

Interval meters record energy use in 15-minute intervals, which one can combine into hourly, daily, or monthly consumption.

Inverter

An *inverter* is an electronic device or circuitry that converts power from a direct current (DC) source (such as solar panels or a wind turbine) to alternating current (AC), so that it can be moved over the transmission and distribution system and be used by consumers.

LIDAR

LIDAR, or light detection and ranging, is a remote sensing method that uses light in the form of a pulsed laser to measure variable distances to the Earth.

Microgrid

A *microgrid* is a small, self-contained electricity system with the ability to "manage critical customer resources, provide services for the utility grid operator, disconnect from the grid when the need arises, and provide the customer and the utility different levels of critical support when the need exists."

Net load

Net load is electricity load minus solar and wind generation.

Once-through cooling

Once-through cooling technologies intake ocean water to cool the steam that is used to spin turbines for electricity generation. The technologies allow the steam to be reused, and the ocean water that was used for cooling becomes warmer and is then discharged back into the ocean. The intake and discharge processes have negative impacts on marine and estuarine environments.

Overgeneration

Overgeneration occurs when the total supply exceeds the total demand in a balancing authority area.

Pumped storage

Pumped storage (also referred to as *pumped hydro*) plants typically use pumps and generators to move water between an upper and lower reservoir and can provide energy for long periods.

Reach technology

A *reach technology* is not widely commercialized today but has been demonstrated outside laboratory conditions and has the potential to reduce emissions from sectors that are difficult to address.

Reactive power

The portion of electricity that establishes and sustains the electric and magnetic fields of alternating-current equipment. Reactive power must be supplied to most types of magnetic equipment, such as motors and transformers. Reactive power is provided by generators, synchronous condensers, or electrostatic equipment such as capacitors and directly influences electric system voltage. It is usually expressed as kilovolt-amperes reactive (KVAR) or megavolt-ampere reactive (MVAR). For more information, see https://www.eia.gov/tools/glossary/index.php?id=V.

Real power

The component of electric power that performs work, typically measured in kilowatts (kW) or megawatts (MW). For more information, see https://www.eia.gov/tools/glossary/index.php?id=V. *Real power* refers to the electricity used to provide services such as lighting, turning motors, and running air conditioners.

Recloser

A r*ecloser* is a switch or circuit breaker that establishes an electrical circuit again manually, remotely, or automatically after a service interruption.

Reliability-must-run

The California Independent System Operator (California ISO) will allow utilities to generate power that is needed to ensure system reliability. This includes generation:

- Required to meet the reliability criteria for interconnected systems operation.
- Needed to meet load (demand) in constrained areas.
- Needed to provide voltage or security support of the California ISO or of a local area.

Retrocommissioning

Retrocommissioning is the process of seeking improvements to how an existing building's equipment and systems function together.

Seasonal Energy Efficiency Ratio (SEER)

SEER is a metric used to measure how much cooling a system puts out for each unit of energy it consumes. In theory, the higher the SEER rating, the more efficiently the air conditioner operates.

Telemetry

The process of recording and communicating the readings of an instrument.

Thermal energy

Thermal energy storage encompasses a variety of technologies in which thermal energy is stored for later use. Examples include producing ice that can be used later to cool buildings or molten salt used to store heat for later use at concentrating solar plants.

Volt-ampere reactive

Volt-ampere reactive, or *VAR*, is a measure of reactive power that exists when current and voltage are not in phase in the transmission or distribution system. Reactive power reduces system efficiency, and managing it is important to ensure voltage stability throughout the grid.

Voltage

The difference in electrical potential between any two conductors or between a conductor and ground. It is a measure of the electric energy per electron that electrons can acquire or give up or both as they move between the two conductors. For more information, see https://www.eia.gov/tools/glossary/index.php?id=V.

If voltage is not maintained at specified levels, it can damage generation, transmission, and distribution equipment and lead to cascading blackouts.

Water-energy nexus

The relationship between the water used for energy production and the energy consumed to extract, purify, deliver, heat, cool, treat, and dispose of water.

Western Electric Coordinating Council

According to its Web page, the Western Electric Coordinating Council is “a non-profit corporation that exists to assure a reliable bulk electric system in the geographic area known as the Western Interconnection.” For more information, see https://www.wecc.biz/Pages/home.aspx.

APPENDIX A: California Building Efficiency Standards

The California Energy Commission's building standards for residential and nonresidential buildings remain a cornerstone of state policy to reduce statewide energy use and GHG emissions. The building standards focus on building components that affect energy use in newly constructed residential and nonresidential buildings, as well as additions and alterations to existing buildings. As the Energy Commission updates the building standards, providing for building electrification will be an increasing focus of revisions.

The *2019 Building Energy Efficiency Standards*, which take effect January 1, 2020, were adopted by the Energy Commission in May 2018 and approved by the California Building Standards Commission in December 2018.

All-Electric Compliance Pathway

During the *2019 Building Energy Efficiency Standards* update, the Energy Commission worked with stakeholders to develop software modeling capabilities, electrification options, and an alternative energy baseline to allow all-electric buildings to achieve building standard compliance. The heat pump industry has made significant technological advances in recent years, leading to increased energy efficiency, better control systems, and an improved product life. Additional challenges remain in providing comfortable space heating and effective water heating in some climate zones without reliance on inefficient electric-resistance backup heating elements or the need for expensive ground loop heat exchangers.

The *2019 Building Energy Efficiency Standards* update provided a separate baseline for heat pump water heating independent from natural gas. This new baseline removes a compliance barrier in the previous building standards and allows for the installation of highly energy-efficient heat pump water heaters. The building standards have many requirements designed to promote either fuel substitution or all-electric buildings. These requirements include the solar-ready requirements for roof orientation and obstacles, upgraded wiring to allow future electrification of water heating, and electrical panel sizing and conduits for electric vehicle (EV) charging. The Energy Commission has also worked to reduce the electrical consumption of buildings through efficiency measures so that significantly smaller PV systems are necessary to reduce demands on the electrical grid.

California Building Energy Building Standard Compliance Effort

The Energy Commission has worked to reduce the environmental impact of the energy used in buildings through the building standards. Due to recent focus on the reduction of GHG emissions from buildings, the Energy Commission updated the building standards compliance to calculate and report GHG emissions of buildings in addition to energy consumption.

The compliance software capabilities leverage the lab test data generated by using the voluntary Northwest Energy Efficiency Alliance Advanced Water Heater Specification previously discussed.[461] The Energy Commission has implemented a detailed heat pump water heater model that operates on a one-minute time step. The simulation can either use the U.S. Department of Energy UEF rating or specific measured parameter built into each heat pump water heater model. Nearly all the heat pump water heater manufacturers have submitted the voluntary test data, which allow their heat pump water heater to obtain compliance credit in the performance compliance approach.

Future compliance software capabilities include variable-capacity heat pump systems used in the Central Valley Research Homes project. Heat pump systems are being tested using EXP-07 to ensure that the lab tests are appropriately capturing field performance. The Energy Commission will use the results of the field and lab testing to inform the development of simulation algorithms that will use the voluntary EXP-07 test results. The building standard implementation template for this initiative is the current approach in compliance for heat pump water heater. Work will continue to improve EXP-07 to cover residential variable-refrigerant flow systems where there are more than one indoor unit attached to an outdoor unit.

461 NEEA Advanced Water Heater Specification, Version 6.0, updated May 10, 2016. https://neea.org/our-work/advanced-water-heater-specification.