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California Energy Commission

COMMISSION REPORT

Final 2021 Integrated Energy Policy Report

Volume IV: California Energy Demand Forecast

Gavin Newsom, Governor

February 2022 | CEC-100-2021-001-V4

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ABSTRACT

The *2021 Integrated Energy Policy Report* 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 year 2021 has been unprecedented as the state continues to face the impacts and repercussions of challenging events including the continued effects of the COVID-19 pandemic, extreme summer weather, and drought conditions. In addition to these events, the *2021 Integrated Energy Policy Report* covers a broad range of topics, including building decarbonization, energy efficiency, challenges with decarbonizing California's gas system, quantifying the benefits of the Clean Transportation Program, and the *California Energy Demand Forecast*.

Keywords: Integrated Energy Policy Report, California Energy Demand Forecast, Transportation Energy Demand Forecast, Long-Term Energy Demand Scenarios

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EXECUTIVE SUMMARY

The *2021 Integrated Energy Policy Report (IEPR)* provides information and policy recommendations on advancing a clean, reliable, and affordable energy system for all Californians. The *2021 IEPR* is presented in the following volumes:

- **Volume I** addresses actions needed to reduce the greenhouse gases (GHGs) related to the buildings that California's live and work in, with an emphasis on the need for energy efficiency. It also addresses reducing GHGs from the industrial and agricultural sectors.
- **Volume II** examines actions needed to increase the reliability and resiliency of California's energy system.
- **Volume III** looks at the evolving role of gas in California's energy system.
- **Volume IV** reports on California's energy demand outlook, including a forecast to 2035 and long-term energy demand scenarios to 2050. The analysis includes the electricity, gas, and transportation sectors.
- **Appendix** assesses the benefits of California's Clean Transportation Program.

Energy Demand Planning

California is the nation's trendsetter in adopting innovative energy and environmental policies and has a history of success in reducing GHG emissions that cause climate change, improving air quality, and making meaningful strides towards a more equitable future. Policies targeted at the energy sector have been particularly successful, where diligent planning has resulted in reductions in GHG emissions while advancing a more reliable and affordable energy system.

A foundational component of the state's energy planning is the California Energy Commission's (CEC's) California Energy Demand Forecast (CED). The CED is a set of several forecasting products that are used in various energy planning proceedings. It is relied upon in statewide energy planning, including the California Public Utilities Commission's (CPUC's) oversight of energy procurement and the California Independent System Operator's (California ISO's) transmission planning.

California's energy system planning is complex and is continuously challenged by events that impact energy supply and demand. More recently, challenges such as a pandemic, frequent extreme weather events, historic drought conditions, and record-breaking wildfires have had a profound impact on the lives of all Californians, including the way they use energy. These challenges also strain efforts to balance energy supply and demand — a balance that is critical to maintaining a reliable energy system. Climate change is the main culprit causing uncertainty in near- and long-term planning, and recent extreme weather events in California and the rest of the West have had a real impact on energy demand and system planning. California's energy system planning must continuously adapt and evolve to keep pace with changing climate conditions.

Evolving Forecasting Needs

CEC staff is dedicated to making continual improvements to forecasting methods and developing new products that best serve the planning process. As detailed in the January 2021 *Final Root Cause Analysis Mid-August 2020 Extreme Heat Wave*, the CEC, CPUC, and California ISO have committed to refine various elements of the state's electricity planning process in response to the increasing risk from extreme weather events. Reliability concerns related to recent extreme heat, drought, and wildfire events across western states have elevated the need to address climate change more directly and comprehensively within the energy planning processes, including the CED. While the forecast already accounts for climate change and provides peak demand projections for a broad range of weather scenarios, analytical improvements and new forecasting products are needed to help maintain grid reliability and to meet the state's decarbonization goals, such as widespread electrification. The 2021 forecast includes a new element to better reflect future electrification in the buildings sector, as well as updates to future transportation electrification projections.

Going forward, the CEC is committed to making ongoing improvements to its forecasting assessments. In his proposed 2022–2023 California budget, Governor Gavin Newsom allocated $7 million to support energy modeling improvements and bolster the state's energy planning and policy development.

Electricity and Gas Demand Forecast

As part of the IEPR process, the CEC develops and adopts 10-year forecasts of end-user electricity and gas demand. For the 2021 forecast, these energy demand forecasts are extended out beyond 10 years to 2035 to provide planners with a longer forecasting horizon and support planning for transportation electrification goals. These forecasts include updates to economic and demographic drivers and incorporate an additional year of (2021) historical data for electricity and gas consumption, and peak demand. Further, CEC staff update electricity and gas rate projections, as well as adoption forecasts for behind-the-meter photovoltaic (BTM PV) systems, energy storage, energy efficiency, fuel substitution, and electric vehicles. BTM systems are those that directly supply buildings with electricity and are on the customer's side of the meter.

The forecast includes three energy demand cases designed to capture a reasonable range of outcomes through 2035:

- ***High-energy demand case*** incorporates relatively high economic/demographic growth, relatively low energy rates, higher adoption of zero-emission vehicles (ZEVs), lower self-generation, and climate change impacts.
- ***Low-energy demand case*** includes lower economic/demographic growth, higher assumed rates, low adoption of ZEVs, higher self-generation impacts.
- ***Mid-energy demand case*** uses input assumptions at levels between the high and low cases.

Also, the 2021 forecast includes adjustments to account for changes in demand from temperature increase due to climate changes, based on modeling conducted by the Scripps

Institution of Oceanography. Consistent with previous years, this forecast provides peak demand projections for a broad range of weather scenarios. The 2021 forecast projects electricity sales that are 1.1 percent higher than the CEDU 2020 mid case and by 2035 reach almost 280,000 gigawatt hours (GWh). The managed peak forecast for the California ISO control area grows at a rate of 0.9 percent annually, reaching 52,437 megawatts (MW) by 2035. By 2030, this managed forecast is 4.3 percent higher than projected by CEDU 2020. The increase can be attributed to a higher weather-normal base-year peak, a higher growth in the baseline consumption forecast, lower additional achievable energy efficiency (AAEE) impacts, and the addition of fuel substitution.

Impacts of COVID-19 on California's Economy and Energy Demands

Following the abrupt shocks to the economy caused by the global COVID-19 pandemic, California quickly shifted toward recovery supported by the CARES Act, the America Rescue Plan Act, and the Golden State Stimulus among other federal, state, and local recovery and relief efforts. Although California is on the path to the recovery, the ongoing pandemic continues to add uncertainty in energy demand forecasts. The California gross state product has bounced back from the recession in the first and second quarters of 2021 and is expected to maintain steady growth going forward, but a gap in employment still remains compared to prepandemic levels and trends. Further, potential structural impacts from the pandemic such as the persistence of teleworking options for office workers, expanded remote learning, and declines in brick-and-mortar retail sales remain uncertain. The economic scenarios used in the 2021 forecast include varied assumptions for how the California economy will continue its recovery from the pandemic.

Additional Achievable Energy Efficiency and Fuel Substitution

AAEE is the incremental energy savings from market potential that is not included in the baseline demand forecast but is reasonably expected to occur. This includes many future updates of building standards, appliance regulations, and new or expanded energy efficiency programs. AAEE is central to developing a managed demand forecast, which, in turn, is the basis for resource planning and procurement efforts at the CPUC and the California ISO.

For the 2021 forecast, CEC staff developed additional achievable fuel substitution (AAFS) as a new annual and hourly load modifier to the baseline demand forecast in a manner analogous to AAEE. Fuel substitution refers to substitution of one end use fuel type for another, such as changing out gas appliances in buildings for cleaner more efficient electric end uses. AAFS development was accelerated by using the AAEE method as a template. The aim is to develop realistic projections of energy efficiency and fuel substitution that are useful for planning.

Transportation Energy Demand Forecast

The CEC's transportation energy demand forecast presents expected energy demand from transportation through 2035. The forecast uses models that consider vehicles and associated fuels, incorporating consumer preferences, regulatory impacts, economic and demographic projections, projected improvements in technology, and other market factors. The approach starts with current market conditions and forecasts transportation energy demand based on the projected inputs and advanced quantitative modeling. No constraints are imposed for the forecast to meet a future target. By contrast, other approaches commonly used for strategic planning begin with a target (such as a quantity of vehicles, fuels, or emissions goals to meet by a future year) and work backward to stipulate intermediate conditions for the intervening years. In conjunction with the CEC's forecast, policy makers can use their strategic plans to assess progress toward statewide goals and determine whether further action is needed.

Long-Term Energy Demand Scenarios

Energy demand forecasting is a core CEC activity. Over the decades, the forecasts developed have evolved to meet internal needs, the needs of planning partners, and those of policy makers. The increasing policy and planning focus on climate change in recent years has accentuated the need for developing longer-term demand projections for all energy forms. Because time horizons further out necessarily involve increased uncertainty, CEC staff has been reluctant to use the term *forecast* to describe possible energy demand to 2050. Instead, the term *demand scenario* has been coined to reflect that any one specific projection is just one of several scenarios that result from assessing a set of assumptions with numerous uncertain values.

The impacts of climate change and decarbonization policies have created a need for a routinely produced set of long-term energy demand scenarios to be used for planning. To meet this need, CEC staff has embarked on a new long-term demand scenario development and assessment project to identify energy demand and supply, as well as GHG emission reductions from existing and near-term policies. This is a major undertaking that will take several years to fully implement. The CEC formally began this work in the 2021 IEPR cycle, which includes discussions on progress to date. The analysis and results will be presented publicly in early 2022.

CHAPTER 1: California Energy Demand Forecast

A foundational component of the state's energy planning is the California Energy Commission's (CEC's) California Energy Demand Forecast (CED).[1] CED is a set of several forecasting products that are used in various energy planning proceedings, including the California Public Utilities Commission's (CPUC's) oversight of energy procurement and the California Independent System Operator's (California ISO's) transmission planning. Over the past 15 years, the demand forecast generally includes:

- Ten-year annual end-use consumption forecasts for electricity and gas by customer sector, eight planning areas, and 20 forecast zones.
- Annual peak electric system load with different weather variants for eight planning areas.
- Annual projections of load modifier impacts including adoption of photovoltaic (PV) and other self-generation technologies, energy efficiency standards, and program impacts.

California's energy system planning has been challenged in recent years due to several events that impact energy supply and demand. These events include a pandemic, frequent extreme weather events, historic drought conditions, and an alarming number of wildfires that have blanketed the state in smoke and precluded hundreds of thousands of would-be tourists from visiting many of the state's popular destinations. These events have had a profound impact on the lives of all Californians, including the way they use energy. That impact contributes to a more challenging balancing of energy supply and demand that is critical to maintaining a reliable energy system. Climate change is the main culprit causing uncertainty in near- and long-term planning, and recent extreme weather events in California and the rest of the West have had a real impact on energy demand and system planning. California's energy system planning must continuously adapt and evolve to keep pace with changing climate conditions.

1 Public Resources Code section 25301(a) requires the CEC to "conduct assessments and forecasts of all aspects of energy industry supply, production, transportation, delivery and distribution, demand, and prices" and to "use these assessments and forecasts to develop and evaluate energy policies and programs that conserve resources, protect the environment, ensure energy reliability, enhance the state's economy, and protect public health and safety."

The changing dynamics of the California energy system require regular improvements to the forecast, as well as new forecasting product development. For example, over the past five years, several forecasting improvements have been implemented, including:

- Development of climate change impacts to electricity and gas consumption as well as annual peak demand. Impacts correspond to projected increases of average temperatures.
- Projections of residential and commercial battery storage adoption.
- Development of an hourly system load model for California ISO planning areas. The model includes estimating hourly impacts of PV, electric vehicle charging, climate change, energy efficiency measures, time-of-use rates, water pumping, and economic dispatch of battery storage. Hourly loads are necessary for assessing the timing of system peak load as well as the timing and magnitude of system ramps.
- Incremental projections for areas of significant load growth, including cannabis cultivation and large data center construction.

Forecast Improvements: Climate Change and Decarbonization Policies

CEC staff is committed to continual improvements to forecasting methods and developing new products that best serve planning. As detailed in the January *2021 Final Root Cause Analysis Mid-August Extreme Heat Wave*,[2] the CEC, CPUC, and California ISO have committed to refining various elements of the state's electricity planning process in response to the increasing risk from extreme weather events. Reliability concerns related to recent extreme heat, drought, and wildfire events across western states have elevated the need to address climate change more comprehensively within the energy planning processes, including the CED. While the forecast already accounts for climate change and provides peak demand projections for a broad range of weather scenarios, analytical improvements and new forecasting products are needed to help maintain grid reliability and to meet the state's decarbonization goals. Volume II of the *2021 IEPR* is on reliability.

The forecast developed for the *2021 Integrated Energy Policy Report* (*2021 IEPR*) includes adjustments to account for changes in demand due to climate change and resulting increases in temperature based on modeling conducted by Scripps Institution of Oceanography. Consistent with previous forecasts, this forecast provides peak demand projections for a broad

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2 California ISO, CPUC, CEC. January 2021. *Final Root Cause Analysis: Mid-August 2020 Extreme Heat Wave*. http://www.caiso.com/Documents/Final-Root-Cause-Analysis-Mid-August-2020-Extreme-Heat-Wave.pdf.

range of weather scenarios. Specifically, the forecast considers peak demand under extreme temperature conditions that should be expected only once every two, five, ten, or twenty years. These scenarios are referred to as 1-in-2, 1-in-5, 1-in-10, and 1-in-20 probability weather scenarios, respectively.

In developing these peak weather variants, staff had previously used a 30-year rolling window of daily temperature statistics to distinguish a *normal* peak load event from more extreme events. As part of the 2021 IEPR forecast, staff explored alternative methods to account for a general warming trend when establishing a base-year estimate of normal peak load. Also, staff updated the 1-in-5, 1-in-10, and 1-in-20 peak factors to reflect the extreme heat waves of summer 2020.

To combat climate change, California is implementing strategies to achieve its decarbonization goals which also need to be factored into the forecast. A key decarbonization strategy is electrification in the state's transportation and buildings sectors that collectively account for 75 percent of statewide GHG emissions.[3] For the 2021 forecast, the CEC developed a new product called additional achievable fuel substitution (AAFS). Fuel substitution generally refers to substituting one fuel type for another at the end use (for example, replacing a gas water heater with an electric heat pump water heater). A decarbonization strategy of replacing gas end uses with cleaner and more efficient electric end uses has significant implications for the electricity and gas forecasts. AAFS is intended to develop a set of scenarios that capture the uncertainty in the pace and intensity of building electrification, providing policy makers with planning options. AAFS is discussed further in Chapter 2 and Appendix A.

Transportation electrification is perhaps the most critical decarbonization strategy, given the sector accounts for more than 50 percent of statewide GHG emissions (including emissions associated with fuel production). The transportation forecast inputs and assumptions have been updated and are discussed in Chapter 3.

Lastly, the state's decarbonization goals along with the effects of climate change call for structural changes in California's economy. The CEC is adapting its forecasting efforts to meet these challenges and has expanded assessments to include long-term projections of energy demand through 2050 under various scenarios. Chapter 4 defines and discusses these long-term demand scenarios.

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3 California Air Resources Board. July 2021. *California Greenhouse Gas Emissions for 2000 to 2019: Trends of Emissions and Other Indicators*. See Figure 4. Both residential and commercial buildings are counted. https://ww3.arb.ca.gov/cc/inventory/pubs/reports/2000_2019/ghg_inventory_trends_00-19.pdf.

These rapidly evolving factors require new approaches and further advancements in energy modeling. In his proposed budget, Governor Gavin Newsom proposed allocating $7 million in 2022–2023 to support improvements to energy modeling activities, including better reflecting climate change in state energy planning and policy development. The funding would also support analytical efforts presented in the *2021 IEPR, Volume II: Ensuring Reliability in a Changing Climate*.

Electricity and Gas Forecast

As part of the IEPR process, the CEC develops and adopts 10-year forecasts of end-user electricity and natural gas demand in odd-numbered years. For CED 2021, these energy demand forecasts are extended to year 2035 to support planning for California's transportation electrification goals.

These forecasts include updates to economic and demographic drivers and incorporate 2021 historical data for electricity and gas consumption, and peak demand. Further, staff updates electricity and gas rate projections, as well as adoption forecasts for behind-the-meter photovoltaic (BTM PV) systems, energy storage (such as batteries), energy efficiency, fuel substitution, and electric vehicles.

The forecast includes three energy demand cases designed to capture a reasonable range of outcomes through 2035:

- ***High-energy demand case*** incorporates relatively high economic/demographic growth, relatively low energy rates, higher adoption of ZEVs, lower self-generation, and climate change impacts.
- ***Low-energy demand case*** includes lower economic/demographic growth, higher assumed rates, low adoption of ZEVs, higher self-generation impacts.
- ***Mid-energy demand case*** uses input assumptions at levels between the high and low cases.

As well as the forecast, the *Draft 2021 IEPR, Volume IV* dedicates chapters to additional achievable energy efficiency (AAEE) and fuel substitution, the transportation energy demand forecast, and the long-term energy demand scenarios. AAEE is the incremental energy savings not included in the baseline demand forecast but reasonably expected to occur. Similarly, AAFS is the incremental energy impacts not included in the baseline demand forecast but reasonably expected to occur. AAFS is a new load modifier introduced in 2021 forecast and is expected to be more uncertain than AAEE.

The Forecast Is Foundational to Statewide Energy Planning

The CEC's forecast of end-use electricity demand informs the need for major infrastructure investments in California. It is used in various proceedings, including the CPUC's Integrated Resource Plan (IRP) process and the California ISO's Transmission Planning Process (TPP). IRPs are long-term plans outlining how load-serving entities (including investor- and publicly owned utilities, community choice aggregators, and private electricity suppliers) will meet demand reliably and cost-effectively while achieving state policy goals and mandates. The TPP is a roadmap for short- and long-term transmission infrastructure needs in the California ISO service territory. The CEC also provides annual year-ahead peak demand forecasts for the resource adequacy process in coordination with the California ISO and the CPUC.

Impacts of COVID-19 on California's Economic Outlook

Following the abrupt shocks to the economy induced by the global COVID-19 pandemic, California quickly shifted toward recovery supported by the CARES Act, the America Rescue Plan Act, and the Golden State Stimulus among other federal, state, and local recovery and relief efforts. Although California is on the path to the recovery, the ongoing pandemic continues to add uncertainty in energy demand forecasts. California gross state product has bounced back from the recession in the first and second quarters of 2021 and is expected to maintain steady growth going forward, but a gap in employment remains compared to prepandemic levels and trends. Further, potential structural impacts from the pandemic such as the persistence of teleworking options for office workers, expanded remote learning, and declines in brick-and-mortar retail sales remain uncertain.

All three economic scenarios used in the CED 2021 forecast include varied assumptions for how the California economy will continue its recovery from the pandemic. The previous economic scenarios were focused on assumptions around the availability of vaccines. With the availability of vaccines in early 2021, the scenario assumptions have shifted toward varying degrees of vaccination and infection rates with higher assumed vaccination rates and, therefore, lower assumed infection rates, resulting in quicker or more robust recovery outcomes. Generally, the high scenarios assume higher than anticipated levels of vaccinations with lower infection rates, while the low scenarios assume delays in vaccinations leading to higher levels of infection.

Summary of Key Drivers and Trends

The CED 2021 energy demand cases use the May 2021 vintage of economic projections from Moody's Analytics (Moody's) and January 2021 demographic projections from the California Department of Finance (DOF). The high-energy demand case uses a custom economic scenario that Moody's developed for the CEC. It incorporates more optimistic assumptions, leading to a higher long-term growth trend. The low-energy demand case uses Moody's slow long-term growth scenario. The mid-energy demand case uses Moody's baseline scenario that is described as a "50/50" likelihood with assumptions between Moody's high and low scenarios.

Demographic assumptions are derived from forecasts of population and number of households developed by DOF. The population forecast is used in all three energy demand cases, while the household forecast is used for the mid and low cases. For the high case, CEC staff developed a more optimistic household growth projection using a combination of DOF and Moody's more optimistic forecast data.

Other drivers in energy consumption forecasts are the retail cost of energy, adoption of self-generation and energy storage technologies, and vehicle electrification. The electricity rate scenarios incorporate recent and pending utility rates and rate actions, and projected costs of electric generation procurement, transmission and distribution revenue requirements, and other costs. Key drivers of increasing electricity rates in this IEPR are the costs of wildfire mitigation, risk management, and other investment in the distribution grid to support state policy goals. The electricity rate scenarios also effect the adoption of self-generation. High electricity rates should create a more economically favorable condition for self-generation technologies such as BTM PV, while a low electricity rate assumption would create a less favorable condition. Electric vehicles are discussed in detail in a later chapter of this volume; generally, the low- and high-energy demand cases include lower and higher vehicle adoption than the mid case. Table 1 summarizes the energy demand case assumptions for CED 2021.

Table 1: Summary of Energy Demand Case Assumptions

Energy Demand Case	Key Assumptions
High-Energy Demand Case	• Higher economic and demographic projections • Lower electricity and gas rates • Higher electric vehicle adoption • Lower self-generation and storage adoption
Low-Energy Demand Case	• Lower economic and demographic projections • Higher electricity and gas rates • Lower electric vehicle adoption • Higher self-generation and storage adoption
Mid-Energy Demand Case	• Expected case with assumptions generally between the high and low electricity demand cases

Source: CEC

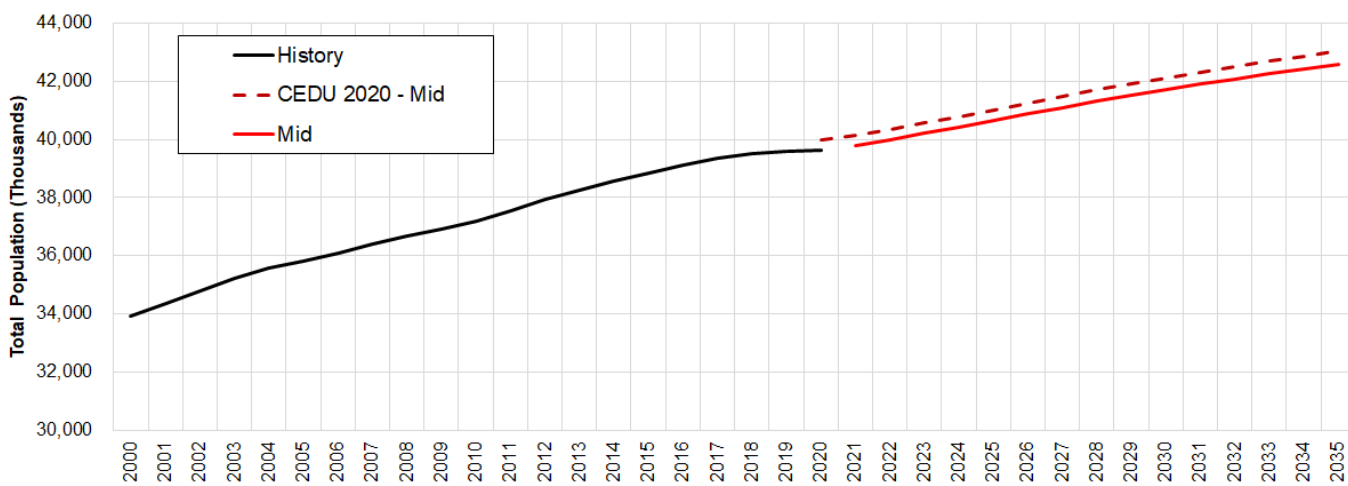
Economic and Demographic Drivers and Trends

Statewide population growth for CED 2021 continues at 0.5 percent annually from 2021 to 2035, as with the previous population projections from the DOF. The total population in 2035 is expected to be about 1 percent lower compared to *California Energy Demand Update 2020* (CEDU 2020).[4] The reduction in population is due to several factors:

- Lower starting population due to less estimated growth since the 2010 Census
- A reduction in net migration
- A decline in birth rates
- A slowdown of life expectancy gains

Regionally, inland areas such as the Sacramento Valley, Central Valley, and Inland Empire have seen stronger historic growth and are expected to continue to drive future growth in California's population compared to coastal regions and the far northern counties. Los Angeles County, for example, has experienced declines in population over each of the last three years and is only expected to add an additional 1.5 percent to its population by the end of the decade. Riverside County, however, is expected to add 11 percent over the same period. Figure 1 compares statewide population forecasts for CED 2021 and CEDU 2020.

Figure 1: Statewide Population Comparison, CED 2021

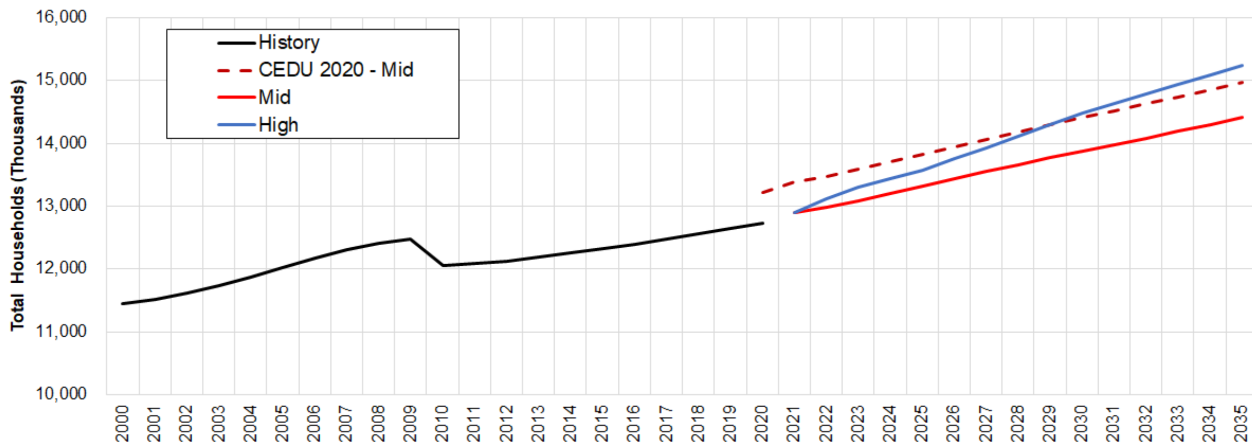


Source: CEC using data from DOF

4 Bailey, Stephanie, Nicholas Fugate, and Heidi Javanbakht. 2021. *Final 2020 Integrated Energy Policy Report Update, Volume III: California Energy Demand Forecast Update*. California Energy Commission. Publication Number: CEC-100-2020-001-V3-CMF.

The total household forecast is lower in CED 2021 than CEDU 2020, although the mid case growth rates are similar — 0.8 percent annually from 2021 to 2035. The new household forecast is driven by changes in the household formation rate, which is derived from underlying population segment forecasts — millennials reaching prime household formation years but being limited by affordability. As with population, inland regions of California are projected to see the highest levels of household growth. Figure 2 compares total household forecast for CED 2021 and CEDU 2020.

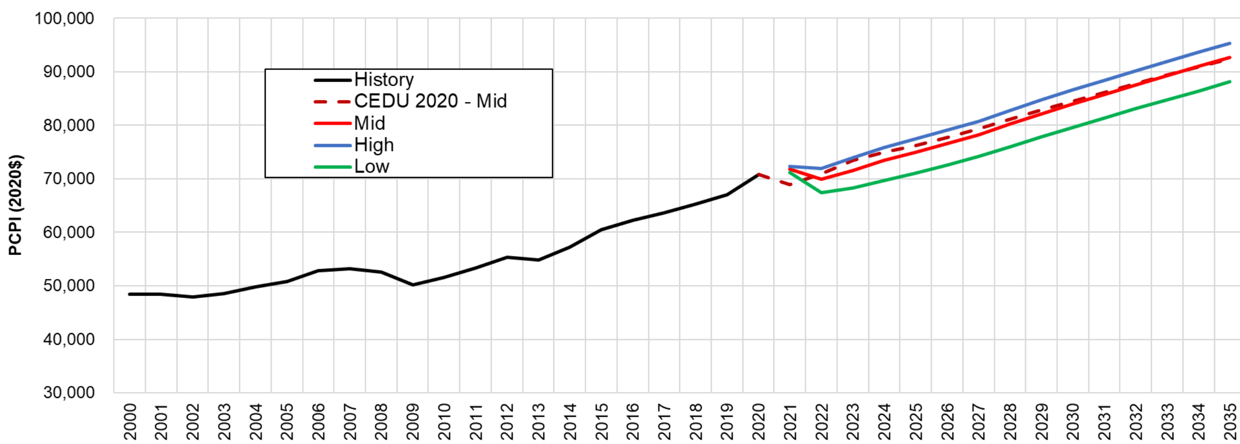
Figure 2: Statewide Total Household Comparison, CED 2021



Source: CEC using data from DOF

Figure 3 compares statewide per capita income scenarios against the mid-case scenario from CEDU 2020. Per capita income in 2020 was higher than expected due to the significant federal aid in the form of direct stimulus payments and enhanced unemployment benefits. All three demand scenarios show declines in per capita income for 2022 as this aid expires. The new mid case grows at 1.8 percent annually from 2021 to 2035, a small decrease compared to the CEDU 2020 growth rate of 2 percent over the same period. By 2035, both mid case projections reach similar levels.

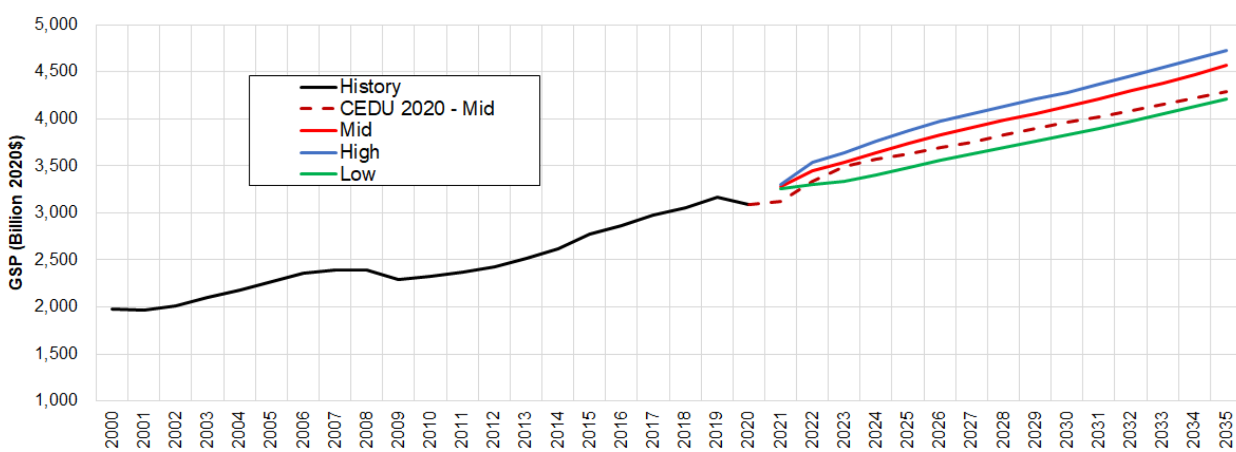
Figure 3: Statewide Per Capita Personal Income Comparison, CED 2021



Source: CEC using data from Moody's Analytics and DOF

Figure 4 compares gross state product scenarios with the mid case scenario from CEDU 2020. Gross state product expectations have increased as economic activity rebounded more quickly following the recession in 2020. The new mid case now grows similar to the previous mid case at 2.4 percent annually from 2021 to 2035 but remains higher than the previous forecast due to more optimistic growth through 2022.

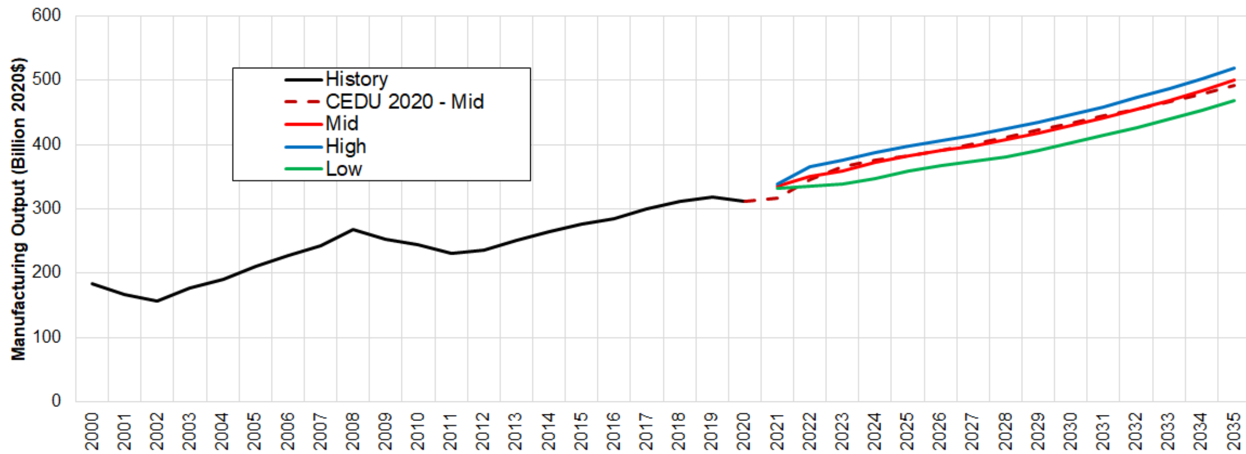
Figure 4: Gross State Product, CED 2021



Source: CEC using data from Moody's Analytics

Figure 5 compares statewide manufacturing output scenarios with the CEDU 2020 mid case. Following the pandemic-induced supply chain disruptions, the manufacturing sector is expected to benefit as businesses replenish depleted inventories. Although there are more optimistic expectations in the short term, long-term growth for 2021 to 2035 remains similar between the new mid case and the CEDU 2020 mid case — growing 3 percent annually.

Figure 5: Statewide Manufacturing Output, CED 2021

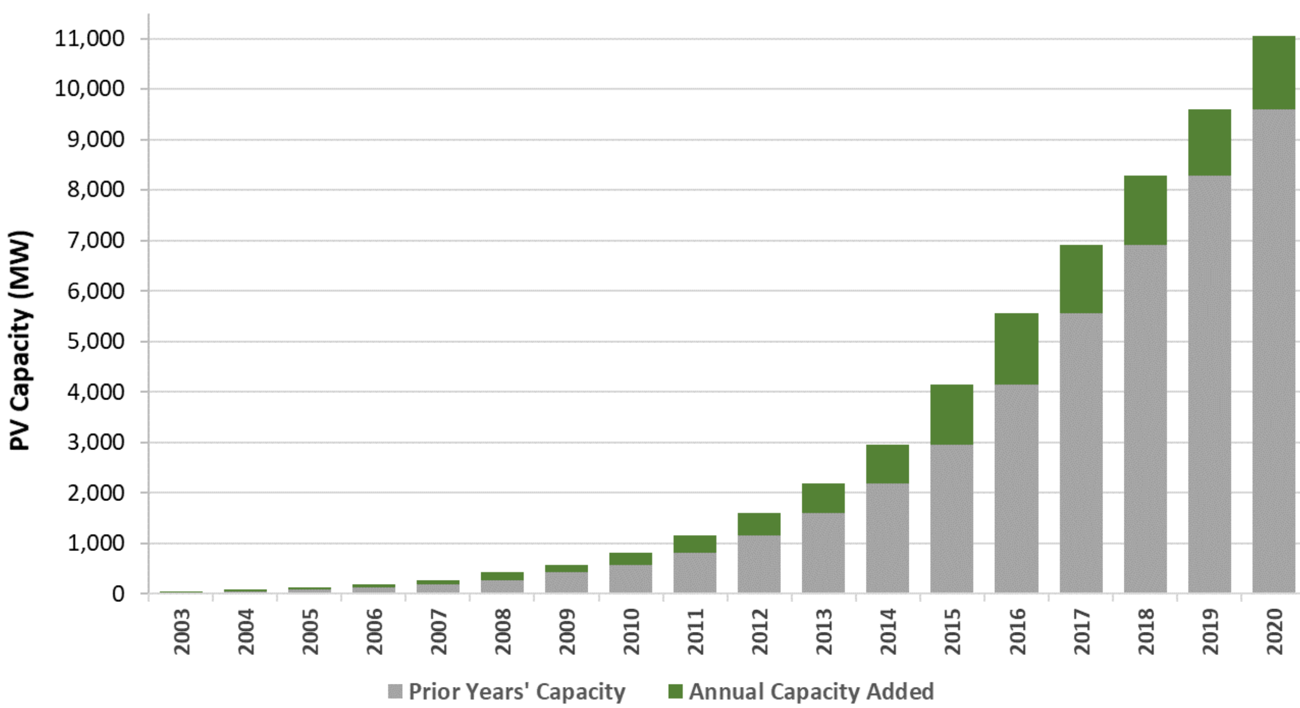


Source: CEC using data from Moody's Analytics

Behind-the-Meter Photovoltaic and Storage Trends

Since 2016, California has added about 1,300 to 1,400 megawatts (MW) of new BTM PV capacity annually. By the end of 2020, there was more than 11,000 MW of installed BTM PV capacity in California. The CEC estimates that more than 18,000 gigawatt-hours (GWh) of electricity was produced by BTM PV systems in 2020.

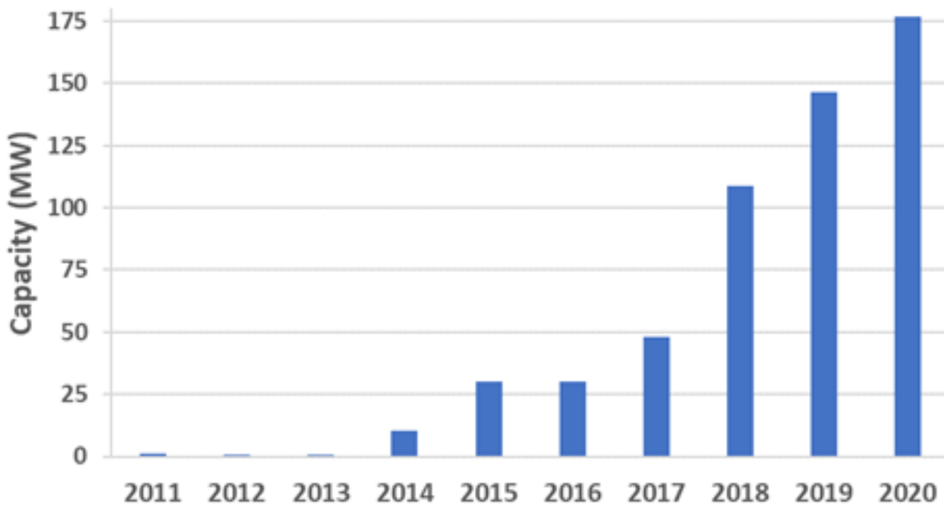
Figure 6: Total and Incremental BTM PV Capacity in California by Year



Source: CEC

BTM storage adoption in California continues to increase at a rapid pace. At the end of 2020, an estimated 550 MW of BTM energy storage was installed in California, with more than 75 percent of the capacity having been installed in the last three years.

Figure 7: Estimated BTM Storage Additions by Year



Source: CEC

Overview of CED Process and Methods

The CEC seeks input into its forecast development through various venues including public workshops. The IEPR workshop held February 2, 2021,[5] featured moderated panels of expert economists, demographers, and industry representatives responding to questions about California's economy, population characteristics, transportation trends, and business outlook. The perspectives presented informed the selection of a reasonable set of forecast inputs and assumptions, which staff then presented at another workshop August 5, 2021.[6] At workshops

5 February 2, 2021, IEPR workshop on California's Evolving Economic and Demographic Landscape (Session 1: California Economy Now and in the Future, https://www.energy.ca.gov/event/workshop/2021-02/session-1-california-economy-now-and-future-iepr-commissioner-workshop and Session 2: Transportation Future and California's Post Covid-19 Business Economy, https://www.energy.ca.gov/event/workshop/2021-02/session-2-transportation-future-and-californias-post-covid-19-business.)

6 August 5, 2021, IEPR workshop on California Energy Demand Forecast- Inputs and Assumptions (Session 1: 2021 Energy Demand Forecast Modeling Updates and Future Vision, https://www.energy.ca.gov/event/workshop/2021-08/session-1-commissioner-workshop-data-inputs-and-

on December 2, 2021, and December 16, 2021, staff presented draft results and sought additional stakeholder comments before the forecast was finalized and adopted in January 2022.

The CEC staff also convened meetings of the Demand Analysis Working Group (DAWG) to review proposed methodological updates. DAWG meetings covered topics related to the development of new AAEE and fuel substitution scenarios, transportation forecast inputs and assumptions, electric vehicle charging profiles, estimating PV and storage for new commercial buildings based on the new code requirements, rooftop PV generation profiles, and climate change and weather normalized peak loads.

Updates to the CED 2021 Forecast

Generally, the CED 2021 forecast employs the same models and methods used to develop the previous odd-year IEPR forecast (for the *2019 IEPR*). The same models are used to produce the electricity demand forecast and gas demand forecast. Demand for these two fuels is interdependent and using the same models for both ensures these forecasts are consistent and rely on the same inputs and assumptions.

Residential and commercial demand were forecast using a combination of econometric models and detailed *accounting* models that track stock and average energy use of specific appliance categories across different fuel types, building types, and climate zones. The industrial demand forecast is developed using econometric models that use past demand, gross state product, manufacturing output, and other key variables to predict demand for various types of business activities that comprise industrial demand. Gas demand for power plants comes from a separate process that uses production cost modeling to dispatch power plants and calculate the required amount of gas as discussed in the *2021 IEPR Volume III*.

This section summarizes some of the key updates that are new for CED 2021.

Climate Change and Weather-Normal Peak Loads

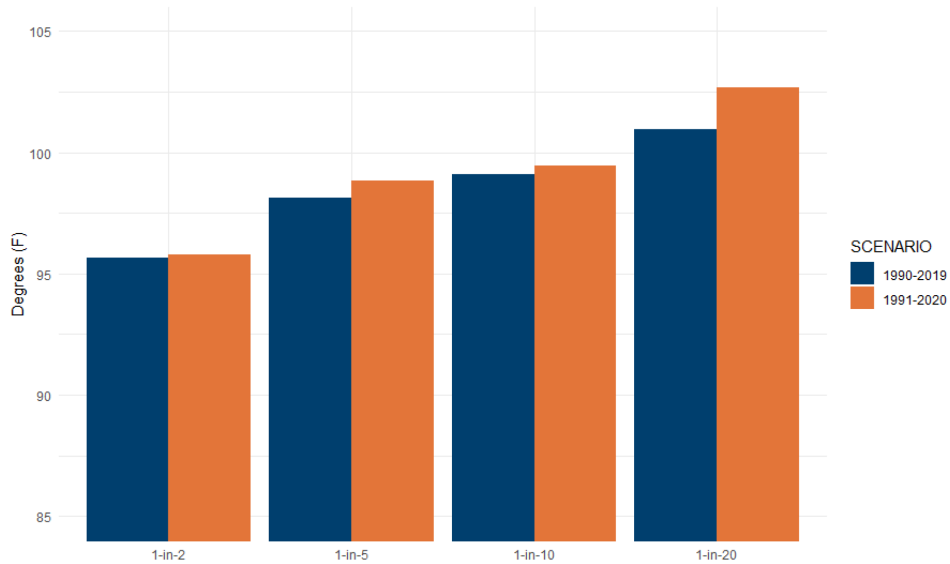
A critical and first step in developing the CEC's peak forecast is estimating *weather-normal* peak load to use as a starting point. The process involves analyzing recent historical data to establish a relationship between daily peak loads and daily maximum and minimum temperatures. That relationship is then applied to 30 years of historical weather data to simulate annual peak loads, creating a distribution from which the median value can be

assumptions-2021-iepr and Session 2: Forecast Modeling Inputs and Analysis, https://www.energy.ca.gov/event/workshop/2021-08/session-2-iepr-commissioner-workshop-accelerate-industrial-decarbonization.)

considered "weather normal." Similarly, the distribution can be used to estimate the relationship between normal peak loads and peaks that should be expected only once every 5, 10, or 20 years.

For the CED 2021, the 30-year historical window will include summers 2020 and 2021. A preliminary analysis of annual maximum temperatures indicates that the record-setting temperatures of summer 2020 are likely to influence weather variant peak estimates. Figure 8 illustrates how the addition of just one weather year to the historical data set — while doing little to influence the 1-in-2 maximum temperature — increases the 1-in-5 temperature and significantly increases the 1-in-20 temperature.

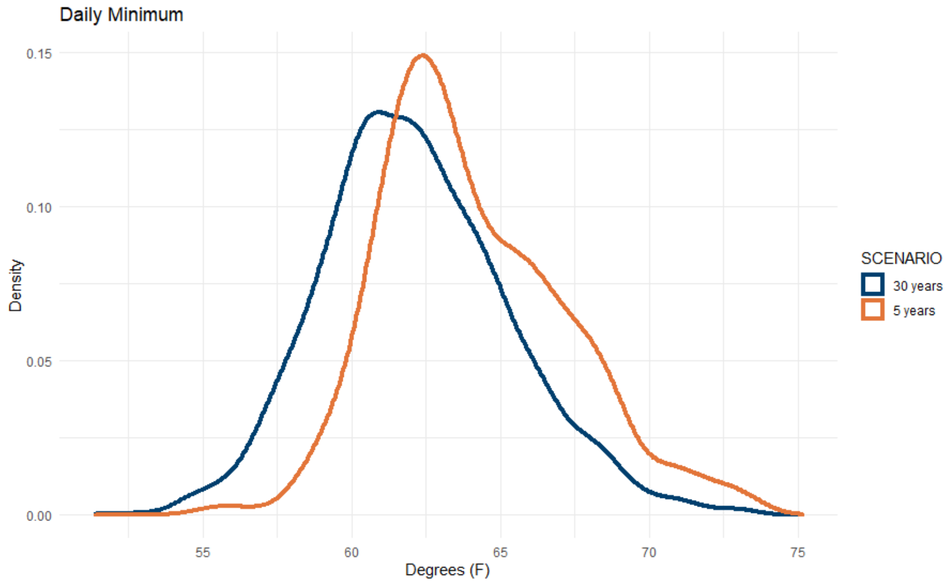
Figure 8: Hotter Maximum Temperatures Expected When Accounting for Most Recent Temperature Data (California ISO Weighted Average)



Source: CEC

At an IEPR workshop on August 5, 2021, CEC staff presented an analysis of recent weather trends which indicate that temperature distributions taken from a 30-year historical record — without adjustment — may not accurately reflect the current likelihood of observing a particular temperature. Figure 9 shows the density of a weighted average of daily minimum temperatures across the California ISO control area over two periods — the most recent five summers and the most recent 30 summers.

Figure 9: Warmer Daily Minimum Temperatures Expected When Accounting for Most Recent Temperature Data (California ISO Weighted Average)



Source: CEC

The figure illustrates a clear upward shift in the distribution of recent daily minimum temperatures relative to temperatures in the past 30 years. A similar but less pronounced shift can be seen with maximum temperatures. Both minimum and maximum temperatures are strong predictors of daily peak load. To the extent these shifts indicate the general warming trend predicted by climate models, the use of a full 30-year historical record may underestimate normal peak load conditions.[7] At a DAWG meeting on September 30, 2021, staff explored options for modifying its standard normalization approach to better account for these warming trends. Ultimately, staff settled on an approach which gives greater weight to more recent historical years.

Hourly Load Models

For planning areas within the California ISO control area, CED 2021 peak and hourly demand forecasts were developed using the CEC's top-down hourly load model (HLM). This model is estimated at the system level and driven primarily by growth in annual consumption. The key functionality of the HLM is that it allows for specific profiles for PV, electric vehicle charging, and other load modifying resources to be layered onto the baseline consumption profile,

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7 Climate model projections are available at the CEC-sponsored CalAdapt website, https://cal-adapt.org/.

ensuring that the resulting peak forecast accurately captures the contribution of these resources.

In 2019, ADM Associates, Inc. (ADM) completed an EPIC-funded project to develop load profiles for residential and commercial end uses, as well as whole-building profiles for other customer sectors, PV generation profiles, energy efficiency savings profiles, and electric vehicle charging profiles.[8] Also, ADM developed a software platform — HELM 2.0 — which will allow CEC staff to apply its detailed annual consumption forecast to these load profiles to produce peak forecasts which reflect sector specific growth rates and end-use compositions. While many of the specific profiles developed by ADM have been incorporated into the HLM, staff are seeking in future cycles to more fully integrate the HELM 2.0 model into the CEC's peak forecasting process. As an initial step, staff will consider benchmarking the HLM hourly forecast results to annual consumption peaks taken from HELM 2.0 results.

Behind-the-Meter Photovoltaics

The BTM PV forecast is updated annually to capture the latest market information, historical trends, economic and demographic forecasts, and policy changes related to PV adoption. As is the case with each new forecast, for CED 2021 the PV adoption models were updated with new electricity rate, housing addition, commercial account, and commercial floorspace projections. Historical PV interconnection data were also updated through December 2020. Staff also updated the residential PV model with the *2019 Residential Appliance Saturation Study* (RASS) data.[9] RASS provides information about residential electricity consumption, which is used to estimate average PV system size when forecasting PV adoption. Staff also incorporated compliance-based PV forecasts for new homes (based on Title 24 requirements) into the residential PV model. Previously, the PV forecast for new homes was completed separately from the PV model, which led to double counting of existing homes available for PV adoption.

For CED 2021, staff also updated the PV models to reflect important policy changes taking shape since the completion of last year's forecast, including an extension of federal tax

8 California Investor-Owned Utility Electricity Load Shapes website, https://www.energy.ca.gov/publications/2019/california-investor-owned-utility-electricity-load-shapes.

9 The California RASS collects information from residents about appliance, heating and cooling equipment, and energy, and is a comprehensive look at residential energy use. The 2019 RASS results can be found at www.energy.ca.gov/publications/2021/2019-california-residential-appliance-saturation-study-rass. In CEDU 2020, the PV forecast used data from the 2009 RASS.

incentives,[10] the Commercial Building Code adopted in August 2021,[11] and proposed changes to California's net energy metering[12] (NEM) policy consistent with the requirements of California Assembly Bill 327 (Perea, Chapter 611, Statutes of 2013).[13] CEC staff has modeled a hypothetical NEM 2.0 successor tariff in the PV forecast since 2015. In particular, the high demand (low PV adoption) case modeled a successor tariff having a $3/kilowatt (kW) monthly capacity (or grid) charge, a fixed $0.10/kilowatt-hour (kWh) compensation for any export by the customer-generator, and monthly true-ups. The high demand case tried to capture a more aggressive reform to NEM that might be proposed by utilities to reform NEM to address a perceived shift in cost from customers with PV to customers without PV.[14] Since the CPUC has opened a proceeding for a NEM 2.0 successor (or Net Billing Tariff) in the last year[15] and received proposals from stakeholders, CEC staff has updated the high demand case to reflect the joint investor-owned utility (IOU) NEM 3.0 proposal.[16] The proposed decision was released December 18, 2021, which was too late in the process to be assessed for the forecast.[17] A final decision on the Net Billing Tariff is not expected until after the completion of CED 2021 and will be incorporated into the *2022 IEPR Update* forecast.

10 The Federal Investment Tax Credit for PV and storage systems was scheduled to expire after 2021 for residential systems and decrease to 10 percent for commercial systems. In December 2020, the United States Congress extended these tax credits for an additional two years, so that the expiration for residential systems, and the decrease to 10 percent for commercial systems do not occur until after 2023.

11 The 2022 Building Energy Efficiency Standards adopted in August 2021 and effective starting January 2023 require new construction commercial buildings to install PV and battery storage. https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2022-building-energy-efficiency.

12 *Net energy metering* is a billing arrangement that provides credits to BTM PV customers who export excess electricity to the utility. The credits can be used to pay for electricity drawn from the utility.

13 The state last changed NEM policy in 2016, when the CPUC instituted modest reforms to the original NEM. However, the CPUC deferred on additional changes and retained the full retail rate compensation for exported electricity.

14 NEM 2.0's cost shift was substantiated and documented in Verdant Associates, LLC report *The NEM 2.0 Lookback Study*. https://www.cpuc.ca.gov/industries-and-topics/electrical-energy/demand-side-management/net-energy-metering/net-energy-meeting-nem-2-evaluation.

15 CPUC Net Energy Metering Rulemaking (R.) 20-08-020 webpage, https://www.cpuc.ca.gov/nemrevisit.

16 Joint Proposal of Pacific Gas and Electric Company, San Diego Gas & Electric Company and Southern California Edison Company, March 15, 2021, https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M371/K711/371711892.PDF.

17 CPUC. December 18, 2021. Proposed Decision for ALJ Hymes Rulemaking 20-08-020. https://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M430/K903/430903088.PDF.

The updates to the different components of the PV forecast were discussed with stakeholders during a DAWG meeting September 30, 2021, and more details can be found in the posted slide decks.[18]

California Energy Demand Baseline Forecast, 2020–2035

CEC staff presented draft forecast results at an IEPR workshop on December 16, 2021.[19] After considering public comments, staff developed a final set of forecast updates that was adopted by the CEC at its business meeting in January 2022.

Electricity Consumption, Sales, and Peak Demand

Statewide electricity consumption is estimated to have been more than 279,000 GWh in 2020. The CED 2021 sales forecast represents the amount of electricity load-serving entities will need to provide to their customers and is derived by subtracting projected customer generation from the updated consumption forecast. Statewide sales were more than 240,000 GWh in 2020, which was 3 percent higher than the 2020 CEDU forecast. The peak demand forecast is derived from the annual consumption forecast by applying hourly load profiles to projected annual consumption. In 2020, the hourly net peak demand for the California ISO system was just under 47,000 MW which was 2.6 percent higher than the 2020 CEDU 1-in-2 coincident net peak forecast.

From 2020 to 2021, the mid baseline electricity consumption case declines 0.5 percent reflecting weak employment growth and a slight decline in residential consumption from the pandemic-driven record high experienced in 2020. From this point, the mid electricity demand case grows at a rate of about 1.6 percent annually through 2035 as the economy recovers and transportation electrification adds to load. By 2030, mid-case consumption is 2.3 percent higher than the CEDU 2020 mid case and reaches 340,000 GWh by 2035.

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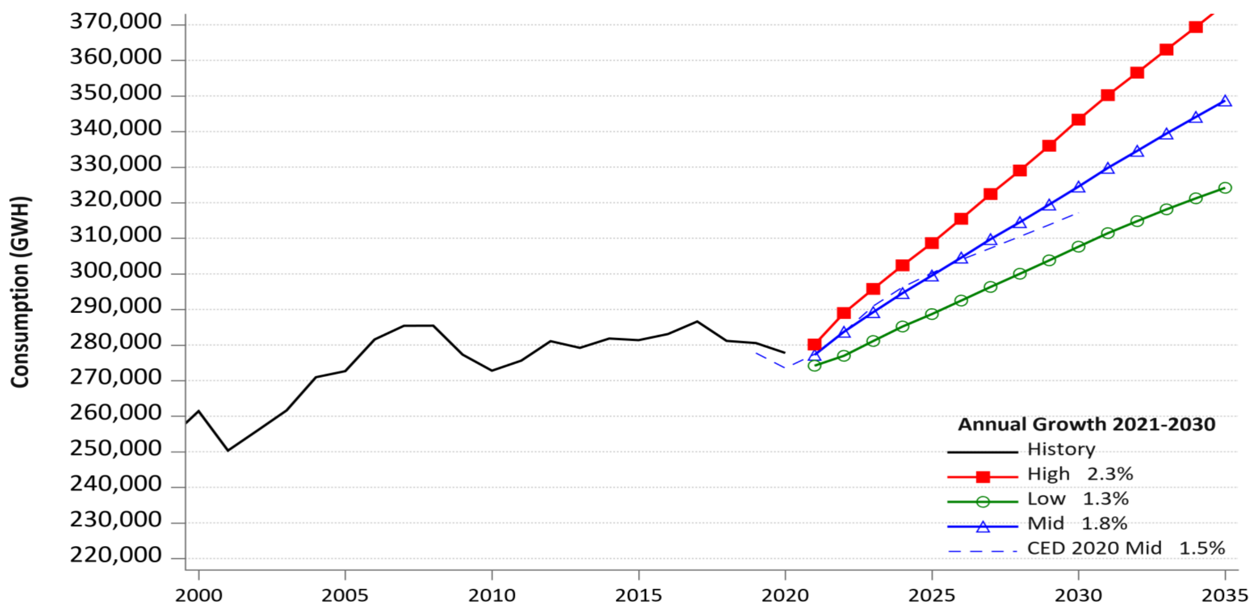
18 Documents from the September 30, 2021, DAWG meeting are available at https://www.energy.ca.gov/event/meeting/2021-09/demand-analysis-working-group-dawg-meeting-proposed-updates-california-energy.

19 Documents from the December 16, 2021, workshop notice are available on the *2021 IEPR* Workshops, Notices, and Documents webpage, https://www.energy.ca.gov/data-reports/reports/integrated-energy-policy-report/2021-integrated-energy-policy-report/2021-iepr.

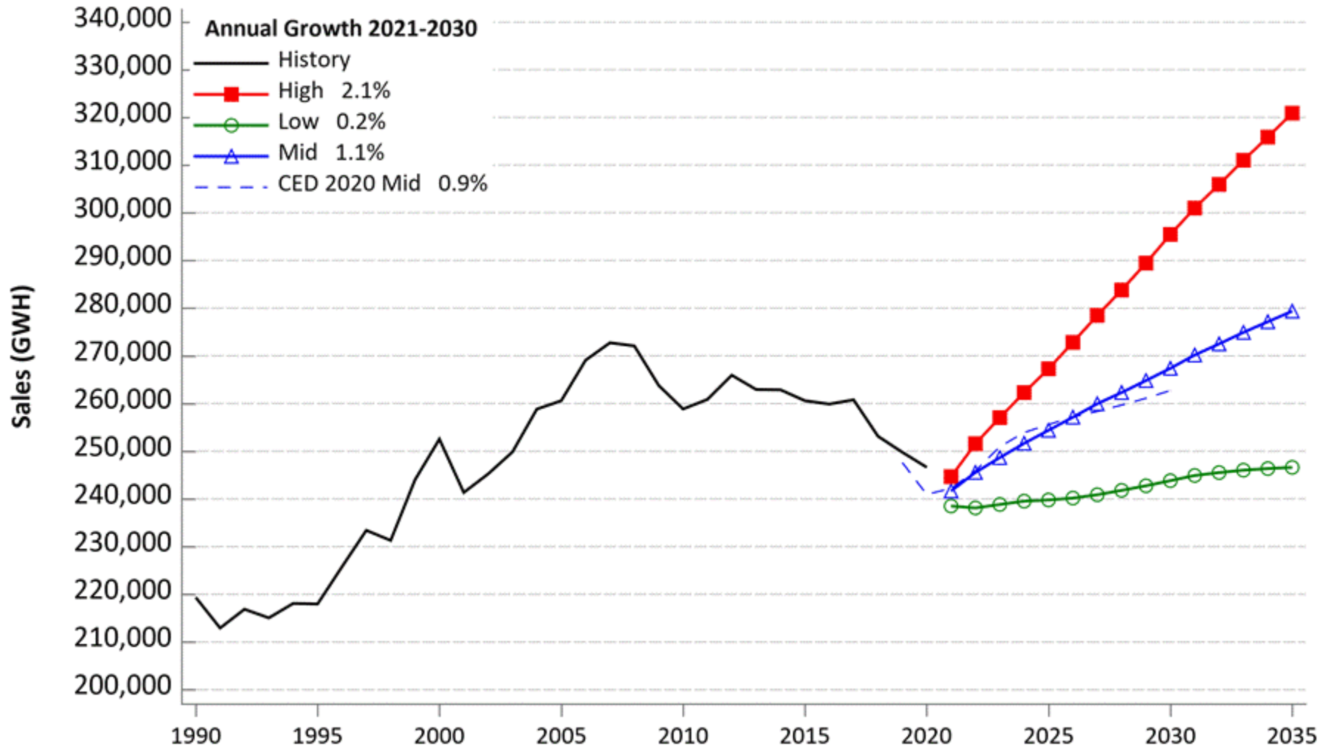
Figure 10: Baseline Electricity Consumption (Statewide)



Source: CEC

The CED 2021 sales forecast represents the amount of electricity load-serving entities will need to provide to their customers and is derived by subtracting projected customer generation from the consumption forecast. As such, the statewide sales forecast reflects many of the same characteristics as the consumption forecast, but the substantial amounts of incremental PV generation (discussed in a later section) added each year reduce annual growth relative to consumption. In 2021, the minimal increase in consumption is more than offset by the increase in self-generation, causing sales to decrease by 2 percent. Between 2021 and 2035, annual growth in the mid baseline case averages about 1 percent. By 2030, mid-case sales are 1.1 percent higher than the CEDU 2020 mid case and by 2035 reach almost 280,000 GWh.

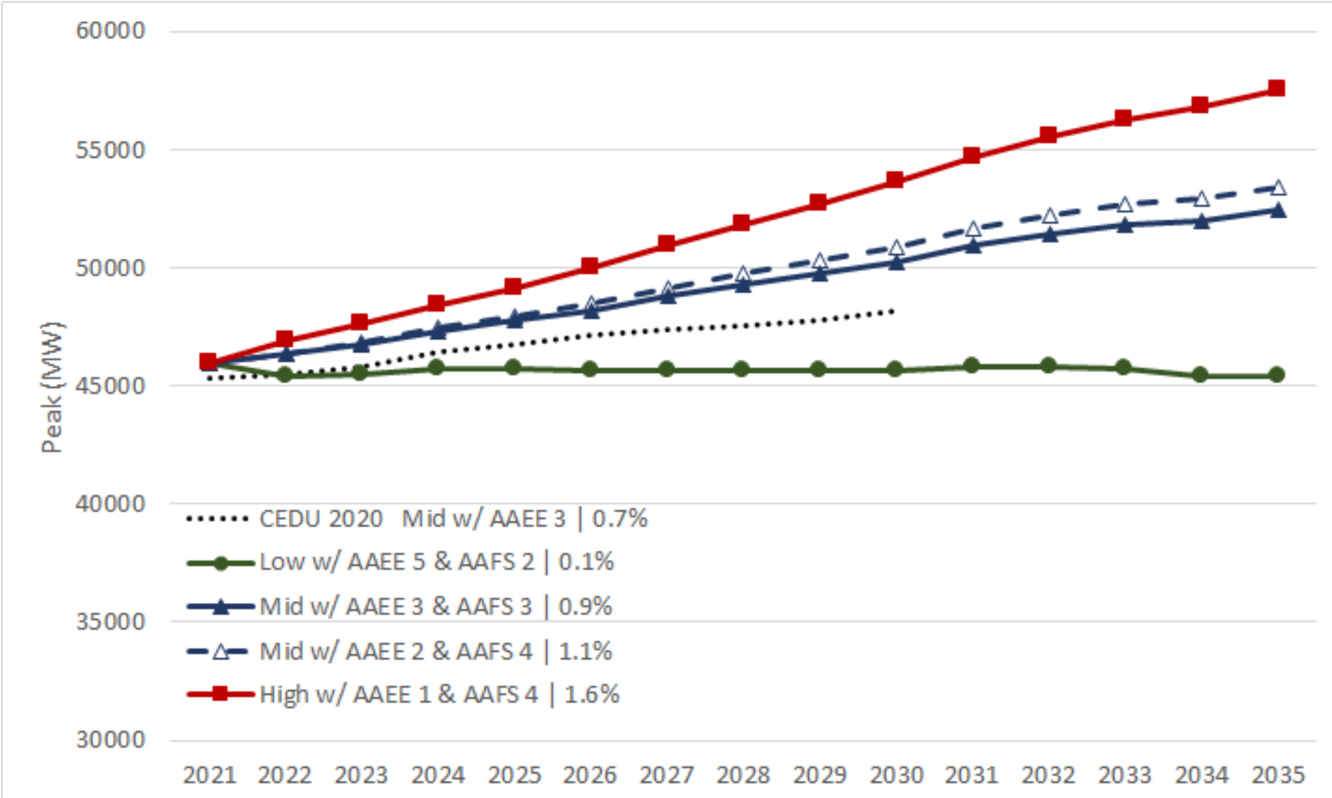
Figure 11: Baseline Electricity Sales (Statewide)



Source: CEC

The peak demand forecast update is derived from the annual consumption forecast — by applying hourly system load profiles to projected annual consumption. CEC staff benchmark the peak forecast to weather-normalized peaks from the most recent historical year — from summer 2021, in this case. The baseline peak forecast updates can be combined with the AAEE scenarios to create managed forecasts for use in planning studies. The CED 2021 mid baseline forecast, combined with the AAEE Scenario 3 and AAFS Scenario 3, creates a managed peak forecast for the California ISO control area that grows at a rate of 0.9 percent annually, reaching 52,437 MW by 2035. By 2030, this managed forecast is 4.3 percent higher than projected by CEDU 2020. The increase can be attributed to a higher weather-normal base-year peak, a higher growth in the baseline consumption forecast, lower AAEE impacts, and the addition of fuel substitution. Additional details regarding AAEE and AAFS scenarios can be found in Chapter 2 of this volume.

Figure 12: Managed System Peak Demand (California ISO)



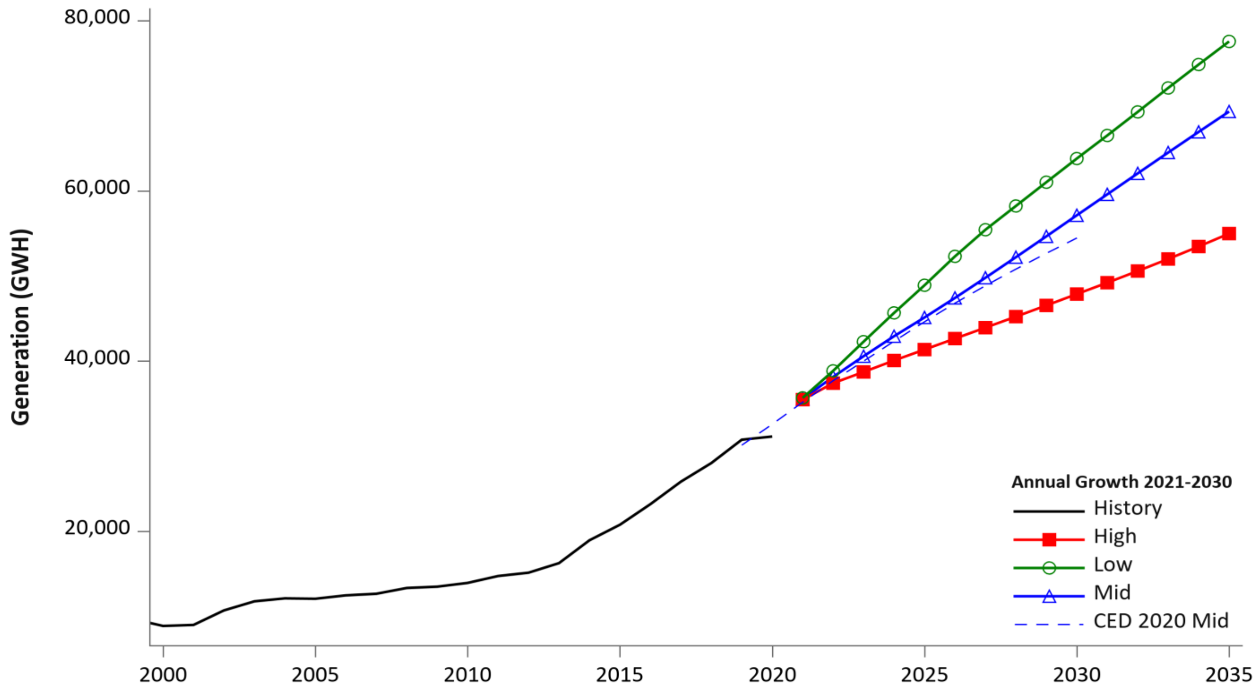
Source: CEC

Self-Generation and Storage

Adoption of BTM PV and energy storage systems is a key consideration in deriving retail sales from end-user consumption and analyzing the timing and magnitude of system peaks.

The CEC presented new forecasts at the December 16, 2021, IEPR workshop. The forecast of statewide BTM PV generation for the three CED 2021 baseline demand cases, as well as the CEDU 2020 mid case, are shown in the figure below. In the mid case, self-generation grows at almost 5 percent annually. By 2035, the CED 2021 forecast projects generation from PV to reach about 55,000 GWh, 67,000 GWh, and 78,000 GWh in the high, mid, and low electricity demand cases, respectively.

Figure 13: Estimated Statewide Behind-the-Meter Generation



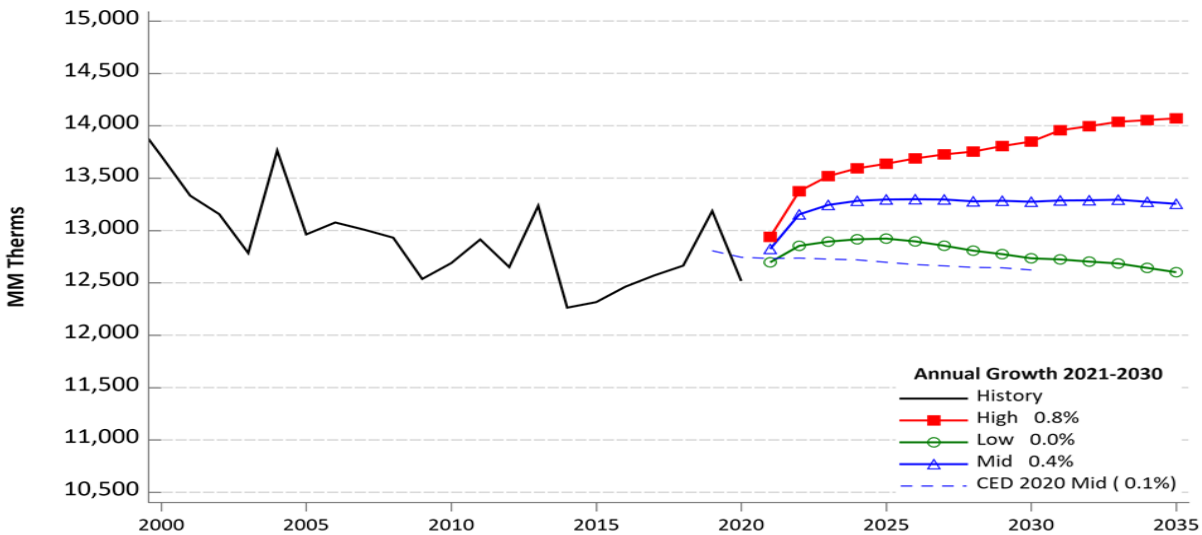
Source: CEC

The forecast of statewide BTM energy storage for the three CED 2021 baseline demand cases, as well as the CEDU 2020 mid case, are shown in the figure below. By 2035, the CED 2021 forecast projects BTM energy storage capacity to reach about 34,000 MW, 42,900 MW, and 48,200 MW in the high, mid, and low electricity demand cases, respectively.

Statewide End-User Pipeline Gas Consumption

Figure 14 shows the statewide end user pipeline gas consumption demand for the three CED 2021 cases. Note that this excludes gas used for electricity generation, which is covered in Volume III of the *2021 IEPR*. In the mid scenario, consumption increases 2.5 percent annually between 2020 and 2022, reflecting economic recovery and an adjustment for mild weather in 2020. After that growth in consumption is negligible. By 2035, statewide end-user gas consumption in the mid case is unchanged at 13,254 million therms.

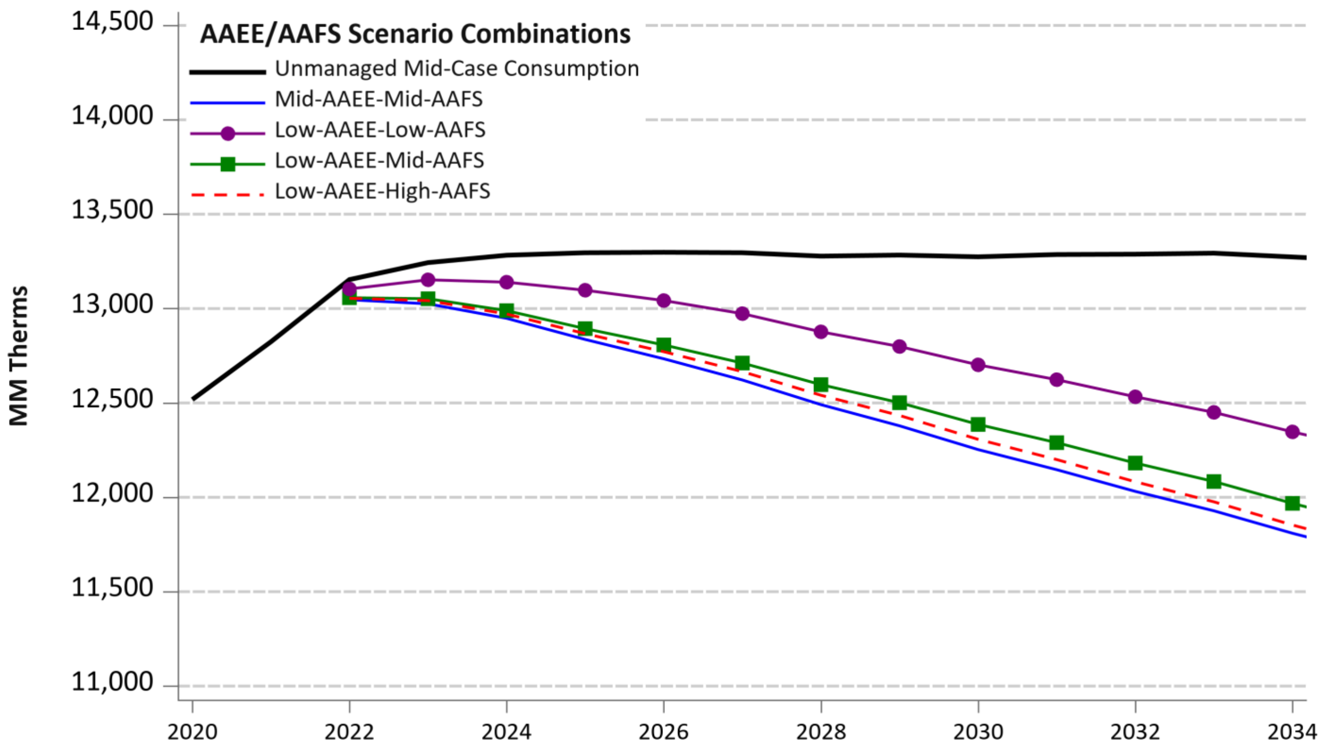
Figure 14: Statewide End-User Pipeline Gas Consumption



Source: CEC

Figure 15 shows the baseline mid-case natural gas consumption scenario combined with the AAEE and AAFS scenarios discussed elsewhere. In the mid-mid scenario used for system planning, pipeline gas consumption is reduced by almost 12 percent by 2035. In the low AAEE-low AAFS scenario, consumption is reduced by 8 percent.

Figure 15: Statewide Managed Pipeline Gas Scenarios



Source: CEC

To plan for meeting the state's decarbonization goals, additional analyses for the gas forecast are needed to assess the impacts of decreasing pipeline gas usage. Staff is exploring available gas data to develop a methodology to forecast monthly demand and peak-day pipeline gas demand for future IEPRs. This method is discussed further below and will be presented for feedback at stakeholder meetings in 2022.

Choice of Single Managed Forecast Set for Planning Purposes

The three baseline demand cases, when combined with six AAEE savings scenarios and five AAFS scenarios developed and adopted as part of this IEPR, create managed forecasts that constitute options for a "single forecast set" to be used for planning purposes in CEC, CPUC, and California ISO (the Joint Agencies and California ISO) proceedings. With guidance from leadership at each organization, the lead staff of the Joint Agencies and California ISO guiding the processes listed below have agreed that specific elements of this forecast set will be used for planning and procurement in the California ISO's TPP and the CPUC's IRP, resource adequacy, and other planning processes as outlined below. The details of this agreement will be adapted through time as the needs of planning and procurement evolve.

The term "single forecast set" is intended to clarify that what has commonly been called a "single forecast" is not a single number, but actually a set of forecast numbers adopted as part of the IEPR. This includes six managed forecast scenarios which combine baseline forecasts using alternative weather variants, AAEE and AAFS scenarios, and hourly load forecasts for transmission access charge (TAC) areas.[20] Agreement on a single forecast set includes specification on the use for each component of the set.

The single forecast set consists of three components of the IEPR demand forecast:

- Three baseline scenarios of annual energy and peak demand, each with three peak event weather variants (for example, 1-in-2, 1-in-5, and 1-in-10).
- Three scenarios of hourly loads for baseline forecasts for each of three IOU TAC areas.
- Six scenarios of AAEE described by annual energy and hourly load impacts.
- Five scenarios of AAFS described by annual energy and hourly load impacts.

20 A TAC area denotes a portion of the California ISO balancing authority area that has been placed in the California ISO's operational control through an agreement with an electric utility or other entity operating a transmission system component. A TAC area typically consists of an IOU and multiple publicly owned utilities using the transmission system owned by the IOU.

The combination of a CED 2021 baseline forecast using a specific weather variant plus an AAEE and AAFS scenario depends on their use. The selected CED 2021 baseline case will be the "mid demand" case for the combined IOU service areas that comprise the California ISO balancing area. The mid demand case includes variants for different weather conditions. The practices and procedures used in local capacity studies address uncertainty about the location-specific impacts of various assumptions by systematically using adverse assumptions about weather-induced peak load, and conservative load modifiers to base loads. For energy efficiency savings, this has meant using the Mid-Mid Low AAEE scenario rather than the Mid-Mid scenario used in most planning studies. With the introduction of fuel substitution load modifiers, the corresponding practice would be to increase speculative fuel substitution impacts. This means that for local capacity studies the California ISO should use the mid demand forecast, the Mid-Mid Low AAEE scenario savings, and the Mid-Mid Plus AAFS scenario impacts.

To account for unforeseen uncertainties, variations of IEPR CED outputs that diverge from the single forecast set may be used in CPUC IRP modeling under specific circumstances with consensus from joint agency and California ISO leadership.[21] However, lead CPUC staff agrees to ensure that adopted IRP portfolios will not deviate from the single forecast set.

The following list describes[22] the current agreement among the lead staff of the Joint Agencies and California ISO:

- CPUC IRP Reference System Plan, Preferred System Plan, and California ISO economic studies[23]
    - Baseline mid-case annual energy and annual peak demand

21 In 2021, CPUC staff approached leadership of the Joint Agencies and California ISO about using the CEC's high zero-emission vehicle forecast for the 2021 IRP Preferred System Plan. Leadership concluded that using the high-case was prudent given recent policy and market conditions that are increasingly favorable towards zero-emission vehicles, such as electric vehicles.

22 To avoid misunderstandings, the following defines the meaning of colloquial terms used to describe load modifier elements:

- "Mid-mid" means Scenario 3 when describing AAEE or AAFS load modifiers applied to the "mid" baseline forecast;
- "Mid-low" means Scenario 2 when describing the AAEE load modifier applied to the "mid" baseline forecast; and
- "Mid-mid plus" means Scenario 4 when describing the AAFS load modifier applied to the "mid" baseline forecast.

23 In consultation with the CEC and California ISO, the CPUC may authorize procurement using an alternative weather variant.

    - AAEE mid-mid scenario annual energy and peak demand
    - AAFS mid-mid scenario annual energy and peak demand
    - 1-year-in-2 peak event weather conditions
- California ISO TPP policy studies and bulk system studies:
    - Baseline mid-case annual energy and annual peak demand
    - AAEE mid-mid scenario annual energy and peak demand
    - AAFS mid-mid scenario annual energy and peak demand
    - 1-year-in-5 peak event weather conditions
    - Mid-mid hourly loads
    - CEC staff allocations of AAEE and AAFS to load busses used in transmission studies
- California ISO TPP and resource adequacy local capacity studies:
    - Baseline mid-case annual energy and annual peak demand
    - AAEE mid-low scenario annual energy and peak demand
    - AAFS mid-mid plus scenario annual energy and peak demand
    - 1-year-in-10 peak event weather conditions
    - CEC staff allocations of AAEE and AAFS to load busses used in transmission studies
- California ISO Maximum Import Capability allocation for CPUC's system resource adequacy requirements for load-serving entities (LSEs)
    - Baseline mid-case monthly peak demand derived from the mid-mid managed demand forecast case of hourly loads
- CPUC resource adequacy LSE system requirements[24]
    - Baseline mid-case monthly peak demand derived from mid-case hourly loads
    - AAEE mid-mid annual and monthly peak demand
    - AAFS mid-mid annual and monthly peak demand
    - 1-year-in-2 peak event weather conditions

24 In consultation with the CEC and California ISO, the CPUC may authorize procurement using an alternative weather variant.

- CPUC IOU distribution planning requirements
  - Baseline peak demand (also known as the IEPR demand forecast) and AAEE and AAFS scenarios (also known as "distributed energy resource growth forecasts")
  - Weather variants and AAEE and AAFS scenario variants may differ by IOU as per CPUC D. 18-02-004[25]
- California ISO flexible capacity studies for resource adequacy:[26]
  - Baseline mid-case hourly loads by California ISO area
  - AAEE mid-mid scenario hourly loads by California ISO area
  - AAFS mid-mid scenario hourly loads by California ISO area
  - 1-year-in-2 peak event weather conditions

Lead staff of the Joint Agencies and California ISO have developed a process by which the CPUC or California ISO can make a formal request to the CEC for a desired demand forecast variant or combination which is not yet produced. If the CEC does not have the resources to develop such a variant, then lead staff from the requesting agency may consider deviating from this agreement to independently develop and use such a variant for the period until the CEC is able to develop it. Such requests should also be made and approved using appropriate procedures of the requesting agency to ensure all interested stakeholders are aware of such a deviation.

Future Work

It is critical that California's energy forecasting and planning continue to evolve and improve to keep pace with the changing dynamics of the energy sector. Staff plans to expand and update the forecast to improve how climate change is incorporated and forecast fuel switching driven by the state's decarbonization goals. Reliability concerns related to recent extreme heat, drought, and wildfires across western states have elevated the need to address climate change

25 Pursuant to a May 11, 2020, CPUC Distribution Resources Plan Ruling (R.14-08-013), the same IEPR datasets are used by each IOU. The IOUs meet and confer to establish which IEPR datasets to use and present a listing of the selected datasets to CPUC staff for approval. In all cases, IEPR datasets are used where feasible for disaggregation and forecasting, and the IOUs clearly state in their filings which datasets were used.

26 The methodology for assessing flexible capacity utilizing the hourly CEC Forecast was first used for flexible capacity resource adequacy planning for year 2020, and the Joint Agencies and California ISO are collaborating to evaluate this use case into the overall CEC demand forecasting workflow and the California ISO's flexible capacity projection methodology. The Joint Agencies and California ISO are actively working to evaluate and potentially modify the flexible capacity analysis going forward. Until finalization of evaluation and potential changes are made, the California ISO will continue to use the CEC's hourly forecast.

more comprehensively within energy planning in general and the CEC's demand forecast in particular. While the forecast currently provides peak demand projections for a broad range of weather scenarios, analytical improvements and new forecasting products are being developed to maintain grid reliability as the state progresses toward its decarbonization goals.

Replacing gas equipment with electric equipment will be required to meet the state's decarbonization goals. Currently, the same models used to forecast electricity in each sector are also used to forecast gas demand, as it is important that these forecasts are consistent. For the *2021 IEPR*, additional achievable fuel substitution (AAFS) analyses are conducted for the first time, and the results are discussed in Chapter 2. Fuel substitution will increase demand for electricity and decrease demand for pipeline gas, adding reliability concerns for both fuels. To better inform gas reliability assessments, staff plans to expand analyses conducted under the gas forecast, discussed more below.

Climate Change and Summer Reliability Assessments

The *2021 IEPR* forecast includes estimated load impacts due to climate change based on projected increases in average temperatures developed for the CEC by the Scripps Institute of Oceanography. The climate models that the Scripps Institute uses to predict increasing average temperatures can also be used to predict increasing frequency of extreme heat events.[27] Staff is tracking CEC-sponsored energy-related climate assessments that are slated to begin producing data sets in the second quarter of 2022 and is planning uses of these data once available. In future IEPR cycles, staff will explore ways such data can inform the CEC's forecasts of peak load under critical planning contingencies — such as the type of extreme weather that should be expected once every 10 years.

The CEC produces 1-in-2 peak and hourly load forecasts for the California ISO region. However, the CPUC's Integrated Resource Plan and the CEC's summer reliability assessments require distributions of hourly system loads for all balancing authorities in California corresponding to different weather patterns. Staff plans to develop such profiles, correlating weather-sensitive loads and modifiers such as efficiency impacts, fuel-substitution impacts, water pumping load, PV, and behind-the-meter generation for each specific weather pattern.

Gas Forecast Improvements and Expansion

California seeks to reduce GHG emissions by 80 percent below 1990 levels by 2050. To reach this goal, residential and commercial buildings will electrify where feasible, and so the state

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27 Cal Adapt web page. "Extreme Heat Days and Warm Nights." Accessed December 15, 2020. https://cal-adapt.org/tools/extreme-heat/.

must plan for optimizing gas use on the state's gas system. Staff is expanding the gas demand forecast to support long-term planning and decision-making. The CEC worked with a panel of expert modelers to identify improvements or expansions to the gas forecast.[28] The identified improvements and expansions included:

- Reporting as a specific category the gas delivered by interstate pipelines directly to end users in California.[29]
- Developing an approach for forecasting daily peak gas demand under different weather conditions (for example, 1-in-10, 1-in-35) to assess CPUC reliability standards.
- Enhancing understanding of industrial uses of gas and other end uses that cannot electrify.
- Analyzing climate change impacts on occurrence of extreme events (for example, polar vortex).

These end-use forecast expansions will be presented for feedback at stakeholder meetings in 2022. These are also discussed in the context of the overall gas system planning in Volume III of the *2021 IEPR*.

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28 These experts included Dr. Hilliard Huntington of the Stanford Modeling Forum; Dr. Max Auffhammer of U.C. Berkeley; Dr. James McMahon of Lawrence Berkeley National Laboratory (LBNL), who managed demand forecasting programs at the U.S. Department of Energy; and Dr. Alan Sanstad, also affiliated with LBNL. The panel has advised staff on several forecast-related matters over the last 10-plus years.

29 This pertains to the "Mining" category that is primarily gas delivered by Kern River Gas Transmission directly to end users and is not demand served by either of California's large investor-owned gas utilities. Moreover, the name "Mining" derives from the associated North American Industry Classification System (NAICS) code and does not align with the sectors used by gas utilities.

CHAPTER 2: Additional Achievable Energy Efficiency and Fuel Substitution

This chapter discusses additional achievable energy efficiency (AAEE) and additional achievable fuel substitution (AAFS). As described in Chapter 1, AAEE is the incremental energy savings from market potential that is not included in the baseline demand forecast but is reasonably expected to occur. These savings include many future updates of building standards, appliance regulations, and new or expanded energy efficiency programs. AAEE is central to developing a managed demand forecast, which, in turn, is the basis for resource planning and procurement efforts at the California Public Utilities Commission (CPUC) and the California Independent System Operator (California ISO). AAFS is a new annual and hourly load modifier to the baseline demand forecast in a manner analogous to AAEE. Fuel substitution refers to substitution of one end use fuel type for another, such as changing out gas end-use appliances in buildings for cleaner more efficient electric end uses. A detailed description of the analytical methods for the various components to AAEE and AAFS can be found in Appendix A.

Senate Bill 350 (De León, Chapter 547, Statutes of 2015) directed the California Energy Commission (CEC) to establish annual targets to double statewide energy efficiency savings in electricity and gas by the beginning of 2030.[30] The basis of this doubling is the mid-case estimate of AAEE savings in the California Energy Demand Updated Forecast from 2015 to 2025, extended to 2030. A constraint is that the doubling must be cost-effective, be feasible, and will not adversely impact public health and safety. Updated SB 350 projections are discussed in Volume I of the *2021 Integrated Energy Policy Report* (*2021 IEPR*).

Development of a portfolio of AAEE scenarios is the mechanism for capturing current reasonably expected savings from programs developed in support of several goals and standards. These savings projections include programs developed to support SB 350 aspirational goals, California Building Standards (Title 24), California (Title 20) and Federal Appliance Standards, and potential program savings projected by investor-owned utilities (IOUs) and publicly owned utilities (POUs). As in the previous *2019 California Energy Demand*

30 Senate Bill 350 (De León, Chapter 547, Statutes of 2015), https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB350.

Forecast (2019 CED), scenario design condenses forecast uncertainties into six scenarios ranging from conservative to optimistic. Since the CEC has explicit agreements with other agencies that plan on using specific AAEE scenarios in various resource planning and transmission planning studies,[31] staff rigorously vets scenario design with stakeholders throughout a multistep process.

AAEE Forecast Improvements and 2021 Overview

Improvements to highlight for the 2022–2035 AAEE forecast include:

- A more robust analysis of *beyond utility* programs (programs not run by IOUs or POUs or not reported by them) that were originally evaluated in the *2017 IEPR*,[32] as well as consideration of additional programs not included in the *2019 IEPR*.
- Further analysis performed on data obtained from the updated POU potential savings derived from the California Municipal Utilities Association's (CMUA's) *2020 Energy Efficiency Potential Forecast*.[33]
- Enhancement of software tools to aggregate savings streams to allow for extrapolation of potential savings to midcentury.

Different from the *2019 IEPR* cycle, the 2021 AAEE scenarios focus on the variability of potential energy efficiency savings, and each is defined by the mid-demand case. Thus, the 2021 AAEE scenarios all share the same assumptions for building stock and retail rates. Staff included a range of three reasonably expected scenarios, one more conservative and one more aggressive than the business-as-usual (BAU) forecast. Also, staff considered a very conservative savings scenario (Scenario 1) and two more optimistic high energy efficiency savings scenarios (Scenarios 5 and 6). The most optimistic AAEE scenarios maximize the impacts of any existing programs and include potential achievable savings not expected from existing programs or standards. These energy efficiency savings are more speculative, but they may be realized through current and new programs.

The six AAEE savings scenarios are defined as follows:

- Scenario 1: Mid Demand-Very Low AAEE Savings (mid-very low)

31 The single forecast set agreement is listed in its entirety in Chapter 1 of this document.

32 CEC staff. 2017. *2017 Integrated Energy Policy Report*. California Energy Commission. Publication Number: CEC-100-2017-001-CMF. pp. 54–58. https://efiling.energy.ca.gov/getdocument.aspx?tn=223205.

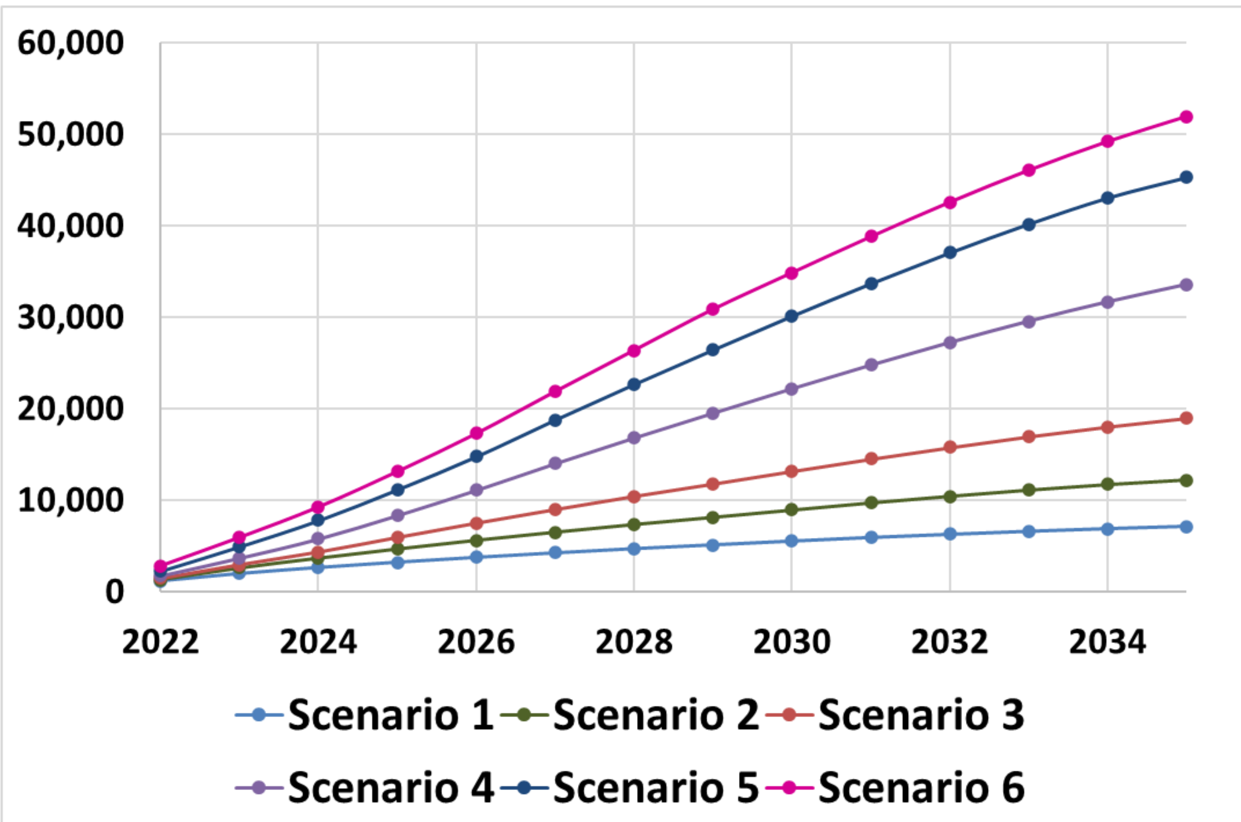
33 GDS Associates, Inc. April 2021. *2020 Energy Efficiency Potential Forecast*. CMUA. https://www.glendaleca.gov/home/showdocument?id=63721&t=637661956279678151.

- Scenario 2: Mid Demand-Low AAEE Savings (mid-low)
- Scenario 3: Mid Demand-Mid AAEE Savings (mid-mid)
- Scenario 4: Mid Demand-High AAEE Savings (mid-high)
- Scenario 5: Mid Demand-Very High AAEE Savings (mid-very high)
- Scenario 6: Mid Demand-High Plus AAEE Savings (mid-high plus)

The mid-mid and mid-low scenarios are designated as the options to be applied to the *CED 2021 Revised* mid baseline forecast to yield a managed forecast or forecasts for planning.

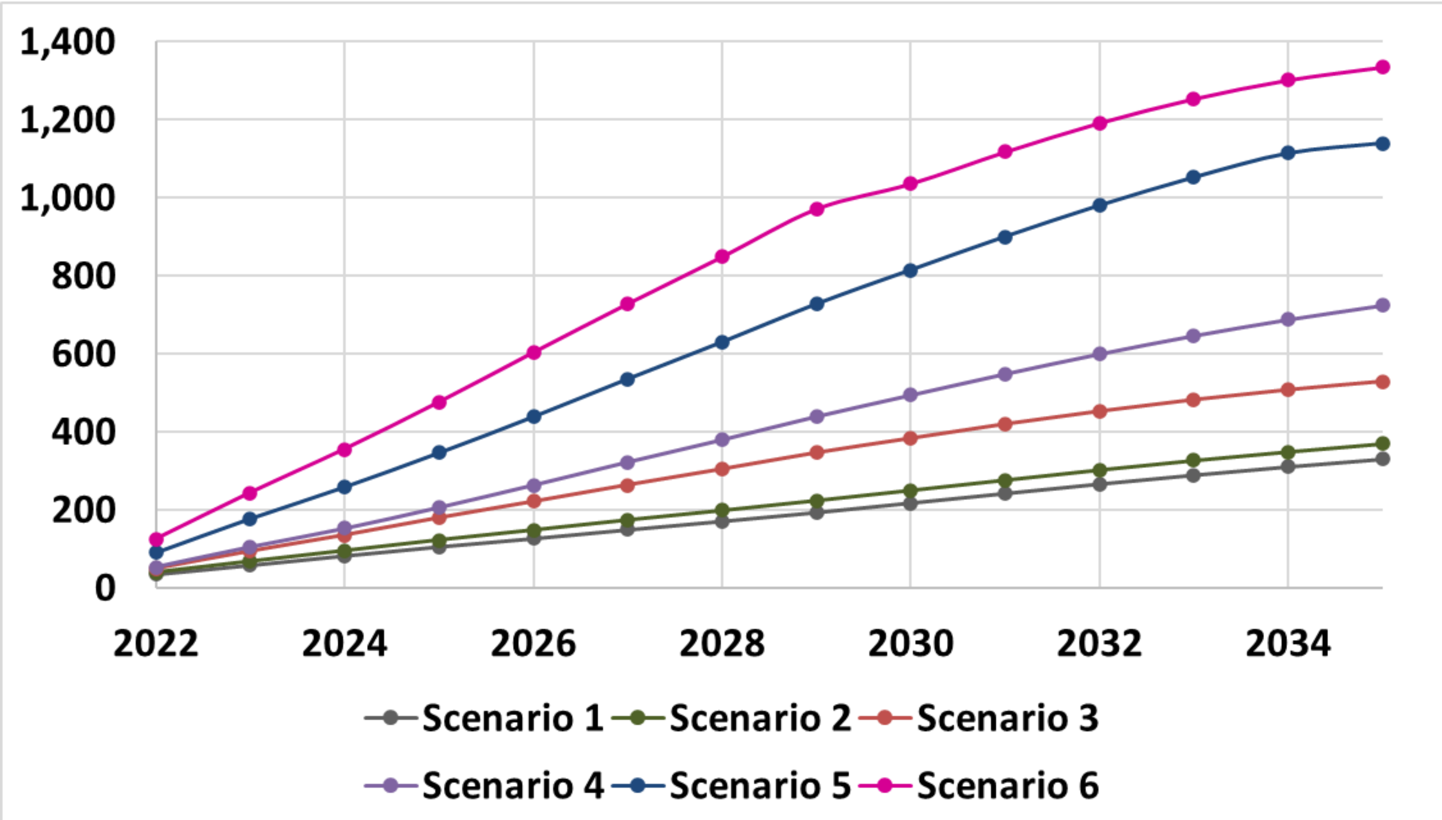
The spectrum of statewide electric and gas AAEE scenarios is shown in Figures 16 and 17.

Figure 16: 2021 Total AAEE Electricity (GWh) Savings for Scenarios 1–6



Source: CEC

Figure 17: 2021 Total AAEE Gas (MM Therm) Savings for Scenario 1–6



Source: CEC

Variation in the 2021 AAEE scenarios was focused on the spread of possible savings and did not contain any variation in baseline demand. The results illustrated in this forecast also begin to illustrate the limits of energy efficiency being decarbonization focus grows (see Volume I of the *2021 IEPR* for more information).

The savings accounted for in the six AAEE scenarios come from three main sources:

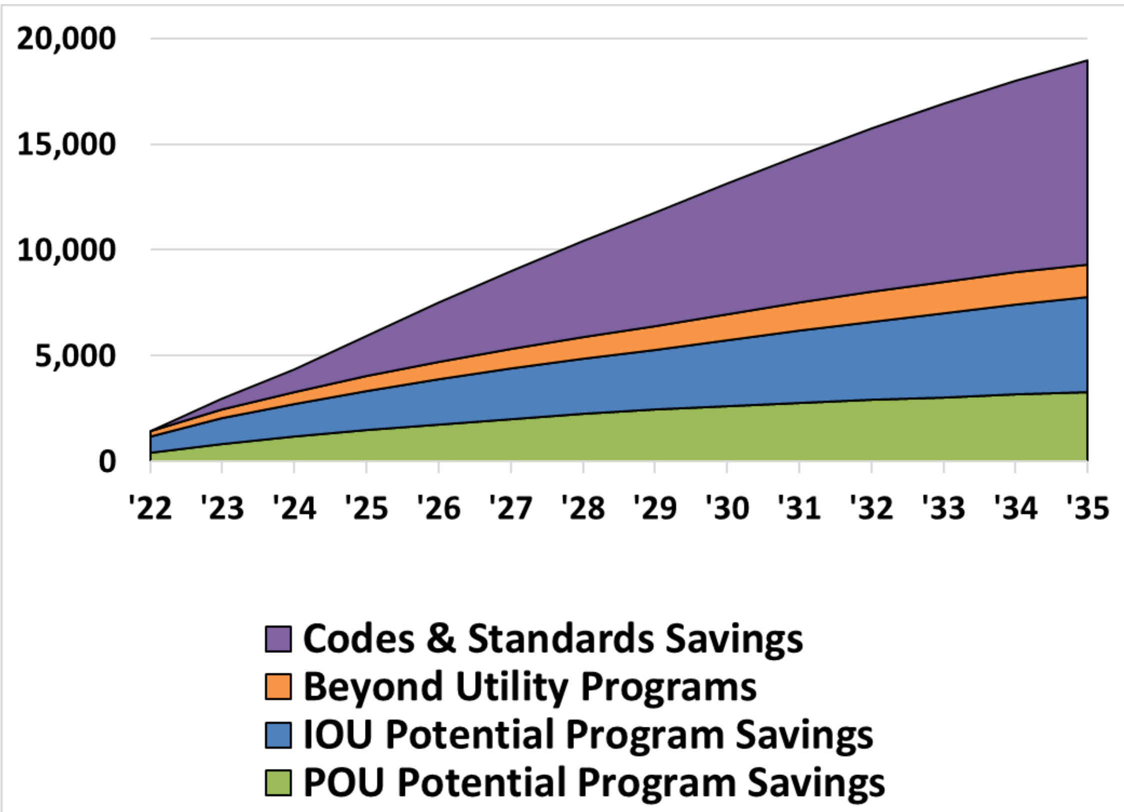
1) IOU potential savings derived from the CPUC's *2021 Energy Efficiency Potential and Goals Study* (*PG Study*).[34]

34 CPUC. 2021. *2021 Potential and Goals Study*. https://pda.energydataweb.com/#!/documents/2527/view.

2) POU potential savings derived from the CMUA's *2020 Energy Efficiency Potential Forecast*.[35]
3) Beyond utility savings from programs run by the CEC and other agencies as well as savings derived from future ratcheting of codes and standards (C&S).

A breakdown of the Statewide AAEE Business-As-Usual Scenario 3 into the main data streams is shown in Figures 18 and 19 for electricity and gas respectively.

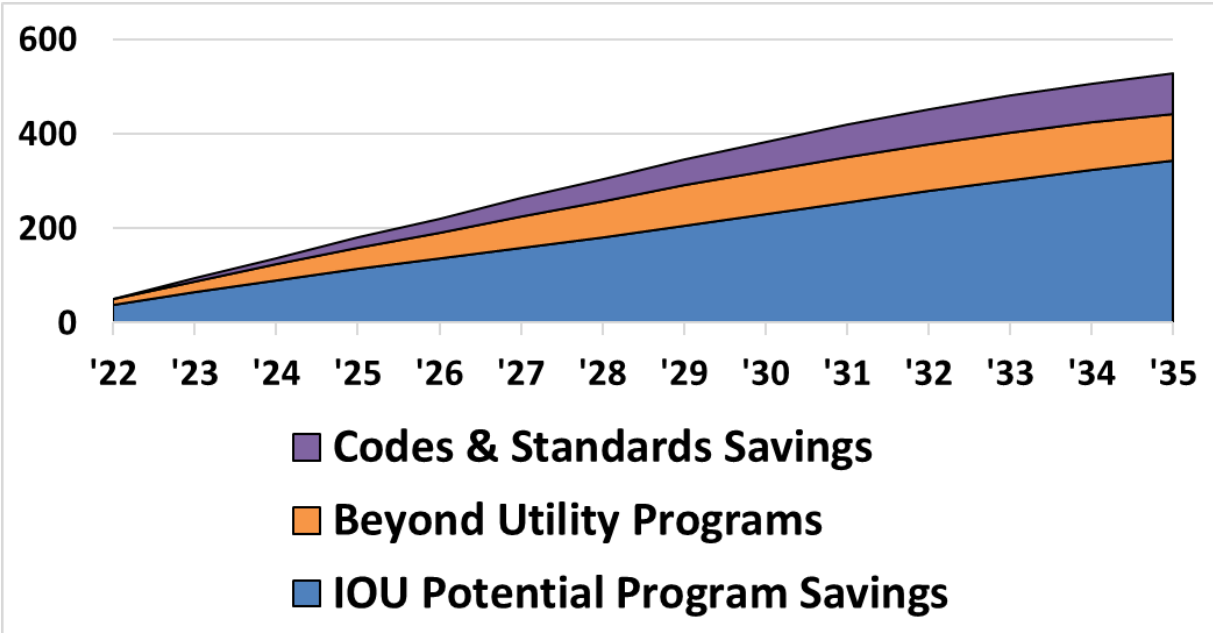
Figure 18: Statewide AAEE Business-As-Usual Scenario 3 (GWh)



Source: CEC

35 GDS Associates, Inc. April 2021. *2020 Energy Efficiency Potential Forecast*. CMUA. https://www.glendaleca.gov/home/showdocument?id=63721&t=637661956279678151.

Figure 19: Statewide AAEE Business-As-Usual Scenario 3 (MM Therm)



Source: CEC

IOU Programs Contributions to AAEE

AAEE impacts for the IOU service territories are based on the CPUC's *PG Study*. This study is undertaken biennially, and the main differences between the 2021 proposed goals and the 2019 predecessor are:

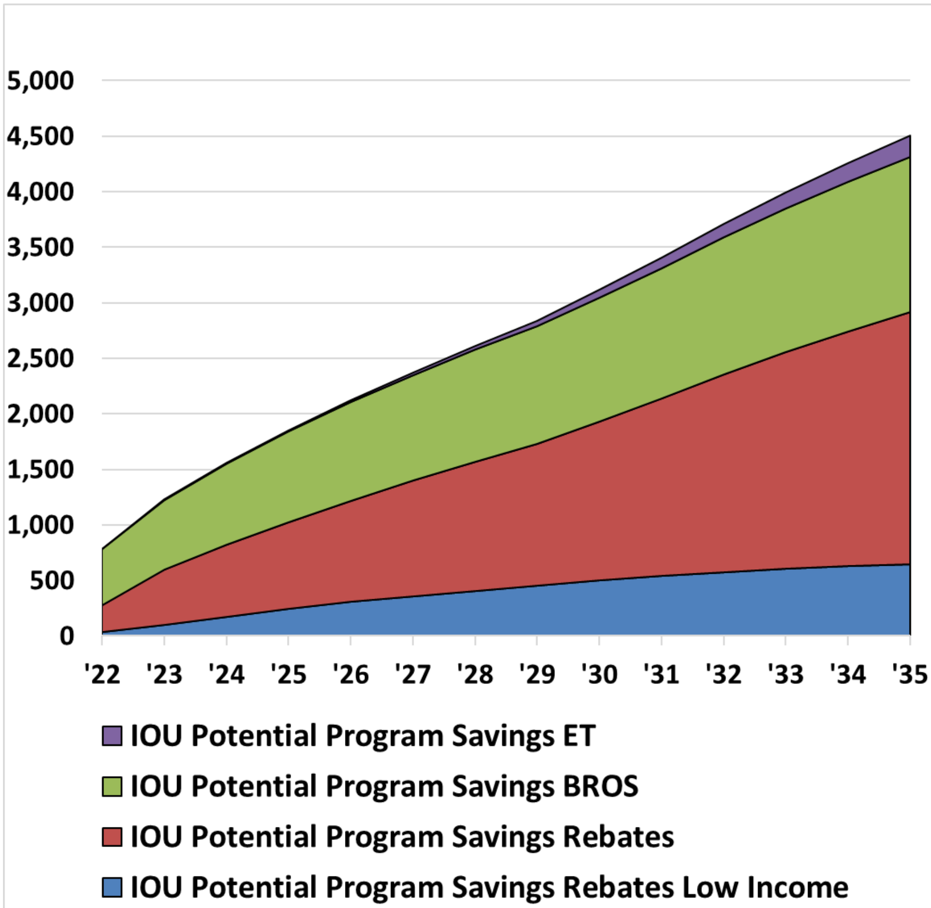
- A decrease in the threshold for cost-effectiveness of specific measures in most scenarios, 0.85 total resource cost (TRC) was selected by the CPUC in 2021 rather than the 1.0 TRC threshold selected by the CPUC in their 2019 goals scenario and still required for program portfolios in their entirety.[36]
- A significant decrease in cost-effective rebate program savings beginning in 2024 due to the updated 2021 Avoided Cost Calculator (ACC) and increasing stringency in future codes and standards.

36 Cost-effectiveness is usually defined as a ratio of greater than or equal to 1.0. The change allows for greater flexibility in the cost-effectiveness of specific measures as long as the cost-effectiveness of the overall portfolio average is greater than or equal to 1.0.

- Addition of fuel substitution impacts as permissible by the 2019 fuel substitution decision.[37]

A breakdown of IOU contributions to the Statewide AAEE Business-As-Usual Scenario 3 is shown in Figures 20 and 21 for electricity and gas respectively.

Figure 20: 2021 IOU AAEE Program Savings Breakdown (GWh)

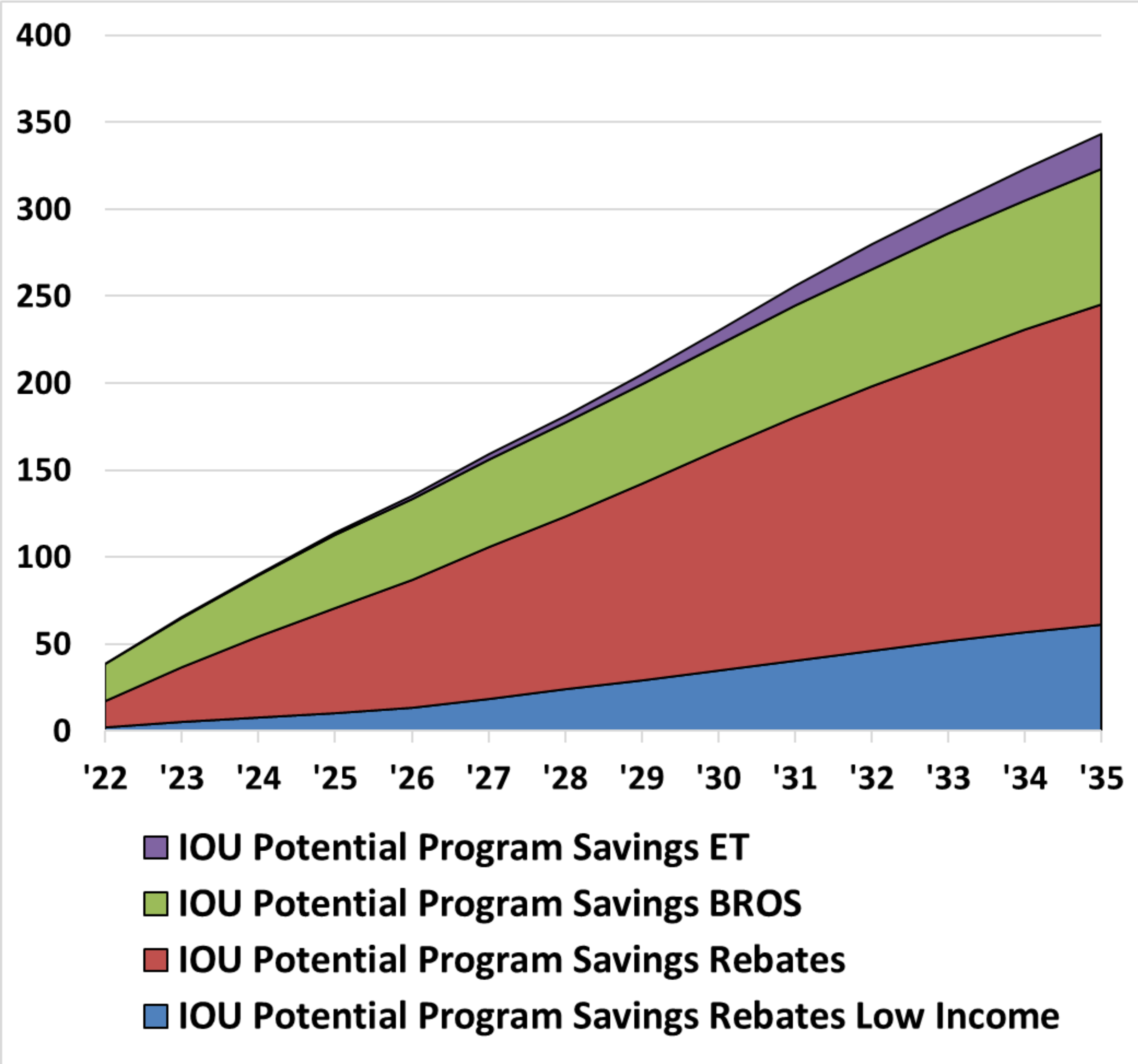


Source: CEC

37 Fuel substitution contributions from the *PG Study* as well as other savings streams will be discussed in the latter half of the chapter: Introducing Additional Achievable Fuel Substitution (AAFS).

CPUC. 2019. *Decision Modifying the Energy Efficiency Three-Prong Test Related to Fuel Substitution*. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M310/K159/310159146.PDF.

Figure 21: 2021 IOU AAEE Program Savings Breakdown (MM Therms)



Source: CEC

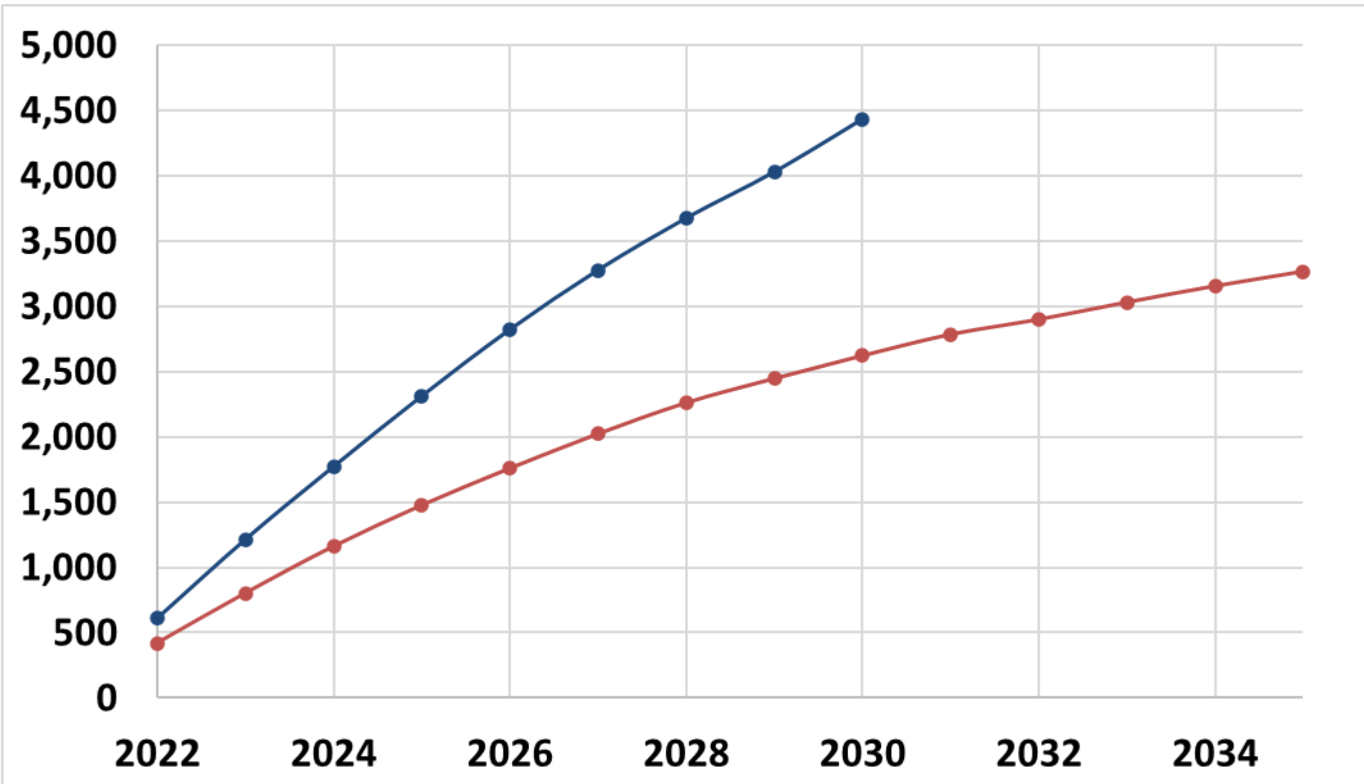
POU Programs Contributions to AAEE

AAEE impacts for the POU service territories are based on the CMUA's *2020 Energy Efficiency Potential Report*,[38] prepared every four years as directed by Assembly Bill 2021 (Levine,

38 GDS Associates, Inc. *2020 Energy Efficiency Potential Forecast*. CMUA. April 2021. https://www.glendaleca.gov/home/showdocument?id=63721&t=637661956279678151.

Chapter 734, Statutes of 2006) and Assembly Bill 2227 (Bradford, Chapter 606, Statutes of 2012). The report, prepared by GDS Associates Inc. and published in April 2021, contains a set of energy efficiency savings projections for each of the 38 POUs.

Figure 22: POU Program GWh Savings for 2019 vs 2021 AAEE (Scenario 3)



Source: CEC

Total POU savings forecasts from 2017 and 2019 were necessarily similar because they were both based on the 2017 CMUA potential savings report. The updated report[39] received spring of 2021 reflected a significant drop of POU rebates similar to the one observed in 2019 for IOUs.

39 GDS Associates, Inc. *2020 Energy Efficiency Potential Forecast*. CMUA. April 2021. https://www.glendaleca.gov/home/showdocument?id=63721&t=637661956279678151.

Beyond Utility (BU) Contributions to AAEE

For the 2015 IEPR Demand Forecast and prior forecasts, only future California Title 24 Buildings Energy Efficiency Standards, California Title 20 Appliance Standards, and Federal Appliance Standards ratchets attributable to IOU and POU advocacy efforts were included in AAEE scenario design. In 2017, all C&S savings were included, as well as some additional beyond utility programs, which had been assessed to set SB 350 savings goals. The doubling of projected energy efficiency savings called for in SB 350 still exceeds the significant savings that are projected to be achieved by 2030 through California's existing plans for energy efficiency, which are incorporated in the demand forecasts through AAEE. Staff therefore continued the approach used in 2017 and 2019 to adjust these BU savings elements downward from an aspirational SB 350 perspective to those savings reasonably expected to occur given program specific assumptions.[40]

The BU analysis was enhanced in 2019 to include all savings suitable for AAEE purposes from each of the programs analyzed as potential contributors toward the state's SB 350 doubling goal as well as for all future C&S. For the *2021 IEPR*, a large contractual effort was undertaken with consulting firm Guidehouse to update and enhance the BU analysis for programs previously assessed, as well as savings projections from additional programs.

Codes and Standards Contributions to AAEE

For the 2021 AAEE forecast, staff included a substantial amount of committed but future building standards and appliance regulations in the baseline forecast. These C&S had completed the rulemaking process, thereby negating the uncertainty otherwise present for implementing future standards. The notable exception is the 2022 vintage of Title 24 building standards, which the CEC adopted in August 2021. Significant uncertainty remains around how much energy efficiency savings versus fuel substitution impacts the standard will generate. The team made a concerted effort to benchmark the previous beyond utility Title 24 analysis with the *2019 Impact Analysis*,[41] as well as with data provided to support the 2022 Title 24 rulemaking. To avoid double counting, measures already captured in the baseline forecast

40 California Energy Commission staff. 2017. *2017 Integrated Energy Policy Report*. California Energy Commission. Publication Number: CEC-100-2017-001-CMF. pp. 54–58. https://efiling.energy.ca.gov/getdocument.aspx?tn=223205. p. 177.

41 Dimitri Contoyannis, Skye Lei, Chitra Nambiar, John Arent, Silas Taylor, Nikhil Kapur NORESCO (Non-residential) and Ken Nittler Enercomp (Residential). 2018. "IMPACT ANALYSIS 2019 Update to the California Energy Efficiency Standards for Residential and Non-Residential Buildings" *Contract 400-15-006, Work Authorization 9, Task 2.2.*

were removed from the projected savings, (for example, savings streams that have first-year savings in or after 2020), which would otherwise have been included in the AAEE scenarios.

BU Program Contributions to AAEE

BU program savings contributions in AAEE, other than C&S elements, were first presented in a limited fashion in the *2018 IEPR Update* forecast,[42] with more programs included in the *2019 IEPR* AAEE analysis. Initiatives in the analysis are listed below, including financing programs, additional ratchets of Title 24 Building Standards, Title 20 Appliance Standards, and Federal Appliance Standards described previously.

- **Initiatives Included in 2019:** Proposition 39; Department of General Services (DGS) Energy Retrofit; Energy Conservation Assistance Act (ECAA); Greenhouse Gas Reduction Fund (GGRF); Water Energy Grant (WEG) Program; GGRF Low-Income Weatherization Project (LIWP); property assessed clean energy (PACE); behavioral, retrocommissioning, operations savings (BROs); Local Government Challenge (LGC); local government ordinances (LGO); energy asset rating; smart meter data analytics; air quality management districts (AQMD); conservation voltage reduction (CVR); industrial programs; and agricultural programs.
- **Initiatives Added in 2021:** Programs implemented by community choice aggregators (CCAs) and regional energy networks (CCA RENs), the Self-Generation Incentive Program (SGIP), the Clean Energy Optimization Program (CEOP), and the Food Production Investment Program (FPIP).

Introduction of Additional Achievable Fuel Substitution

Fuel substitution was first introduced in the demand forecast as an element of AAEE in the *2019 IEPR*. In 2019, staff used a *what-if* percentage of all electric new construction varying from low to high:

- **Low**: Assumed all electric penetration rate of 0.5 percent per year beginning 2020, ramping linearly to a cumulative of 5.5 percent in 2030 for Scenarios 1 and 2.
- **Mid**: Assumed all electric penetration rate of 1.5 percent per year beginning 2020, ramping linearly to a cumulative of 16.5 percent in 2030 for Scenarios 3 and 4.

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42 Kavalec, Chris, Asish Gautam, Mike Jaske, Lynn Marshall, Nahid Movassagh, and Ravinderpal Vaid. 2018. *California Energy Demand 2018–2030 Revised Forecast*. California Energy Commission, Electricity Assessments Division. Publication Number: CEC-200-2018-002-CMF. pp. 67–72. https://efiling.energy.ca.gov/getdocument.aspx?tn=223244.

- **High**: Assumed all electric penetration rate of 2.5 percent per year beginning in 2020, ramping linearly to a cumulative of 27.5 percent in 2030 for Scenarios 5 and 6.

In late 2019 and throughout 2020, CEC staff contracted with Guidehouse to develop the *what-if* Fuel Substitution Scenario Analysis Tool (FSSAT). CEC staff used FSSAT to analyze building electrification scenarios in support of the AB 3232 (Friedman, Chapter 373, Statutes of 2018) analysis described in the *California Building Decarbonization Assessment*.[43] The analysis showed that each of the speculative electrification scenarios that met or exceeded the AB 3232 target added substantial incremental electric energy consumption. These scenarios also show that there are shifts in the dates and times of peak loads, with winter loads affected more than summer loads. These shifts are expected by 2030 in both Northern and Southern California.

Since the changes were more pronounced in the winter, there is the possibility that a heavily electrified future could result in a winter peaking system previously not considered in California. At a minimum, these results indicate that utilities and grid planners need to account for a change of peak energy consumption patterns in a more electrified future. A commensurate drop in gas demand may similarly change gas utility planning. Electricity and gas system reliability is discussed in detail in Volume II of this IEPR and decarbonizing the gas system is addressed in Volume III.

Additional Achievable Fuel Substitution: A New Load Modifier

For the *2021 IEPR*, CEC staff developed additional achievable fuel substitution (AAFS) as a new annual and hourly load modifier to the baseline demand forecast in a manner analogous to AAEE.

AAFS development was accelerated by using the AAEE method as a template — the first AAEE analysis was developed in 2009 and formalized in the single forecast set language in the *2014 IEPR Update*. Staff has incorporated program-based inputs into the robust data aggregation tools developed for AAEE as part of the *2019 IEPR*. The objective is to focus on firm programs and projections to develop an analysis useful for planning and procurement. This focus precluded the use of the AB 3232 electrification scenarios as a starting point for AAFS.

As established for AAEE, staff develops variations around the most probable futures to show other possible outcomes given less or more effort to implement fuel

43 Kenney, Michael, Nicholas Janusch, Ingrid Neumann, and Mike Jaske. 2021. *California Building Decarbonization Assessment*. California Energy Commission. Publication Number: CEC-400-2021-006-CMF. https://www.energy.ca.gov/data-reports/reports/building-decarbonization-assessment.

substitution programs. Similar to the 2021 AAEE scenarios, the 2021 AAFS scenarios focus on the variability of potential fuel substitution impacts and are defined by the mid-demand case. Thus, they all share the same assumptions for building stock and retail rates. A range of three reasonably expected scenarios were included, one more conservative (scenario 2) and one more aggressive (scenario 4) than the business-as-usual (BAU) forecast (scenario 3). A very conservative impact bookend was not included for AAFS because fuel substitution impacts are still small and the variation between the scenarios is much smaller than variation across the three reasonably expected AAEE scenarios. Two optimistic high fuel substitution scenarios also were developed (scenario 5 and scenario 6). The most optimistic AAFS scenarios were designed to maximize the impacts of any existing programs, as well as include achievable potential fuel substitution impacts not expected from existing programs or standards. These speculative fuel substitution impacts may be realized as currently proposed programs are implemented and other additional programs or standards are developed to meet various policy goals. If the suite of AAFS scenarios is used for planning, the AAFS scenarios containing more aggressive or optimistic fuel substitution impacts would be considered more conservative, as a higher electric load would be forecasted.

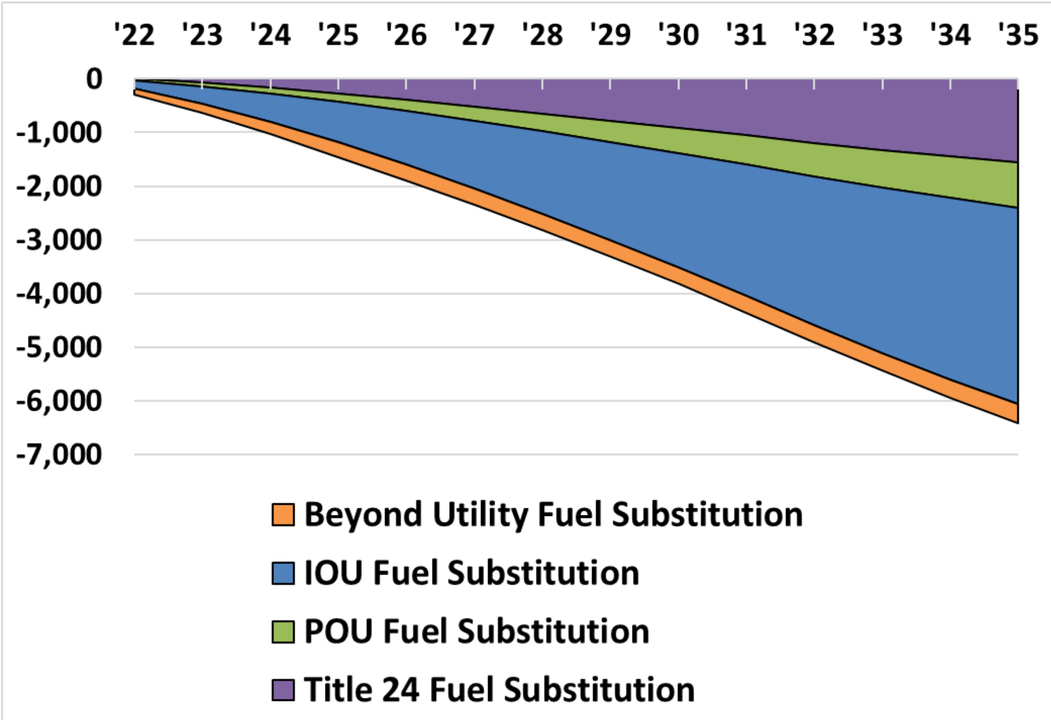
The five AAFS impacts scenarios are defined as follows:

- Scenario 2: Mid Demand-Low AAFS Impacts (mid-low)
- Scenario 3: Mid Demand-Mid AAFS Impacts (mid-mid)
- Scenario 4: Mid Demand-Mid Plus AAFS Impacts (mid-mid plus)
- Scenario 5: Mid Demand-High AAFS Impacts (mid-high)
- Scenario 6: Mid Demand-High Plus AAFS Impacts (mid-high plus)

Appendix A provides a detailed description of the methods for each component of AAFS.

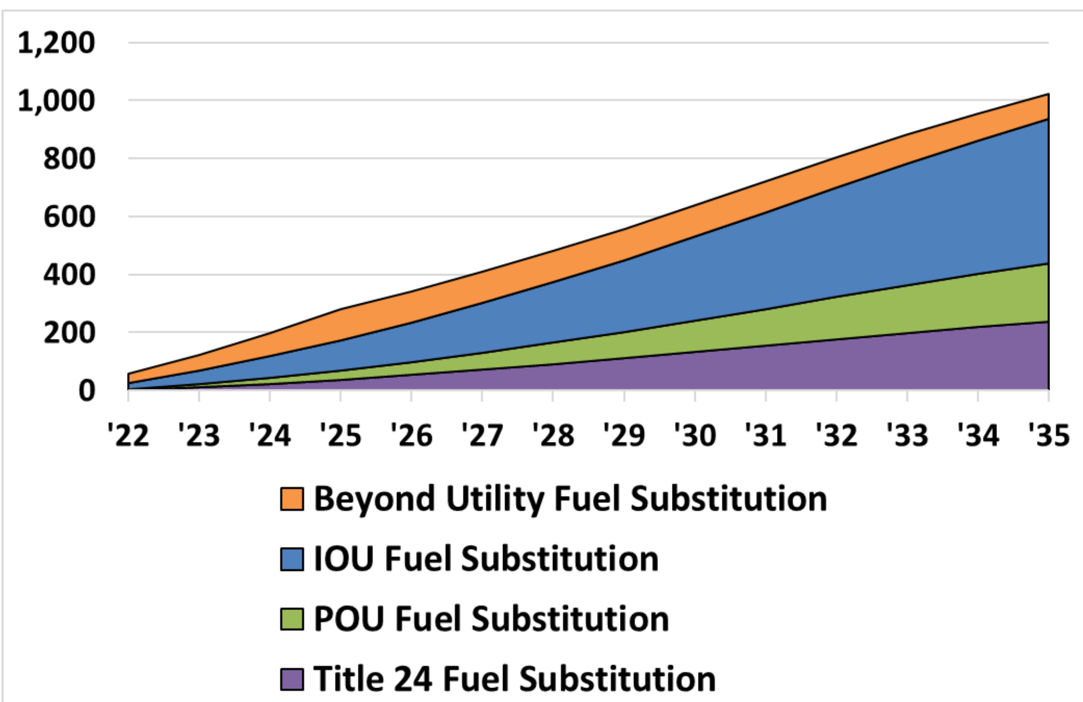
A breakdown of the Statewide AAFS Business-As-Usual Scenario 3 into the main data streams is shown in Figures 23 and 24 for electricity and gas respectively. Gas impacts are positive since it is "saved" or displaced, while electricity is added yielding negative "savings."

Figure 23: Statewide AAEE Business-As-Usual Scenario 3 (GWh)



Source: CEC

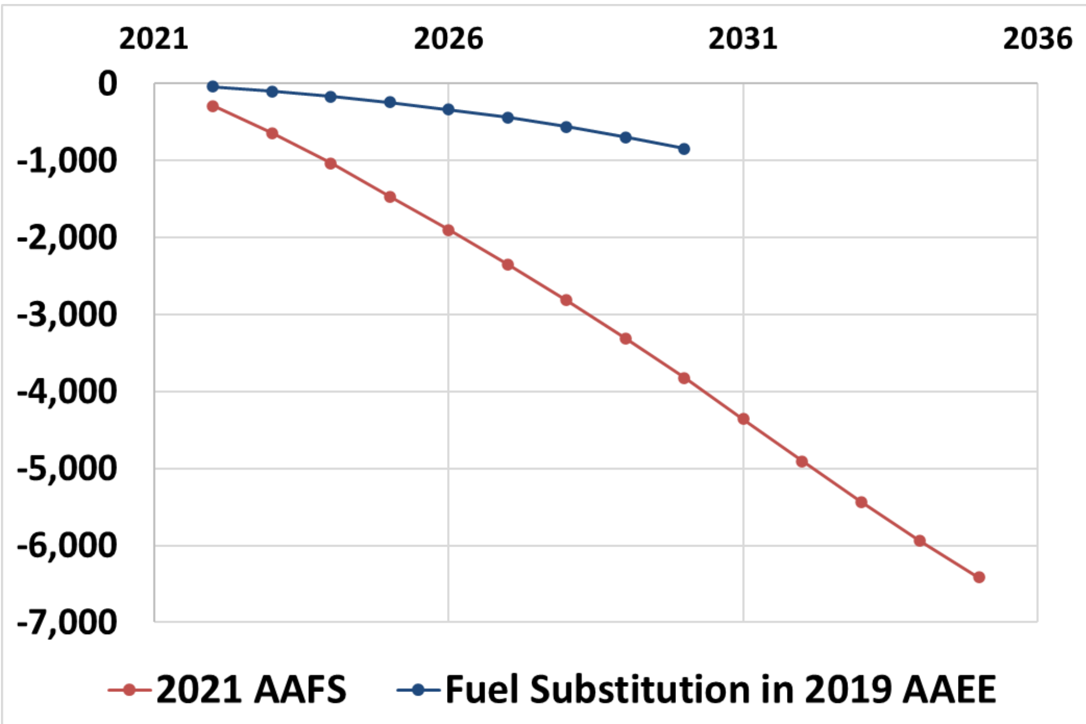
Figure 24: Statewide AAEE Business-As-Usual Scenario 3 (MM Therm)



Source: CEC

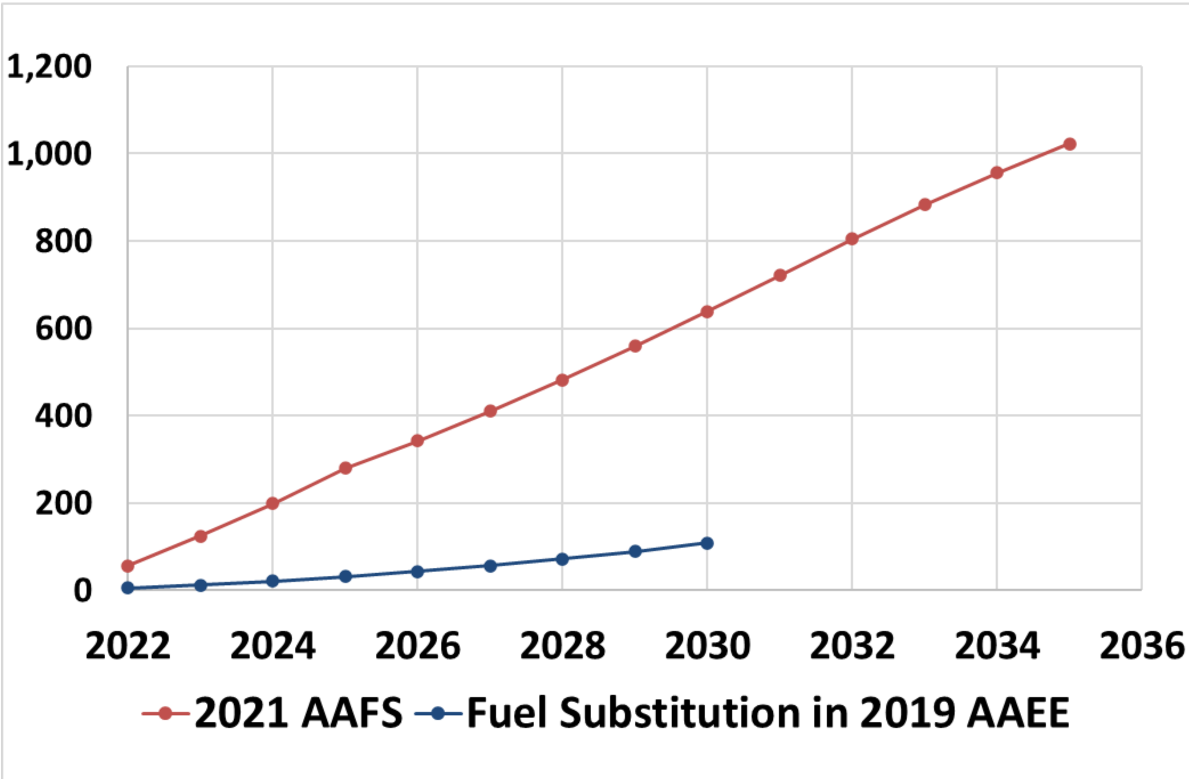
The programmatic fuel substitution considered in the BAU 2021 AAFS Scenario 3 is compared to the speculative amount of fuel substitution included in the 2019 AAEE Scenario 3 in Figures 25 and 26 for electricity and gas respectively.

Figure 25: Total GWh Savings for 2019 Versus 2021



Source: CEC

Figure 26: Total MM Therm Savings for 2019 Versus 2021



Source: CEC

Considerations for AAEE and AAFS Scenario Compatibility and of Use Cases

Given the inherent competition between gas EE and fuel substitution, staff will need to consider which combinations of AAEE/AAFS scenarios are compatible given gas displacement potential. It is possible to proportionately scale down natural gas savings in cases where the total penetration of fuel substitution savings exceeds a specified proportion of the total IEPR demand for a given year and sector.

The fuel substitution impacts of current programs may not be of the magnitude needed to meet various policy goals, and how to estimate any remaining increment is subject to consideration. For example, additional speculative fuel substitution that exceeds modeling results can be applied to the remaining gas consumption to develop more aggressive AAFS scenarios that achieve policy goals. Alternatively, it is possible to separate gas and electric EE using simplified assumptions and using a less aggressive gas AAEE scenario to design a more aggressive AAFS scenario. In the future, more granularity may be achieved in the AAEE and AAFS forecasts to make this separation more sophisticated.

Public Process and Transparency

The concept of AAFS was first formally introduced to stakeholders at a meeting of the Demand Analysis Working Group (DAWG) on June 23, 2021, and then presented at the IEPR Commissioner workshop on Demand Forecast: Inputs and Assumptions on August 5, 2021.

For each broad category of AAEE savings and AAFS impacts contribution — IOU (CPUC-jurisdictional) programs, POU programs, codes and standards, and BU (or nonutility) programs — the associated scenario design elements described in this chapter were discussed with stakeholders at a meeting of the DAWG on September 9, 2021.[44]

At the December 2, 2021, IEPR workshop, staff presented final savings estimates associated with each scenario. Further, staff presented the effects of the 2021 iteration of AAEE and AAFS on the managed annual electricity and gas demand forecast and hourly electricity demand forecasts at the December 16, 2021, IEPR workshop.

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44 Presentation by Ingrid Neumann at the September 18, 2019, DAWG meeting, "AAEE Preliminary Definitions for 2019 CED Forecast." https://www.energy.ca.gov/sites/default/files/2019-12/AAEE%20Scenario%20Definitions%20DAWG%209-18-19_ada.pdf.

Presentation by Ingrid Neumann at the October 18, 2019, DAWG meeting, "AAEE Preliminary 2019 Savings Forecast." https://www.energy.ca.gov/sites/default/files/2019-12/AAEE%20Preliminary%20Results%2010-18-19_ada.pdf.

CHAPTER 3: Transportation Energy Demand Forecast

This section provides an overview of the California Energy Commission's (CEC's) transportation energy demand forecast. The Transportation Energy Demand Forecast (TEDF) reflects the implications of a mix of existing policies, consumer vehicle preferences, fuel price cases, and projected market and technological conditions. To frame the TEDF, it is important to be clear that there is a functional difference between CEC forecasts and CEC scenario work. The goal of the TEDF, as a forecast, is to evaluate existing conditions for the purposes of planning and procurement, or to consider forecast results as a reference point to inform state transportation-related goals. For policy-oriented discussions and analyses that explore broader issues — for example, those pertaining to state climate goals or potential policies — consult Chapter 4 on long-term demand scenarios.

The CEC's transportation energy demand forecast uses a suite of models that incorporate consumer preferences, existing regulations, vehicle incentive programs, economic and demographic projections, projected improvements in technology, and other market factors to forecast transportation energy demand. The approach starts with current market conditions and forecasts transportation energy demand based on projected inputs. No constraints are imposed for the forecast to meet nonregulatory targets. By contrast, other approaches commonly used for strategic planning begin with a targeted goal (such as a quantity of vehicles, fuels, or emissions goals to meet by a future year) and work backward to stipulate intermediate energy use for the intervening years. In conjunction with the CEC's forecast, policy makers can use their strategic plans to assess progress toward statewide goals and determine whether further action is needed.

Transportation Decarbonization Trends

Transportation represents more than half of the state's greenhouse gas (GHG) emissions when accounting for emissions associated with fuel production. Transitioning to zero-emission vehicles (ZEVs) is necessary to meet the state's GHG emission reduction goals. Thus, a consideration of existing policies and goals is useful, as they have an influence on market trends.

Recent State Goals, Strategies, and Policies

On September 23, 2020, Governor Gavin Newsom signed Executive Order N-79-20,[45] setting a 100 percent ZEV sales goal for new passenger vehicles by 2035, a 100 percent ZEV operations goal for drayage and off-road vehicles by 2035, and a 100 percent ZEV operations goal for medium- and heavy-duty vehicles in the state by 2045, where feasible. These goals have sent key market signals to vehicle manufacturers and informed some 2021 state budget items, but specific regulatory actions in response to this executive order have not been enacted as of January 2022. Prior ZEV goals include Executive Order B-48-18[46] signed in 2018, calling for 5 million light-duty ZEVs by 2030, as well as Executive Order B-16-12[47] signed in 2012, calling for 1.5 million light-duty ZEVs by 2025.

Assembly Bill 2127 (Ting, Chapter 365, Statutes of 2018) requires the CEC to biennially assess the electric vehicle (EV) charging infrastructure needed to support 5 million ZEVs by 2030. Further, Executive Order N-79-20 directs the CEC to update this assessment to support the ZEV adoption targets necessary to achieve the 100 percent light-duty ZEV sales goal. Shortly after Executive Order N-79-20, the California Air Resources Board (CARB) released its *Draft 2020 Mobile Source Strategy* (MSS),[48] which estimates that about 8 million ZEVs would be needed on the road by 2030 to effectively ramp to the 100 percent 2035 sales goal. In line with this need, the first AB 2127 report, approved in early 2021, estimates that as many as 1.2 million light-duty chargers would be necessary to support the charging needs for 8 million ZEVs.

To support progress on the state's ambitious ZEV goals, recent CARB regulatory proposals include Advanced Clean Cars II (ACC II) for light-duty vehicles and Advanced Clean Fleets (ACF) for medium- and heavy-duty vehicles. ACC II expands the original Advanced Clean Cars regulation adopted in 2012, pursuing stronger ZEV targets and regulatory mechanisms for

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45 Governor Gavin Newsom. Executive Order N-79-20. September 2020. https://www.gov.ca.gov/wp-content/uploads/2020/09/9.23.20-EO-N-79-20-Climate.pdf.

46 Former Governor Edmund G. Brown Jr. Executive Order B-48-18. January 2018. https://www.ca.gov/archive/gov39/2018/01/26/governor-brown-takes-action-to-increase-zero-emission-vehicles-fund-new-climate-investments/index.html.

47 Former Governor Edmund G. Brown Jr. Executive Order B-16-12. March 2012. https://www.ca.gov/archive/gov39/2012/03/23/news17472/index.html.

48 CARB *Draft 2020 Mobile Source Strategy*, https://ww2.arb.ca.gov/sites/default/files/2020-11/Draft_2020_Mobile_Source_Strategy.pdf

vehicles sold after 2025. ACC II is in development and is expected to be adopted in 2022.[49] The ACF regulation is in process and complements the existing manufacturer-focused Advanced Clean Trucks (ACT) regulation by adding regulations for ZEV purchases from public fleets, drayage trucks, and federal and high-priority fleets.[50]

As regulations are adopted, staff incorporate the associated impacts into the forecast. Goals or strategies, however, are not used, as the bases of the forecast are operating market and regulatory conditions. To the extent that goals without yet associated regulations impact the broader vehicle market, they do have an indirect influence. For instance, a few months after Executive Order N-79-20 was signed, General Motors announced a goal for the elimination of tailpipe emissions from its light-duty vehicles by 2035.[51]

ZEV Trends

The market for light-duty ZEVs, including plug-in hybrid electric vehicles (PHEVs),[52] has weathered the pandemic better than other segments of the transportation sector. Figure 27 presents annual ZEV sales and ZEV market share through 2020 and an estimate for 2021 based on data from the California Department of Motor Vehicles. A slight dip in sales from 2018 to 2019 mirrored the light-duty market as a whole. But while COVID-19 was responsible for nearly a 15 percent drop in total light-duty vehicle sales in 2020, ZEV sales only declined by 1.5 percent, increasing ZEV market share. The ZEV market has grown substantially in 2021, with expected sales of about a quarter of a million vehicles by the end of the year, the highest sales year so far. ZEV market share is also up, over four percentage points higher than 2020, the previous record. Continued growth and diversification of ZEV models, especially with sport utility vehicles, crossovers, and pickup trucks, is expected to contribute to additional ZEV market penetration.

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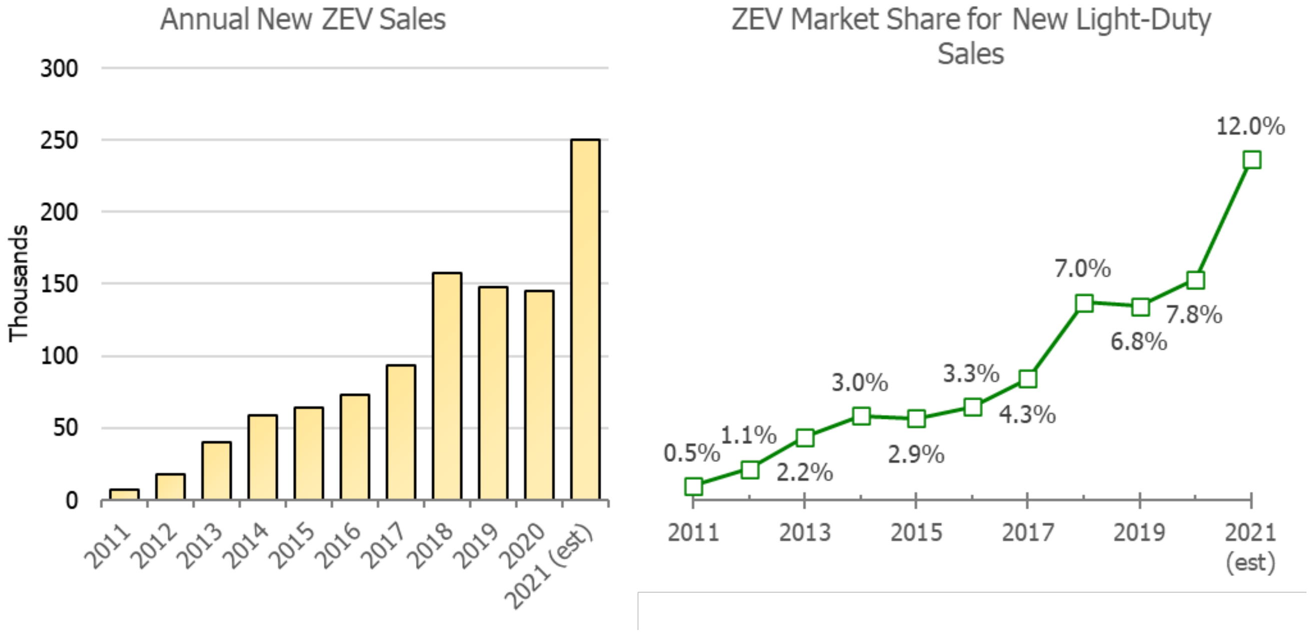
49 CARB Advanced Clean Cars webpage, https://ww2.arb.ca.gov/our-work/programs/advanced-clean-cars-program/about.

50 CARB Advanced Clean Fleets Workshop March 2 and March 4, 2021 presentation. https://ww2.arb.ca.gov/sites/default/files/2021-02/210302acfpres_ADA.pdf.

51 General Motors press release, "General Motors, the Largest U.S. Automaker, Plans to be Carbon Neutral by 2040." January 28, 2021. https://plants.gm.com/media/us/en/gm/news.detail.html/content/Pages/news/us/en/2021/jan/0128-carbon.html.

52 A PHEV may function as a ZEV by operating for several-to-many miles on a battery, but a hybrid system contains an internal combustion engine. This means that the vehicle is not true ZEV. Because of the capability to run on battery power, the IEPR and reports from other agencies have categorized ZEVs and PHEVs similarly, sometimes treating PHEVs as ZEVs, and other times distinguishing them from "true ZEVs." Longer-term, alignment of categorization and terminology with other state agencies will be necessary.

Figure 27: California Annual Light-Duty ZEV Sales and Market Share, 2011–2021

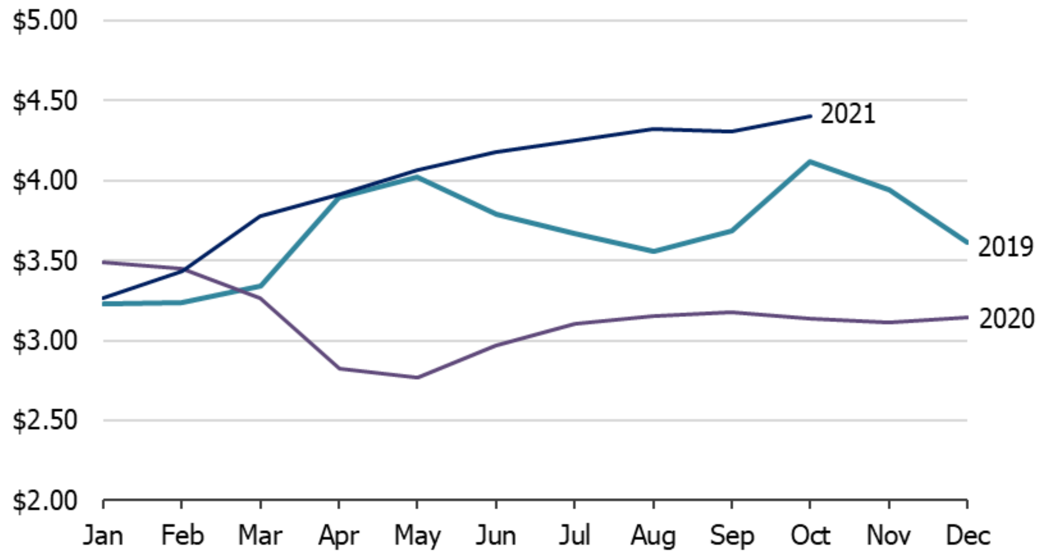


Source: CEC, Department of Motor Vehicles. Note: For this figure, ZEVs include PHEVs. (See footnote 43 for discussion on this distinction.) The 2021 estimated value for sales comprises three quarters of documented sales plus the average sales of the three quarters to estimate the whole year. Market share is the ZEV current market share as of the third quarter of 2021.

Transportation Fuel Trends

The past two years have been tumultuous for transportation fuels, in terms of price, production, and consumption. The disruption in travel caused by COVID-19 had an abrupt impact on fuel consumption in California that began with the stay-at-home order issued on March 19, 2020. This significant change in the economy led to a sharp decline in gasoline consumption of 20 percent in April 2020 (see Figure 28). Prices, however, did not decline as much, as refineries reduced output to match the decline in demand. Nevertheless, substantial existing inventories of gasoline in storage drove down prices, with May 2020 seeing the largest decline, at 20 percent below the February average price. Prices rebounded somewhat in June, and from July through the end of 2020 stayed between $3.10 and $3.20. Since the turn of the year, gasoline prices experienced sustained strength through fall 2021.

Figure 28: California Gasoline Prices



Data Source: U.S. Energy Information Administration

The decline in gasoline demand has been more than offset by a decline in gasoline supply. The decline in California supply, however, will have lasting impact. Marathon Petroleum temporarily idled its Martinez refinery on April 27, 2020, and then made it permanent on July 31, 2020.[53] Additionally, on August 23, 2020, Phillips 66 announced plans to close its facilities in Rodeo and Santa Maria at the end of 2023.[54] Phillips 66's two facilities are operated jointly as a single refinery, directly connected by 200 miles of pipeline. The closure of these refineries will remove 281,000 barrels per day of capacity, which amounts to 34 percent of petroleum refining capacity in Northern California and 15 percent of statewide capacity.

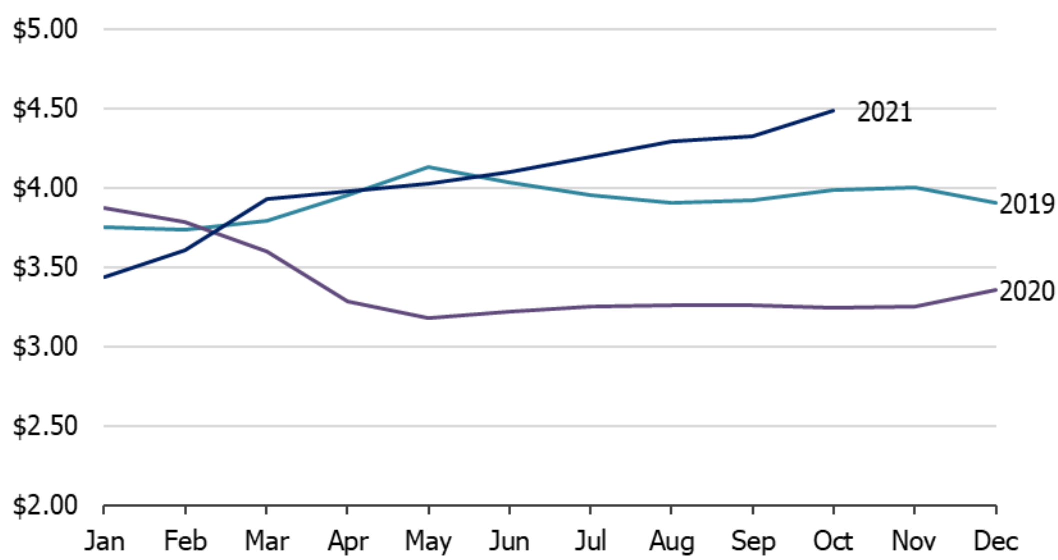
Compared to gasoline, the diesel market has experienced relatively muted price changes. (See Figure 29.Figure 28) This is due to two factors: historically, the California diesel market has

53 "Marathon Martinez Refinery 'Indefinitely Idled' Due to Pandemic-Driven Drop in Auto Travel." CBS SF Bay Area, August 1, 2020. https://sanfrancisco.cbslocal.com/2020/08/01/coronavirus-marathon-petroleum-refinery-martinez-idle/.

54 Scully, Janene. "Phillips 66 Plans 2023 Closure of Santa Maria Refinery, Pulls Application for Pipeline Project." *Santa Barbara Noozhawk*, August 13, 2020. https://www.noozhawk.com/article/phillips_66_closure_of_santa_maria_refinery_planned_for_2023_20200813.

been relatively well-supplied and consequently less volatile, and demand for diesel remained strong regardless of COVID conditions.

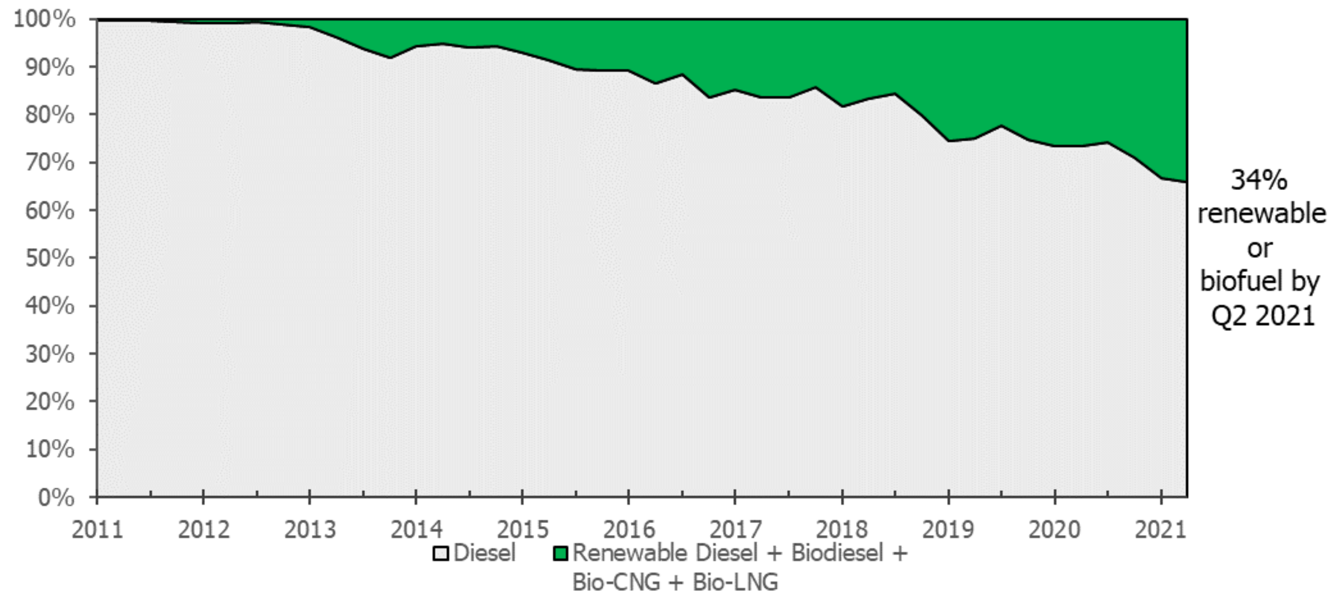
Figure 29: California Diesel Prices



Data Source: U.S. Energy Information Administration

Production of renewable diesel is planned on the sites of both the Marathon and Phillips 66 refineries. The Phillips 66 project is scheduled to commence production of renewable diesel by the end of 2021 and come fully on-line in 2024, with an expected capacity of 52,000 barrels per day. The Marathon project is scheduled to come on-line in early 2022 and will have a capacity of 47,000 barrels per day. Renewable diesel is a desirable product for refiners because it is a cost-effective way to comply with the Low Carbon Fuel Standard (LCFS) and is the leading generator of LCFS credits. It has made substantial inroads in California in recent years, and as of June 30, 2021, it has displaced 22 percent of petroleum-based diesel in California. This is in addition to the 8 percent displaced by biodiesel and the 4 percent displaced by biomethane (see Figure 30). Such a significant decline in fossil-diesel consumption makes it difficult for fossil-diesel refiners to operate economically. California is a high-cost producer of diesel fuel and is geographically disadvantaged compared to other refining centers, like Singapore or the Gulf Coast. Consequently, it is relatively difficult for California refiners to export the increasing amounts of petro-diesel that are displaced by renewable diesel and other biofuels.

Figure 30: California Fossil Diesel Displacement by Renewable Fuels



Data Source: California Air Resources Board

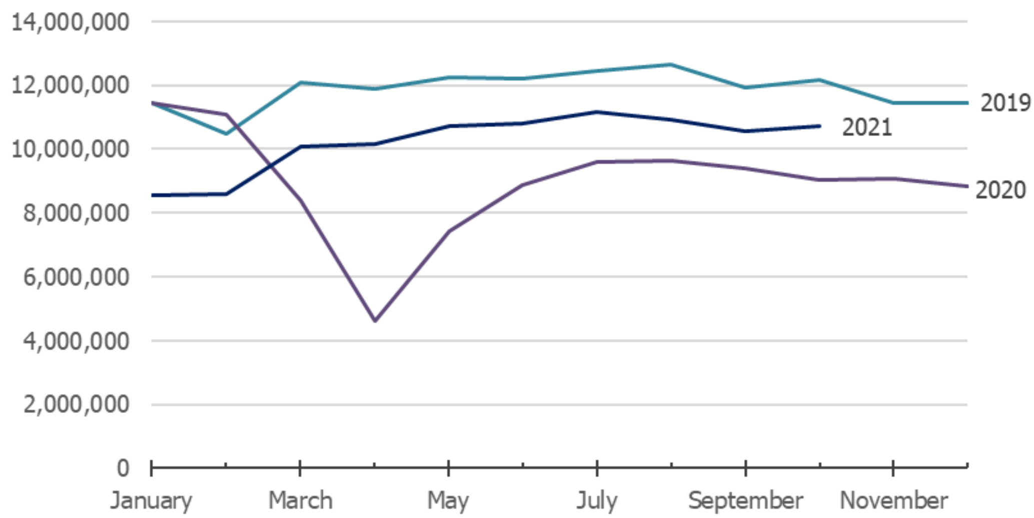
Biodiesel is a complement or additive to petroleum-based diesel. Renewable diesel, as a drop-in substitute for fossil-diesel, is similar in most respects, except that it is cleaner burning. As such, it does not require any blending before being dispensed to existing vehicles. It can use existing fuel dispensers and storage facilities, which gives it a cost advantage over other alternative or low-carbon fuels. Overall, it is difficult to directly observe the adoption of renewable diesel. Although EVs require substantial investment in vehicles and refueling infrastructure, adoption of renewable diesel can pass almost unnoticed, especially since diesel fuel is often used by fleets that purchase fuel through wholesale contracts and avoid much of the retail market.

Impacts of COVID-19 on Travel Demand

The impact of COVID-19 on travel demand has been substantial and varied since March 2020. In general, travel involving light-duty vehicles and transit vehicles bottomed in April 2020 and made a strong recovery over the following two to three months (see Figures 31 and 32 below for examples). Nevertheless, this was not a full recovery, and after July 2020, further recovery was uneven and often showed no clear trend. Los Angeles County Metropolitan Transportation Authority (LA Metro) passenger rides and Bay Area toll bridge crossings are both highly dependent on the number of commuters, so the example figures are useful indicators of how many workers stopped commuting and worked at home, although the increase in unemployment also contributed to the decline. Overall, the sum of toll bridge crossings fell 61 percent from 2019 levels in April 2020. As seen in Figure 31, most of the loss was regained, but in September 2021 was still 11 percent below 2019 levels. Similarly, LA

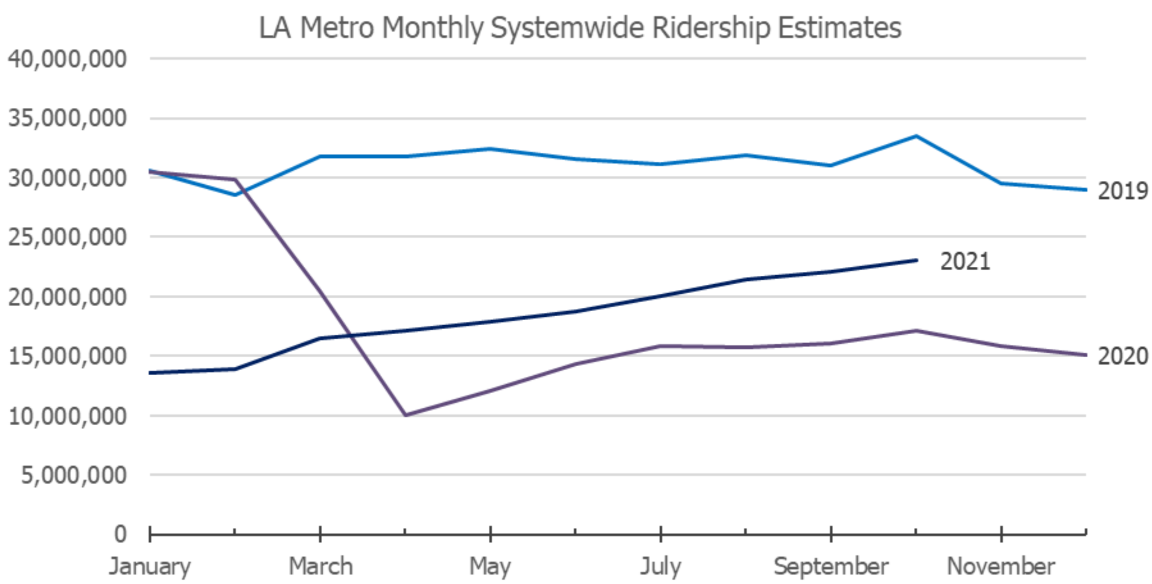
Metro ridership had fallen 68 percent from 2019 levels in April 2020, but in September 2021 was only 29 percent below 2019 levels.

Figure 31: Bridge Crossings in California, 2019–2021



Source: Metropolitan Transportation Commission, https://mtc.ca.gov/tools-resources/data-tools/monthly-transportation-statistics.

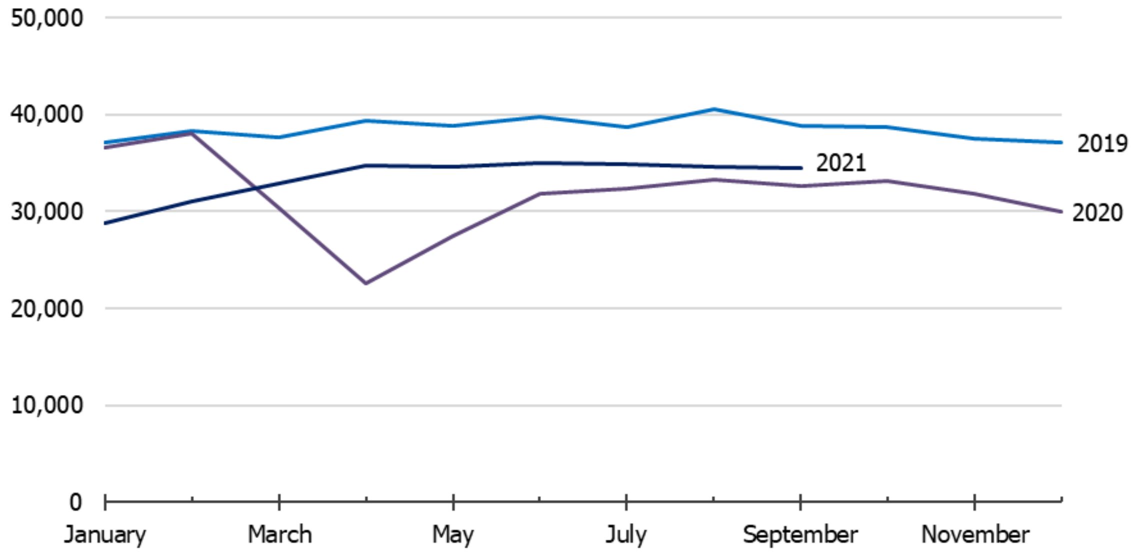
Figure 32: LA Metro Monthly Systemwide Ridership Estimates, 2019–2021



Source: LA Metro webpage, http://opa.metro.net/MetroRidership/.

Monthly gasoline consumption also provides a good snapshot of commuting patterns. Figure 33 contains information for statewide gasoline consumption. This includes both work and nonwork travel for the 95 percent of light-duty vehicles that use gasoline. The decline in gasoline consumption is not as pronounced as the decline in commuter traffic seen in Figure 31 — a 43 percent drop compared to 62 percent. The initial recovery is stronger for gasoline consumption, but commuter travel makes up for some of this with an uptrend in late 2020 and in 2021. The data presented here suggest that nonwork travel did not decline as much as commuting travel and that it has made more of a recovery than commuting travel. Both types of travel remain significantly lower than they were in 2019.

Figure 33: California Gasoline Sales (Thousand Gallons/Day), 2019–2021



Source: U.S. EIA, California Total Gasoline All Sales/Deliveries

Demand Forecast Data, Assumptions, and Analytic Updates

CEC staff used different combinations of inputs and assumptions to design several plausible transportation demand cases. The low-, mid-, and high-electricity demand cases are consistent with the demand cases used for forecasting total electricity and gas demand. These three demand cases are based on different ZEV incentive scenarios, projected vehicle attributes, and economic, demographic, and fuel price inputs, varying in relative favorability for the ZEV market. For light-duty ZEVs, staff also developed aggressive- and bookend-demand cases to explore new plausible conditions due to rapid changes in the light-duty ZEV market. These inputs and assumptions range from less favorable for ZEV adoption in the low-electricity-demand case to more favorable for ZEV adoption in the high, aggressive, and bookend cases.

CEC staff developed all the transportation energy price forecast cases except for the hydrogen prices, which were developed by the National Renewable Energy Laboratory (NREL).[55] The California fuel price forecasts are primarily based on the United States Energy Information Administration's (U.S. EIA's) nationwide forecasts in its Annual Energy Outlook.[56] Fuel prices in California and the nation as a whole have been greatly impacted by COVID-19. Although demand for fuels has not yet recovered, prices for gasoline and other fuels generally exceed pre-COVID highs. The U.S. EIA publishes a short-term energy outlook every month that contains monthly forecasts of fuel prices for the current and following calendar years — currently through the end of 2022. These incorporate the lingering effect of COVID-19 into the price forecasts and are incorporated directly into the California fuel price model. In California, additional factors that might contribute to high fuel prices include refinery closures and the price of LCFS credits.

Light-Duty ZEV Key Inputs and Assumptions

The inputs and assumptions for the low, mid, high, aggressive, and bookend cases range from less favorable to more favorable for ZEV adoption.

For the 2021 forecast, staff modified vehicle classification by consolidating utility vehicle classes, as well as differentiating between standard and premium vehicles within each vehicle class. Staff also updated consumer preferences to reflect the preferences captured in the 2019 California Vehicle Survey, used finer breakdowns of income categories, and introduced income as a factor in assessing state EV rebate eligibility. Key inputs and assumptions for light-duty ZEV forecast cases are in Table 2 below.

55 Hydrogen prices developed by NREL are forecasted using the agency's latest forecasting tools. This price forecast differs from ambitious energy goals that do not have a confirmed market pathway, such as the recent U.S. Department of Energy Hydrogen Energy Earthshot Initiative. The initiative aims to reduce production costs for hydrogen to one dollar per kilogram. CEC staff is actively tracking progress on hydrogen and related investments at all levels, including the federal level, and will continue to consider these developments in forecast work as explored in this chapter and in later demand scenario work similar to that discussed in Chapter 4. For more information on the Hydrogen Energy Earthshot Initiative, see https://www.energy.gov/articles/secretary-granholm-launches-hydrogen-energy-earthshot-accelerate-breakthroughs-toward-net.

56 U.S. EIA Annual Energy Outlook webpage. https://www.eia.gov/outlooks/aeo/.

Table 2: Summary of Light-Duty Case Assumptions

	Low	Mid	High	Aggressive	Bookend
Consumers' PEV Preference	Constant at 2017 Level	Increase with PEV market growth	Increase with PEV market growth	Increase with PEV market growth	Increase with PEV market growth
Federal Tax Credit	Decreasing starting 2019	Decreasing starting 2019	Decreasing starting 2019	Decreasing starting 2019	Decreasing starting 2019
Clean Fuel Rewards	2030	2030	2035	2035	2035
California Vehicle Rebate Project (CVRP)	To 2023	To 2025	BEV & FCV to 2030	BEV & FCV to 2035	BEV, PHEV & FCV to 2035
HOV Lane Access	To 2023	To 2025	BEV & FCV to 2030	BEV & FCV to 2030	BEV & FCV to 2030
Availability of PEVs (in 2035)	ZEV models available in 14 of 15 CEC LDV classes	ZEV models available in 15 of 15 CEC LDV classes	ZEV models available in 15 of 15 CEC LDV classes	ZEV models available in 15 of 15 CEC LDV classes	ZEV models available in 15 of 15 CEC LDV classes
PEV Cost Component / Battery Price (2035)	~$93/kWh	~$69/kWh	~$46/kWh	~$32/kWh	~$32/kWh
BEV Max. Range	~255 miles	~300 miles for Standard, 350 Premium	~400 miles for Standard, 450 for premium	~400 miles for Standard, 450 for premium	~450 miles for Standard, 500 for premium
Refuel Time (2030)	15 -21 min	15 -21 min	10-16 min	10-16 min	10-16 min
Time to Station (2030)	7-8 min	Same as gasoline	Same as gasoline	Same as gasoline	Same as gasoline

Source: CEC

Medium- and Heavy-Duty ZEV Key Inputs and Assumptions

The impacts of existing medium- and heavy-duty vehicle regulations are implicitly and explicitly accounted for in the forecast. Incentives for ZEV trucks are based on CARB’s Hybrid and Zero-Emission Truck and Bus Incentive Program (HVIP). To account for ACT impacts, staff reviewed an initial forecast model result in comparison with the ACT adoption schedule. Where needed, staff then adjusted assumed incentive levels to align vehicle stock in compliance with the ACT adoption schedule. Fleet turnover, in response to CARB’s fleet Truck and Bus Rule and the South Coast Air Quality Management District rules, is implicitly accounted for through use of the EMFAC2021[57] vehicle survival rates. Key inputs and assumptions for medium- and heavy-duty vehicles were discussed at a December 2, 2021, workshop and are displayed in Table 3 below.

Table 3: Summary of Medium- and Heavy-Duty Forecast Cases

	Low Case	Mid Case	High Case
CARB Regulations	Same as MID Case	Innovative Clean Transit, Advanced Clean Trucks, Airport Shuttle	Same as MID Case
Regional Regulations	Same as MID Case	Implicit for refuse trucks and urban transit buses	Same as MID Case
HVIP (all years)	Same as MID Case	2021 HVIP voucher amount a fixed amount for each class. Held constant to 2024. Thereafter trends with incremental truck price.	Same as MID Case
Hydrogen Price	NREL high price	NREL mid price	NREL low price
Electricity Rates	Commercial Rates, High	Commercial Rates, Mid	Commercial Rates, Low
BEV Truck Prices given battery pack price in 2035	BEV prices based on battery price declining to ~$97/kilowatt hour (kWh)	BEV prices based on battery price declining to ~$77/kWh	BEV prices based on battery price declining to ~$58/kWh
Miles Per Gallon (conventional / alternative)	Same as MID Case	Mid / Mid	Same as MID Case

57 EMFAC2021 is CARB's latest emission inventory model and is used to assess emissions from on-road motor vehicles. For more information see https://content.govdelivery.com/accounts/CARB/bulletins/2d48287.

	Low Case	Mid Case	High Case
Range of Operations	Same as MID Case	No constraint on range, assumes available infrastructure with fast charging away from depot	Same as MID Case

Source: CEC

Other Vehicles Key Inputs and Assumptions

Other vehicles included in the model are urban transit buses, all other buses, high-speed rail, aviation, and off-road vehicles.

Urban Transit Buses

The largest transit agencies in California have filed rollout plans with CARB for implementing the Innovative Clean Transit (ICT) regulations. These plans indicate how each transit agency anticipates purchasing new vehicles to meet the ICT requirements.

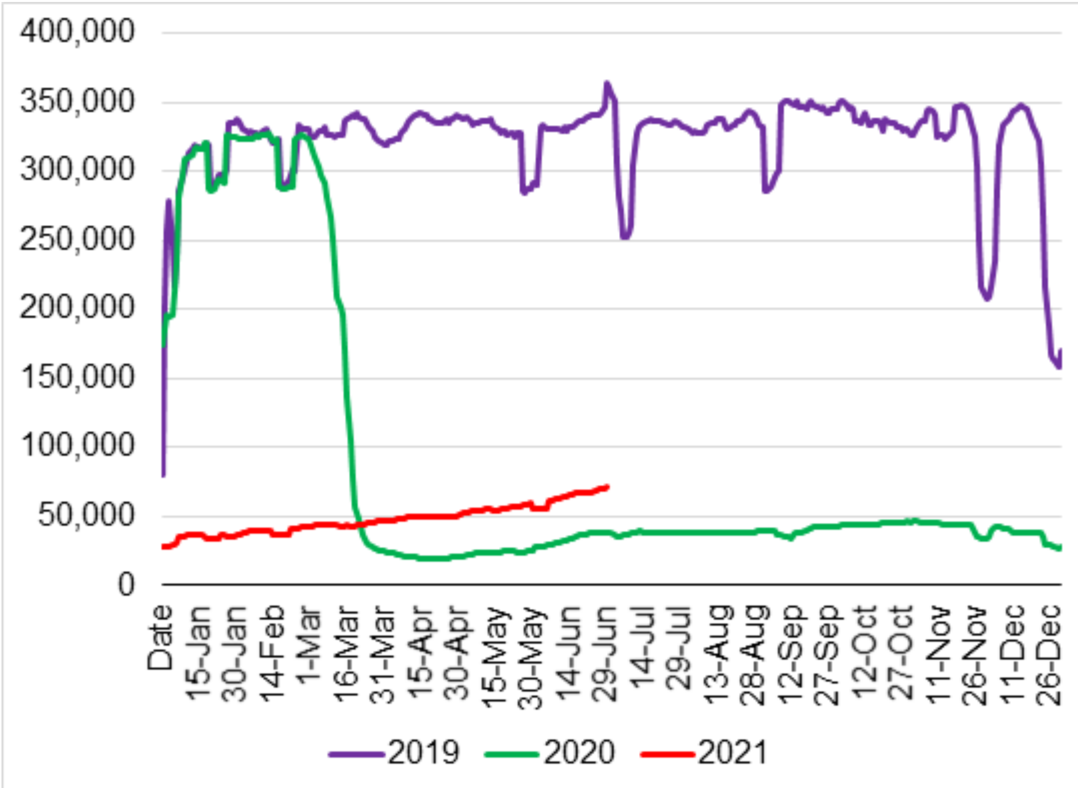
The ICT rollout plans form the foundation for the forecast of fuel consumption by transit agencies. The ICT regulations require diesel and fossil gas bus purchases to be gradually phased out by 2029 and a complete transition to zero-emission buses in an agency's fleet by 2040. Combustion vehicles in an agency's fleet are also required to use renewable diesel or renewable gas, with some exemptions for smaller agencies, beginning in 2020.

The rollout plans generally do not consider a drop in ridership due to lingering effects from COVID-19. Mass transit ridership has been impacted much more severely than travel by automobile, but this does not have a substantial impact on total travel because transit ridership accounts for a small proportion of travel. Before COVID-19, only 5 percent of the California workforce used public transit to commute to work.[58] An extreme experience of the large decline in mass transit ridership is that of the BART system, for which ridership plummeted by 94 percent from 2019 levels in just a few days during April 2020 (Figure 34). Ridership has recovered only slightly since then — as of June 2021, it remained 80 percent below 2019 levels. This decline, especially slow to recover, poses problems for transit agencies

58 Staff calculation from U.S. Census Bureau, American Community Survey. Table K200801. Means of Transportation to Work, California. Accessed 3 Dec 2021. https://data.census.gov/cedsci/table?q=United%20States&t=Commuting&g=0400000US06&d=ACS%201-Year%20Supplemental%20Estimates.

and creates difficulties in forecasting both the number of transit buses and related fuel consumption.

Figure 34: BART Daily Ridership, Seven-Day Moving Average



Source: Metropolitan Transportation Commission, Monthly Transportation Statistics

Other Buses

This category includes demand-response vehicles (such as dial-a-ride buses), school buses, airport and hotel shuttle buses, medium and heavy motor homes,[59] and a category for buses not accounted for elsewhere. Fuel economy for other buses and motorhomes were provided by contractor ICF, based on values in EMFAC2021. Fuel economy for demand response vehicles is drawn from the National Transit Database.

59 Medium-sized motor homes range from 10,001 to 26,000 pounds gross vehicle weight, while large motor homes are 26,001 pounds or greater.

High-Speed Rail

The forecast for high-speed rail comes from the High-Speed Rail (HSR) Authority's most recent Business Plan,[60] as well as its presentation during the July 2021 Demand Analysis Working Group (DAWG) Meeting.

Off-road

CEC staff forecasted annual statewide electricity demand for charging off-road vehicles and equipment in select sectors, including cargo handling equipment, airport ground-support equipment, forklifts, transportation refrigeration units, commercial harbor craft, construction equipment, and agriculture equipment. Generally, staff used statewide population inventories multiplied by typical activity parameters to determine annual electricity demand. Where appropriate, staff aligned projected population inventories with CARB and incorporate the effects of any expected CARB regulatory actions. As well as this electricity demand forecast, staff will publish a standalone off-road charging analysis as part of the CEC's 2022 AB 2127 analysis.

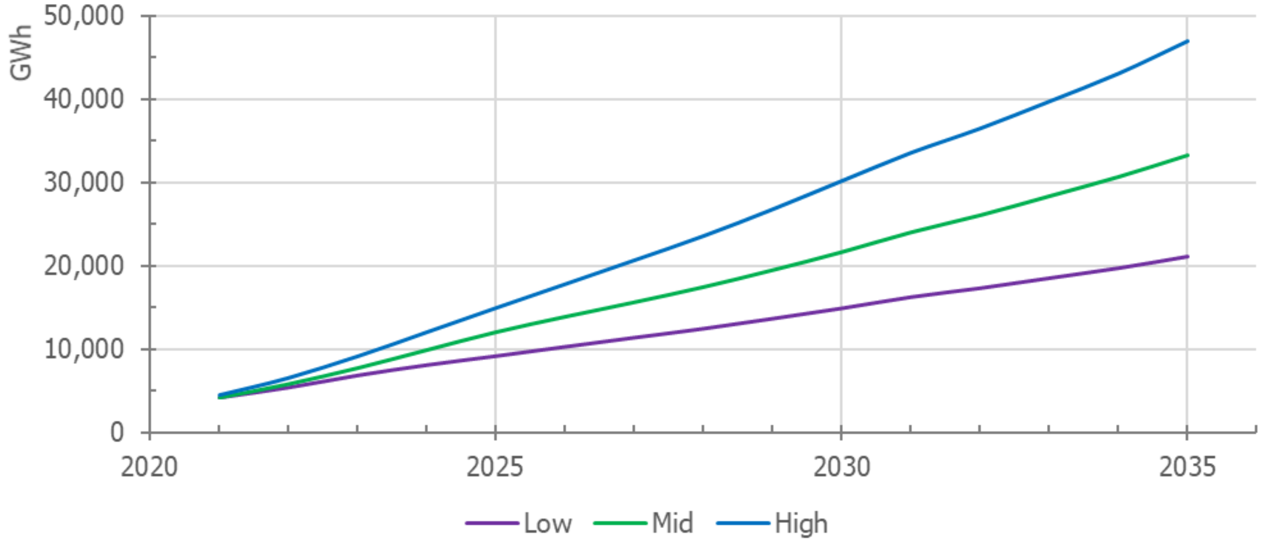
Transportation Electricity Demand Forecast Results

CEC staff presented ZEV forecast results at an IEPR workshop on December 2, 2021. The transportation forecast is integrated into the larger California energy demand forecast. Results include electricity demand for light-duty, medium- and heavy-duty trucks, urban transit, and high-speed rail, through 2035, shown in Figure 35.[61] In the mid-electricity demand case, the transportation electricity consumption represents approximately 6.7 percent of overall forecasted electricity consumption in 2030.

60 California High-Speed Rail Authority, 2020 Business Plan. https://hsr.ca.gov/wp-content/uploads/2021/04/2020_Business_Plan.pdf.

61 December 2, 2021, IEPR Commissioner Workshop on the Electricity and Natural Gas Demand Forecast for 2021–2035: Transportation Forecast and Demand Scenarios Project webpage. https://www.energy.ca.gov/event/workshop/2021-12/session-2-iepr-commissioner-workshop-electricity-and-natural-gas-demand.

Figure 35: Transportation Electricity Demand Forecast



Source: CEC Staff

ZEV Forecast Results

Staff generated forecasts of both light and medium-heavy duty ZEVs. Forecast results for ZEVs are shown below, first for light-duty vehicles, and then for medium- and heavy-duty vehicles.

Light-Duty Vehicle Results

The CEC's forecast shows an increase in light-duty ZEV population to more than 3.7 million vehicles on the road in 2030 in the mid-case and more than 5.5 million in the high-case, as shown in Figure 36 below. The vast majority of these ZEVs in 2030 are PEVs, with about 88,000 being FCEVs and plug-in FCEVs. The forecast for fuel cell electric vehicles is generally consistent with the vehicle manufacturer's stated projections provided in the CEC and CARB joint report for Assembly Bill 8.[62] In 2030, light-duty ZEVs account for 10.9 percent of all LDVs on the road in the mid case and 15.6 percent in the high case. In the aggressive and bookend

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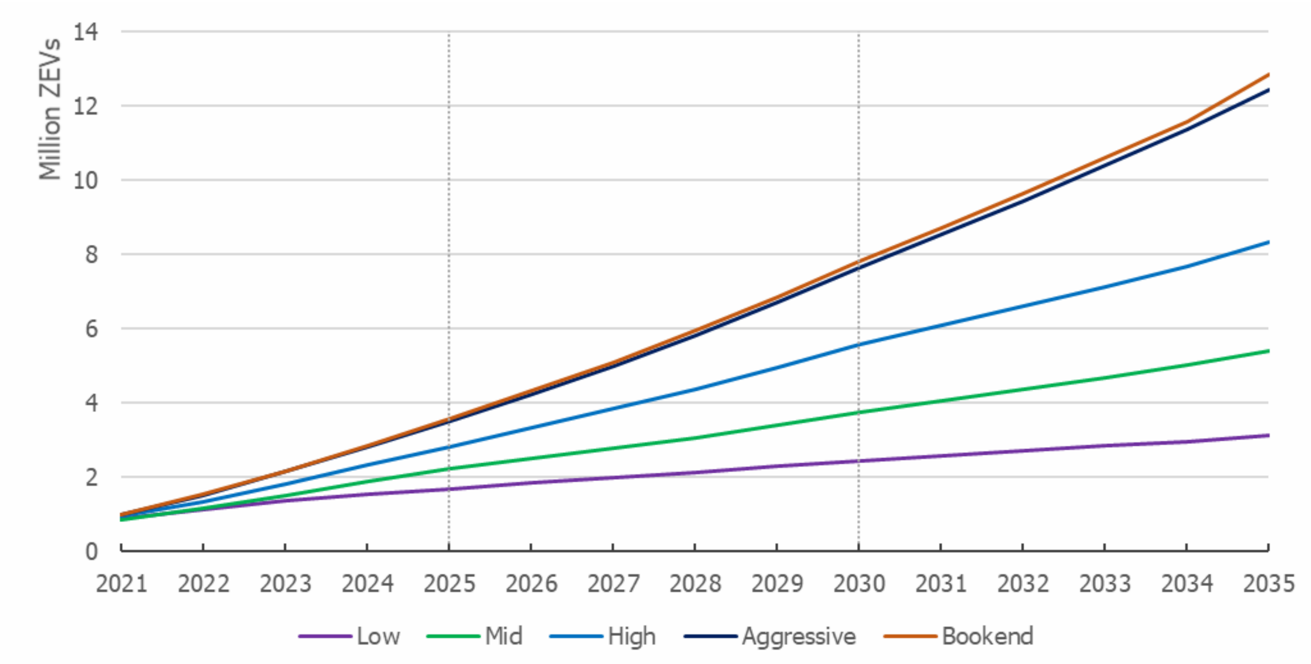
62 Baronas, Jean, and Belinda Chen. 2021. *Joint Agency Staff Report on Assembly Bill 8: 2021 Annual Assessment of Time and Cost Needed to Attain 100 Hydrogen Refueling Stations in California*. California Energy Commission. Publication Number: CEC-600-2021-040. p. 32. https://www.energy.ca.gov/publications/2021/joint-agency-staff-report-assembly-bill-8-2021-annual-assessment-time-and-cost.

The stated manufacturer projections go to 2027 in the report, at 61,100 fuel cell electric vehicles. The IEPR forecast cases for all light-duty fuel cell electric models are about 48,000 and 114,000 for the mid and high cases, respectively.

cases designed to reflect the most optimistic circumstances of the total LDV market, the light-duty ZEV stock is 21.3 percent (7.7 million) and 21.8 percent (7.8 million), respectively. It is important to acknowledge that these forecasts differ from the methods discussed in the demand scenarios section, which explores the new and more aggressive state policies to increase ZEV adoption.

Figure 36: Light-Duty ZEV Population by Forecast Case



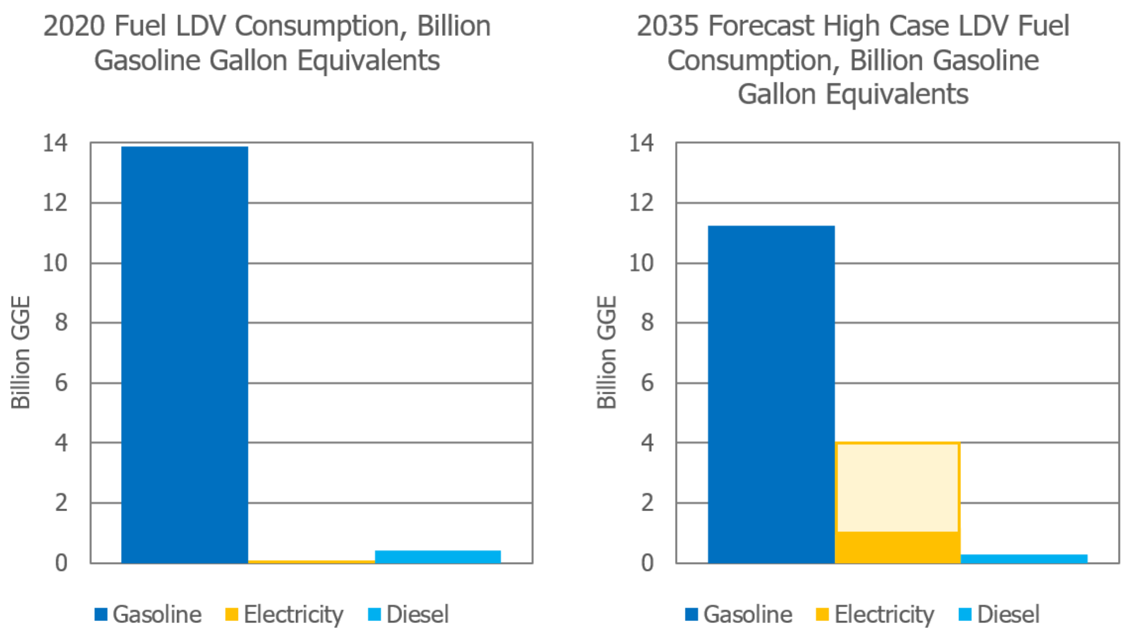
Source: CEC

In terms of existing state goals, the 1.5 million ZEV population achievement for 2025 established by Executive Order B-16-12 is forecasted to be readily accomplished, even in the low case. Executive Order B-48-18 has a goal of 5 million ZEVs on the road in 2030. This is surpassed in the high, aggressive, and bookend cases, but is not forecasted to occur in the mid and low cases.

Looking at 2035, ZEVs represent roughly 33 percent, 48 percent, 73 percent, and 79 percent of the respective mid, high, aggressive, and bookend sales of new light-duty vehicles. These do not fully align with the percent ZEV sales targets established in Executive Order N-79-20, suggesting the need for additional market interventions. It is important to emphasize, however, that as a demand forecast, these results do not incorporate currently nonexistent policies, such as CARB's Advanced Clean Cars II, which is currently in development. Chapter 4 explores potential impacts in scenarios associated with more aggressive policy-compliance and greenhouse gas mitigation efforts.

While ZEV stocks are a useful metric to evaluate in the ZEV forecast, discussion during the December 2, 2021, IEPR Commissioner workshop highlighted the forecast's potential to assess "displaced gasoline" from increased light-duty PEV adoption. Because PEVs use energy more efficiently to produce motive power, a conservative energy efficiency ratio of 3.3 may be used to roughly estimate gasoline that PEVs avoid, rather than simply considering the primary energy that each vehicle type consumes. In the chart on the right side of Figure 37 below, the solid (middle) yellow bar shows the raw energy used by PEVs in the 2035 high case, but the height of the hollow yellow bar shows the approximate gasoline energy avoided by using more efficient plug-in electric vehicles. While gasoline vehicles in this case use about 11.2 billion gallons of gasoline, PEVs taken as a whole avoid about 4 billion gallons of gasoline that would otherwise be burned if the PEVs were not adopted.

Figure 37: Light-Duty Vehicle Energy Consumption for 2020 and 2035 (High Case)

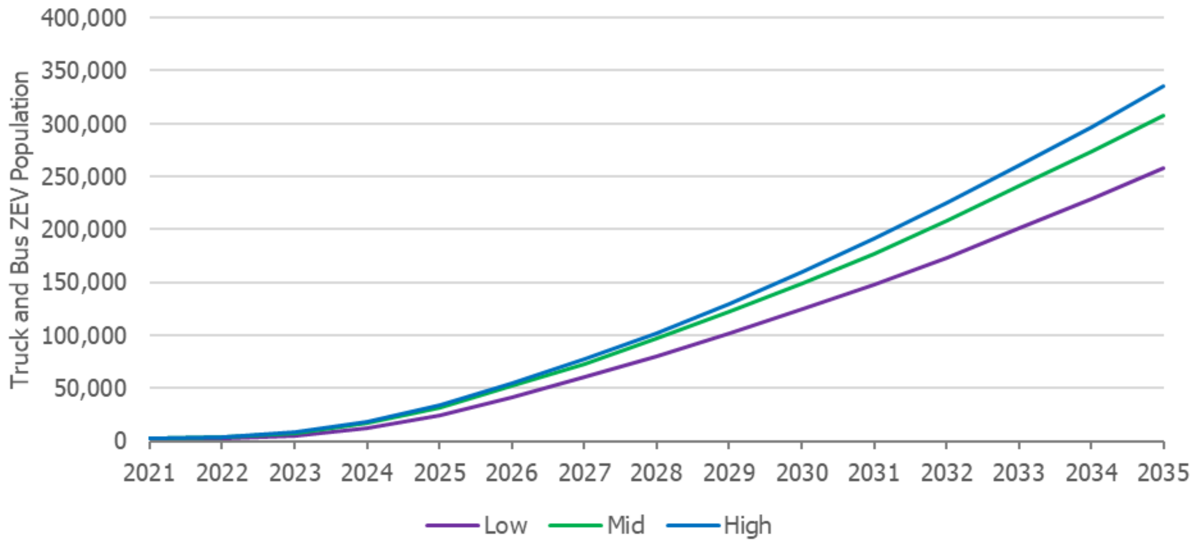


Source: CEC

Medium- and Heavy-Duty Vehicle Results

The medium- and heavy-duty vehicle forecast shows an expansion of ZEV, low NOx, and other advanced technology vehicle sales among trucks and buses, assisted by policies such as HVIP, ACT, and CARB’s ICT regulation. See Figure 38 below for the ZEV forecast.

Figure 38: Zero-Emission Truck and Bus Stock by Forecast Case



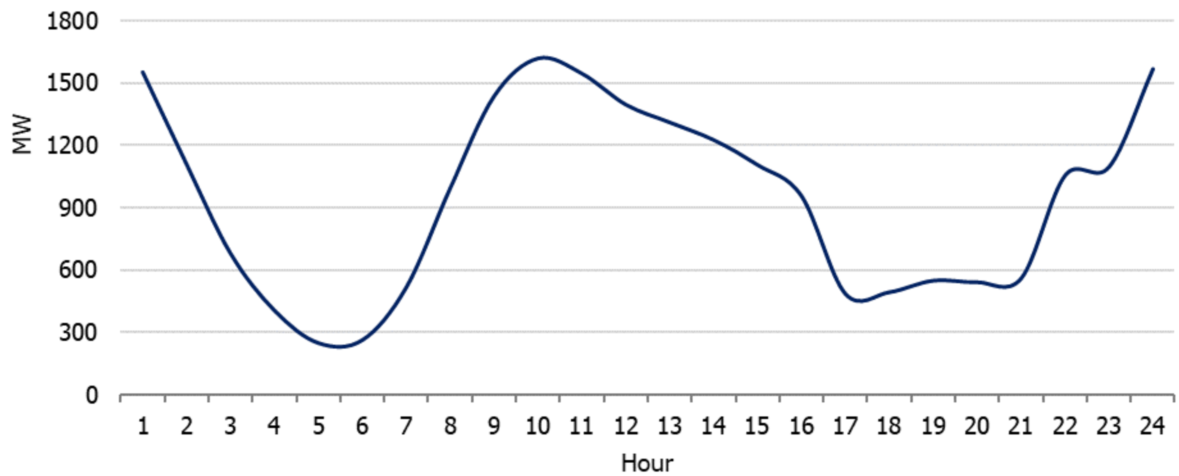
Source: CEC

Battery-electric trucks achieve a 22 percent share of total truck stock in 2035 in the high-electricity demand case and also have a 21 percent share in the mid-electricity demand case. The increase in battery-electric truck adoption is primarily due to decreasing truck prices, combined with the overall total cost of ownership advantage from reduced maintenance and lower fueling costs. Due to different economic and demographic inputs for the high case, hydrogen fuel cell trucks represent a significant additional share of the ZEV population in 2035, about 2 percent of trucks (about 36,000), as opposed to less than 1 percent of trucks (about 15,000) in the mid case. Hydrogen trucks in the forecast are typically Class 8 vehicles, so their share is larger for that class. Low NOx gas Class 8 tractor-trailers also show sustained growth throughout 2030, with about 41,000 vehicles on the road in 2030 and about 43,600 vehicles by 2035. Compared to ZEVs, growth of gas trucks is not as pronounced, but price advantages in the 2020s make them competitive. Increasing sales and price improvements for Class 8 tractor-trailer ZEVs leads to an advantage that shifts in their favor shortly after 2030. The state's low carbon fuel standard provides a strong incentive to use renewable gas as a transportation fuel, resulting in potentially low effective greenhouse gas emissions. For further discussion of greenhouse gas impacts, please see Chapter 4 of this volume.

PEV Charging Load Shape Updates

CEC staff uses the EV Infrastructure Load model to evaluate annual plug-in electric vehicle (PEV) electricity forecasts on an hourly basis for a typical day.[63] The model accounts for hourly shifts in PEV electricity demand by adjusting standard consumer charging profiles in response to price sensitivity from time-of-use (TOU) rates. For the *2021 IEPR*, the TOU rates were updated to reflect the most current rates available from IOUs. See Figure 39 below for an example daily load profile in the California ISO region.

Figure 39: Mid Case Average LDV Load, California ISO Summer Weekday, 2035



Source: CEC

For light-duty personal vehicles, charging locations align with the most recent analysis published in the AB 2127 Electric Vehicle Charging Infrastructure Assessment report.[64] For medium- and heavy-duty vehicles (MD-HD), the load model uses twelve MD-HD class specific base load shapes to disaggregate annual forecasted demand to hourly electricity demand. To update base load shapes, staff leverage updated analysis from the Medium- and Heavy-Duty Electric Infrastructure Load, Operations, and Deployment (HEVI-LOAD) model. The HEVI-

63 Baroiant, Sasha, John Barnes, Daniel Chapman, Steven Keates, and Jeffrey Phung. 2019. *California Investor-Owned Utility Electricity Load Shapes*. California Energy Commission. Publication Number: CEC-500-2019-046. https://www.energy.ca.gov/sites/default/files/2021-06/CEC-500-2019-046.pdf.

64 Alexander, Matt, Noel Crisostomo, Wendell Krell, Jeffrey Lu, and Raja Ramesh. July 2021. *Assembly Bill 2127 Electric Vehicle Charging Infrastructure Assessment: Analyzing Charging Needs to Support Zero-Emission Vehicles in 2030 – Commission Report*. California Energy Commission. Publication Number: CEC-600-2021-001-CMR. https://efiling.energy.ca.gov/getdocument.aspx?tn=238853.

LOAD model, developed under collaboration between the CEC and Lawrence Berkeley National Laboratory, serves to identify regional charging infrastructure needs in accordance with AB 2127.[65] Details on HEVI-LOAD updates as well as information on base load shapes were provided at the DAWG meeting on September 14, 2021.[66]

65 Ibid.

66 Presentations from the September 30, 2021, DAWG meeting are available at https://www.energy.ca.gov/event/meeting/2021-09/demand-analysis-working-group-dawg-meeting-proposed-updates-california-energy.

CHAPTER 4: Long-Term Energy Demand Scenarios

Energy demand forecasting has been a core agency activity since the beginning of the California Energy Commission (CEC). Over the decades, the products developed have evolved to meet internal needs, the needs of client agencies, and the needs of policy makers. The increasing policy and planning focus on climate change in recent years has accentuated the need for developing longer-term demand projections and supply-side consequences for all energy forms. Because time horizons further out necessarily involve increased uncertainty, CEC staff has been reluctant to use the term "forecast" to describe possible energy demand to 2050. Instead, the term "demand scenarios" has been coined to reflect that any one specific projection is just one of several scenarios that result from assessing a set of assumptions with numerous uncertain values.

Although developing a set of demand scenarios has intrinsic value, this value is enhanced when demand scenarios are assessed for supply-side and greenhouse gas (GHG) consequences. Demand scenarios and their assessments which provide objective, independent information are vital inputs into setting or periodically reassessing California's energy and GHG emission reduction goals. These scenario assessments can provide a sense of how easy or difficult it may be to achieve those goals and provide insights into the need for incentives or programs that target customers and industries that may not adapt through market forces alone.

The CEC formally began this work in the 2021 Integrated Energy Policy Report (IEPR) cycle and were the subject of discussion at a December 2, 2021, workshop. The analysis, scenarios, and results will be finalized and presented publicly in early 2022.

Demand Scenarios: A New Product for Long-Term Economywide Energy and GHG Assessments

Staff in the CEC's Energy Assessments Division has embarked on a new long-term demand scenario development and assessment project to identify energy demand and supply consequences, as well as GHG emission reductions from existing and near-term policies. This project is a major undertaking that will take several years to fully implement. Although formally launched during the 2021 IEPR cycle, initial CEC staff efforts began with the Assembly

Bill 3232 (Friedman, Chapter 373, Statutes of 2018)[67] building decarbonization study. The study developed numerous demand scenarios for the residential and commercial sectors and conducted assessment of extensive electric generation sector impacts. Although the time horizon of the AB 3232 study was only out to 2030, the emission consequences of demand-side fuel substitution accomplished through 2030 were assessed out to 2045 to allow life-cycle impacts to be calculated.

Starting in the *2021 IEPR* and to be continued into 2022, building decarbonization and transportation electrification demand scenarios will be developed out to 2050. Traditional forecasting models in the residential, commercial and transportation sectors and supplemental tools developed for Senate Bill 350 (De León, Chapter 547, Statutes of 2015)[68] energy efficiency doubling assessments and fuel substitution tools developed for AB 3232 have been extended out to 2050. Other demand-side sectors (industry, agriculture, water pumping) will be added in future IEPR cycles. In the meantime, the results of staff's assessments replace corresponding sector energy demand in a customized version of the E3 PATHWAYS model to allow a holistic view across all sectors, all fuel types, and thus for nearly all anthropogenic GHG emissions sources.

Using these upgraded assessment tools, staff will assess multiple scenarios and some sensitivities for specific components of these scenarios in terms of end-user energy demand and GHG emissions. These scenarios encompass continuation of current policies and regulatory requirements, the addition of near-term policy actions that build upon business-as-usual efforts, and much more aggressive actions needed to accomplish economywide decarbonization goals. Of course, end-user energy demand and direct emissions resulting from energy use is not the whole story. Energy use and GHG emissions result from supply-side industries that generate, transmit, and distribute energy for use by end users. This initial assessment relies upon the modeling formulations and other assumptions built into the E3 PATHWAYS model to develop supply-side impacts consistent with final energy demand. Assessing supply-side impacts will be initiated for the electric generation sector in the *2022 IEPR Update* and for the remaining supply-side industries (refineries producing petroleum fuels, biomethane feedstock blended into gas pipelines, propane separation from oil/gas extraction) in future IEPR cycles.

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67 Assembly Bill 3232 (Friedman, Chapter 373, Statutes of 2018), https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180AB3232.

68 Senate Bill 350 (De León, Chapter 547, Statutes of 2015), https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB350.

If known policies fail to achieve long-term decarbonization goals, this evolving assessment provides opportunities to understand the limitations of existing policies and the need for additional policies to meet those goals.

Demand Scenarios

How are demand scenarios different from demand forecasts described in earlier chapters? The further out in time projections are made, the greater the uncertainty about input assumptions or even relationships within a modeling tool. For nearly 20 years, the demand forecast has referred to the next 10 years. This is the forward time horizon that balanced reasonable levels of demand certainty with the lead time for procuring and constructing supply-side infrastructure (generation and transmission primarily). All of the key electricity planning processes at the California Public Utilities Commission (CPUC) and the California Independent System Operator (California ISO) use the CEC's 10-year forecast and base most firm commitments and contractual procurement on this time horizon.

However, the further out into the future, the greater the uncertainty of any number of key factors that are the natural basis for energy demand (population growth, housing development, business activity directly supporting California residents, commercial and industrial businesses exporting products to the rest of the nation and around the world). Uncertainty about the energy policies and regulations must also be added.

The demand scenarios project can approach those many uncertainties by creating multiple sets of projections and looking for common outcomes across many scenarios. No single set of energy demand projections will provide the needed clarity to base major long-term commitments or investment decisions. As a result, staff have chosen to reserve the term *demand forecast* for the existing 10-year time horizon that the CPUC and California ISO use to make commitments for new generating resource development or new transmission lines. Staff adopted the term *demand scenarios* to describe a set of longer-term projections to inform thinking about the implications of trying to achieve long-term goals.

Demand scenarios are designed to be a more comprehensive examination of demand-side fuel shifts, supply-side consequences of demand changes, and cross-cutting metrics such as GHG emissions and costs. They typically focus on a long-term horizon and include a variety of fuel types in the analysis. However, the precision is somewhat reduced for scenarios compared to forecasts as greater breadth is covered.

Scenarios also enable a more complete assessment of uncertainties such as economic and demographic variables outside the forecast range, technology cost reductions and performance improvements through time, assumptions about consumer adoption and behavior, and any goals that may not yet have translated to policies.

Scenario Design

The terms *reference scenario* and *mitigation scenario* have been used in numerous California Air Resources Board (CARB), CEC, and CPUC engagements in which E3[69] uses its PATHWAYS model to provide GHG emission projections. E3 has typically characterized these scenario designs based on assumptions about the penetration of various end-user energy-consuming devices reflecting fuel type changes combined with energy efficiency assumptions. The demand scenario project, however, emphasizes a different perspective.

The CEC project seeks to quantify the impact of existing regulatory requirements and program incentives, heightened efforts to achieve compliance with existing requirements, and intermediate goals and mechanisms that until now have not been commonly thought of as means to achieve GHG emission reductions. Whereas E3 has generally explored several themes,[70] this initial phase of the demand scenarios project focusses exclusively on electrification. Staff expects to address further themes in future IEPR cycles.

Staff will develop and quantify impacts of three types of scenarios for this project — a reference scenario, a policy/compliance scenario, and a mitigation scenario. All stress electrification is the basic theme, and so the results will show the impacts of a growing combination of regulations, programs, and policies with electrification as the objective.

Reference Scenario

- This is a business-as-usual scenario using the same core assumptions as the CEC adopted, managed mid-mid demand forecast through 2035.
- Beyond 2035, the reference scenario assumes continuation of the same set of standard-setting processes, relatively constant spending on utility and other retrofit programs, and existing levels of compliance with standards or regulations as reflected in the CEC adopted managed demand forecast.
- This scenario serves as reference against which policy/compliance scenario and sensitivities and mitigation scenarios are assessed. This comparison helps determine how much more needs to be accomplished after the contribution of existing processes, or limited improvements upon them, have been exhausted.

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69 E3 refers to Energy and Environmental Economics, Inc.

70 For example, in the recent Senate Bill 100 (De León, Chapter 312, Statutes of 2018) assessment, E3 used preexisting scenarios that reflected high electrification alone, high electrification in combination with high penetration of hydrogen, and high electrification with high penetration of biomass resources.

Policy/Compliance Scenario and Sensitivities

- The policy/compliance scenario is developed by sequentially layering multiple discrete elements, where each element can illustrate the contributions of a policy initiative to induce changes in energy demand and thus GHG emission reductions.
- The compliance elements of this scenario are essentially quantification of standards, programs, and incentives included in the reference scenario at less than full compliance but are brought up to a higher level or even full compliance.[71]
- The policy elements of the policy/compliance scenario add impacts of policies that are not fully included in the reference scenario because of lack of knowledge, difficulties in precisely quantifying impacts, uncertainty about implementation success, or other reasons.[72]
- The incremental difference between the reference and policy/compliance scenario is the impact of fully achieving the intended goal of policy/regulation/program.

Mitigation Scenario

- The mitigation scenario is aspirational and is designed to show one or more ways that goals stated in terms of results might be achieved. For example, Senate Bill 32, which required a 40 percent reduction of GHG emissions by 2030, or Executive Order B-16-2012, directing 80 percent reduction of GHG emissions by 2050 are stated in terms of broad sectoral GHG emission reductions but do not identify how to achieve the goals.
- For the initial rollout of the mitigation scenario, staff will add additional standards, programs, and policies onto those already included in the policy/compliance scenario

71 For example, the CEC promulgates Title 24 Building Energy Efficiency Standards every three years. These are extremely detailed and include numerous alternative ways in which a builder can trade off one element for another. This complexity makes the job of the local building inspector difficult. As a result of incomplete training, lower-than-desired staffing levels, and options that are difficult to assess, building construction does not always fully achieve the requirements intended. These shortfalls are not fully understood, and so the demand forecast makes assumptions about the energy consequences of non-compliance. If one assumes that better training, higher staffing levels at local building departments, and other factors causing noncompliance were implemented, then energy consumption in all newly constructed buildings built thereafter would be reduced.

72 For example, the South Coast Air Quality Management District (SCAQMD) instituted oxides of nitrogen (NOx) emission limits on standard gas combustion equipment such as water heaters. Generally, water heater manufacturers have been able to devise low NOx burners for water heaters, so SCAQMD regulations have had little impact on fuel choice for appliances. If SCAQMD believes that it needs to further tighten NOx emissions to achieve federal ozone ambient air quality standards, then a further ratchet of burner emission requirements could induce shifts to electric technologies inducing emission reductions for NOx and GHG. As many state and local agencies step up their focus on GHG emissions, activities once thought inconsequential from an energy and GHG perspective may become more critical to GHG emission reduction goals.

until the list of quantifiable policies is exhausted, and then additional penetration of low-GHG technologies will be added until goals are achieved.

- The gap between the policy/compliance scenario and the mitigation scenario reflects the need for further policy development, new program designs, additional incentives within existing programs, or additional approaches not yet articulated and quantified.

Analytic Approach

Approach for Assessing Demand Scenarios in *2021 IEPR*

Staff will create initial demand scenarios by adapting and extending existing models and tools where appropriate and feasible. A few include the sector specific demand forecast models, the additional achievable energy efficiency (AAEE) savings projection tool, the fuel substitution scenario analysis tool (FSSAT), and transportation demand forecasting models. The scenario assessment process will also include understanding what long-term impacts of existing rules, regulations, and policies would be.

The effort will focus on linking reference scenario projections to the CEC's demand forecasts for electricity and gas for the residential and commercial sectors and for all fuels in the transportation sector. It also includes developing a policy/compliance scenario and a mitigation scenario for the high electrification theme and separate sensitivities for various component regulations and policies to trace the likely pattern of GHG emission reductions through time to 2050.

This effort started with working internally to extend the CEC's demand forecast models to 2050. Staff is collaborating with E3 to adapt their PATHWAYS model (Adapted PATHWAYS) to selectively replace internal data inputs and calculations with external inputs from CEC staff. The staff-supplied inputs to Adapted PATHWAYS will include energy projections for electricity and natural gas for the residential and commercial sectors, and all fuels in the transportation sectors using the *2021 IEPR* economywide "economic/demographic" projections, projected occupied households and projected commercial floorspace extended beyond the 2035 final year for the demand forecast out to 2050.

For the residential and commercial sectors, staff assessed the energy consequences of each scenario using the following steps:

- Develop a baseline energy demand projection using the adapted residential and commercial demand forecasting models.
- Develop load modifiers representing programmatic energy efficiency and fuel substitution impacts using the adapted AAEE/AAFS projection tools.
- Use the FSSAT model to develop additional elements of building electrification as needed to satisfy the specification of a particular scenario. This model was also used in

the AB 3232 analysis which was described in the California Building Decarbonization Assessment Report.[73]

For the transportation sector, the transportation energy demand models will be used, which contain key parameters and inputs used to characterize program incentives and mandates.

Staff will provide the energy projections for each scenario to E3 for inclusion in the Adapted PATHWAYS model to generate energy demand and GHG emission consequences that cover all demand sectors for all relevant energy types. Once the analysis is completed, staff and E3 will present the demand scenarios results publicly in early 2022.

Demand Scenarios Framework

Tables 4, 5, and 6 depict the sectors/energy type combinations modeled using staff's capabilities versus those combinations modeled using Adapted PATHWAYS.

73 Kenney, Michael, Nicholas Janusch, Ingrid Neumann, and Mike Jaske. 2021. *California Building Decarbonization Assessment*. California Energy Commission. Publication Number: CEC-400-2021-006-CMF. https://www.energy.ca.gov/data-reports/reports/building-decarbonization-assessment.

Table 4: Reference Scenario Framework

Sectors	Inputs	Electricity	Natural Gas	Traditional Fuels in Transportation	Traditional Fuels Outside Transportation
Residential/ Commercial	Baseline Forecast	2021 IEPR Mid Residential/ Commercial Forecast	2021 IEPR Mid Residential/ Commercial Forecast	N/A	PATHWAYS Variables
Residential/ Commercial	AAEE (Programmatic Contributions From EE/FS Tool)	Mid-Mid Business-as-Usual BAU (Scenario 3)	Mid-Mid Business-as-Usual BAU (Scenario 3)	N/A	PATHWAYS Variables
Residential/ Commercial	AAFS, Programmatic Contributions From EE/FS Tool	Mid-Mid Business-as-Usual BAU (Scenario 3)	Mid-Mid Business-as-Usual BAU (Scenario 3)	N/A	PATHWAYS Variables
Residential/ Commercial	Additional Speculative Contribution from FSSAT	None	None	N/A	PATHWAYS Variables
Transportation	Baseline Forecast	2021 IEPR Mid Transportation Forecast	2021 IEPR Mid Transportation Forecast	2021 IEPR Mid Transportation Forecast	N/A
Other Sectors (Industrial, Oil & Gas Extraction, Agriculture, Petroleum Refining, etc.)	PATHWAYS Model	PATHWAYS Variables	PATHWAYS Variables	N/A	PATHWAYS Variables

Source: CEC

For the *reference scenario*, staff will assess the sectors below:

Residential and Commercial: The residential and commercial consumption forecasts for 2050 will be extensions of the 2022–2035 baseline forecasts prepared for the *2021 IEPR*. The baseline forecast process is driven by economic and demographic projections and a wide range of committed efficiency program- and standards-induced savings. To generate the 2050 demand scenario baseline forecasts, staff will adapt the sector demand forecasting models to make projections out to 2050 and then expand the input variables for the models with the additional years of economic and demographic driver data from the Department of Finance and Moody's Analytics.

Developing a reference scenario requires adjusting the baseline projections for the impacts of incremental energy efficiency and fuel substitution programs reflecting a "business-as-usual" perspective. In staff's judgment, such "business-as-usual" energy efficiency savings are best reflected by AAEE Scenario 3, which has long been the standard choice for a managed demand forecast used by the CPUC and California ISO for general generation and transmission system planning and procurement.[74]

As also explained more fully in Chapter 2, the CEC is adding fuel substitution as a load modifier in parallel to the structure long established for AAEE. Like AAEE, AAFS will have several scenarios encompassing limited to expansive shifts from natural gas consumption to electricity through time. The two general components of AAFS are programmatic contributions and more speculative contributions. The same general elements from AAEE will also be updated to capture fuel substitution impacts if they occur in that data stream. For each of these programmatic elements, scenarios can be based on dialing up or down various assumptions or levers from what is assumed in the business-as-usual case. The FSSAT Model will also be used to add additional fuel substitution at a technology level for programs that are still in development. For the reference case, staff selected an AAFS scenario that encompassed only a limited set of fuel substitution programs that exist today or that have already been adopted and will be implemented in the coming year.

Transportation: The transportation reference scenario will comprise the mid-case 2021 IEPR forecast, which covers 2022–2035, and an extension of the forecast to 2050 using the same policy framework. No new regulations or incentives will be added. Staff will add projections of vehicle attributes where appropriate, such as continued expected decreases in battery costs after 2035. In terms of electrification, the battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) are the major contributors to energy demand, whereas other ZEVs, such as fuel cell electric vehicles (FCEVs) and plug-in hybrid fuel cell electric vehicles

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74 AAEE will come entirely from programmatic contributions developed in our newly updated and enhanced Energy Efficiency/Fuel Substitution Data Aggregation and Projection Tool. As explained in detail in Chapter 2 of this Volume, this tool has been updated to reflect new inputs and to recognize that some programs formerly thought of as energy efficiency delivery mechanisms actually include fuel substitution measures as well. In such cases the measures have been classified as energy efficiency or fuel substitution to extent possible. The tool also now includes multiple programs whose goal is exclusively fuel substitution.

(PHFCEVs) will have a lower impact on electricity demand. The assumptions used for the reference scenario are shown in Table 5.

Table 5: Transportation Reference Scenario Assumptions

	2022–2035	**Post 2035**
Federal Tax Credit	Decreasing through 2035	None
California Vehicle Rebate Project (CVRP)	To 2025	None
Clean Fuel Rewards Program	2022 to 2030	None
Number of LDV Classes with ZEVs Available in 2035 (out of 15 CEC LDV classes), Average Available Models per Class	BEV: 15, 26 PHEV: 14, 3 FCEV: 4, 2 PHFCEV: 2, 2	Values across ZEV categories in development, to be presented in the final IEPR draft
Plug-In Vehicle/Battery Price	LDV prices based on battery price declining to ~$69/kWh in 2035; MD-HD prices based on a 5-year lag from LDV battery prices; general decline in all ZEVs due to technology improvements	Continued battery price decline to ~$67/kWh in 2050; MD-HD prices based on a 5-year lag from LDV battery prices
Range for a Midsize LD ZEV (Miles)	BEVs: ~300 by 2035 FCEVs: ~350 by 2035	BEVs: ~300 FCEVs: ~350
Percentage ZEV Sales for New Light-Duty	Unconstrained	Unconstrained
Percentage ZEV Sales for Medium- and Heavy-Duty (MDHD)	Alignment with ACT requirements	Alignment with ACT requirements
Hybrid and Zero-Emission Truck and Bus Voucher Incentive Project (HVIP)	Decreases in proportion to truck prices	Continued decline in proportion to truck prices
ICE MD-HD Retirement Rates	Standard	Standard

Source: CEC

For the remaining sectors and for all the scenarios, the version of the PATHWAYS model that was used for the 2020 CARB Carbon Neutrality report will be used. It is similar to the model used in the 2018 Deep Decarbonization project. The main update for this project, other than the inclusion of Residential/Commercial/Transportation fuel demands from CEC staff, is that it will be benchmarked to the latest CARB GHG inventory.

Table 6: Policy/Compliance Scenario Framework

Sectors	Inputs	Electricity	Gas	Traditional Fuels in Transportation	Traditional Fuels Outside Transportation
Residential/ Commercial	Baseline Forecast	2021 IEPR Mid Residential/ Commercial Forecast	2021 IEPR Mid Residential/ Commercial Forecast	N/A	PATHWAYS Variables
Residential/ Commercial	AAEE (Programmatic Contributions From EE/FS Tool)	Mid-High (Scenario 4)	Mid-Mid (Scenario 3)	N/A	PATHWAYS Variables
Residential/ Commercial	AAFS, Programmatic Contributions From EE/FS Tool	Mid-Mid Plus (Scenario 4)	Mid-Mid Plus (Scenario 4)	N/A	PATHWAYS Variables
Residential/ Commercial	Additional FS, Speculative Contribution from FSSAT	Incorporate WH & SH NOx control measures from CARB 2022 SIP Strategy beginning in 2029 for BAAQMD and 2030 for the rest of the State	Incorporate WH & SH NOx control measures from CARB 2022 SIP Strategy beginning in 2029 for BAAQMD and 2030 for the rest of the State	N/A	PATHWAYS Variables
Transportation	Baseline Forecast	2021 IEPR Mid Transportation Forecast	2021 IEPR Mid Transportation Forecast	2021 IEPR Mid Transportation Forecast	N/A
Transportation	CARB State SIP Strategy (ACC II for LDV, ACF for MD-HD)	Incremental Impacts Beyond Reference Scenario	Incremental Impacts Beyond Reference Scenario	Incremental Impacts Beyond Reference Scenario	N/A
Other Sectors (Industrial, Oil & Gas Extraction, Agriculture, Petroleum Refining, etc.)	PATHWAYS Model	PATHWAYS Variables	PATHWAYS Variables	N/A	PATHWAYS Variables

Source: CEC

For the *high electrification policy/compliance scenario*, staff will assess the sectors below:

Residential and Commercial: To develop the policy/compliance scenario, staff will start with the baseline residential and commercial consumption forecasts for 2022–2035 and will extend it to 2050 just as the reference scenario. However, the baseline forecast is adjusted to reflect more aggressive energy efficiency and expansive fuel substitution impacts than were included in the reference scenario. For energy efficiency adjustments, the baseline scenario will be reduced by the savings from the electricity AAEE Mid-High (Scenario 4) and the natural gas AAEE Mid-Mid (Scenario 3).

For the portion of AAFS that comes from programmatic contributions, staff will use the Mid-Mid Plus (Scenario 4). These more aggressive AAFS scenarios take the existing elements in the business-as-usual AAFS Scenario 3 and increase them beyond reference scenario values for compliance rates, participation, and funding.

Lastly, staff will use the FSSAT tool to incorporate additional fuel substitution to assess the impacts of policy goals not yet converted to operating programs with firm delivery mechanisms or funding sources. As part of the upcoming State Implementation Plan to achieve federal and state criteria pollutant ambient air standards, CARB and some air quality management districts are proposing residential and commercial emission equipment standards that are so stringent that fuel combustion devices are unlikely to be able to meet the standard. This *de facto* fuel substitution requirement affects new water heater and space heater installations beginning in 2029 for the Bay Area AQMD and statewide in 2030. These requirements will be modeled using shifts in appliance sales share moving from natural gas to electricity.

Transportation: For the high-electrification policy/compliance scenario, staff will assign ZEV populations in general alignment with expected rules to be implemented under the State Strategy for the State Implementation Plan (State SIP). The State SIP is a plan that CARB develops to comply with federal Clean Air Act requirements, incorporating several policies to achieve this goal. For example, Advanced Clean Cars II (ACC II) is a rulemaking process in development that will establish regulatory requirements on vehicle manufacturers to achieve 100 percent light-duty ZEV sales by 2035. Other medium- and heavy-duty ZEV targets include those put forward in early discussions of the Advanced Clean Fleets regulation (ACF).

Table 7: Mitigation Scenario Framework

Sectors	Inputs	Electricity	Natural Gas	Traditional Fuels in Transportation	Traditional Fuels Outside Transportation
Residential/ Commercial	Baseline Forecast	2021 IEPR Mid Residential/ Commercial Forecast	2021 IEPR Mid Residential/ Commercial Forecast	N/A	PATHWAYS Variables
Residential/ Commercial	AAEE (Programmatic Contributions From EE/FS Tool)	Mid-High Plus (Scenario 6)	Mid-Mid (Scenario 3)	N/A	PATHWAYS Variables
Residential/ Commercial	AAFS, Programmatic Contributions From EE/FS Tool	Mid-High Plus (Scenario 6)	Mid-High Plus (Scenario 6)	N/A	PATHWAYS Variables
Residential/ Commercial	Additional FS, Speculative Contribution From FSSAT	CARB Scoping Plan Scenario Alternate 4	CARB Scoping Plan Scenario Alternate 4	N/A	PATHWAYS Variables
Transportation	Baseline Forecast	2021 IEPR Transportation Forecast	2021 IEPR Transportation Forecast	2021 IEPR Transportation Forecast	N/A
Transportation	CARB Mobile Source Strategy (Default Case)	Incremental Impacts Beyond Policy/ Compliance Scenario	Incremental Impacts Beyond Policy/ Compliance Scenario	Incremental Impacts Beyond Policy/ Compliance Scenario	N/A
Other Sectors (Industrial, Oil & Gas Extraction, Agriculture, Petroleum Refining, etc.)	PATHWAYS Model	PATHWAYS Variables	PATHWAYS Variables	N/A	PATHWAYS Variables

Source: CEC

For the *high electrification mitigation scenario*, staff will assess the sectors below:

Residential and Commercial: The residential and commercial consumption forecasts for 2035–2050 will again be extensions of the 2022–2035 baseline forecasts prepared for the *2021 IEPR*, but the energy efficiency and fuel substitution modifications are more extensive than in either the reference scenario or the policy/compliance scenario.

For energy efficiency adjustments, the baseline scenario will be reduced by the savings from the electricity AAEE Mid-High Plus (Scenario 6) and the natural gas AAEE Mid-Mid (Scenario 3). Staff analyses so far have noted that high levels of gas energy efficiency savings and high levels of fuel substitution cannot occur simultaneously, since for such combinations there is insufficient natural gas consumption to allow both to occur. In the higher scenarios for both AAEE and fuel substitution, these "conflicts" occur as early as 2040.

For the portion of the AAFS load modifier that comes from programmatic contributions, staff will use the Mid-High Plus (Scenario 6). These more aggressive AAFS scenarios take the existing elements in the business-as-usual AAFS Scenario 3 and increase them from reference scenario values to maximum achievable values for compliance rates, participation, and funding.

As described for the Policy/Compliance Scenario, the more speculative, nonprogrammatic impacts of fuel substitution will use assumptions about technology substitution in a *what if* manner. As part of its 2022 Scoping Plan effort, CARB has issued several documents describing scenarios encompassing a wide range of measures to reduce GHG emissions through time. In the residential and commercial building sectors, CARB proposes to assess appliance sales mandates that effectively require 100 percent electric appliance sales and some retrofit requirements. The more aggressive scenarios start these requirements sooner and have deeper retrofit specifications. For the mitigation scenario, staff chose Scenario Alternate 4 that requires new construction to be 100 percent electric beginning in 2029, 75 percent electric share for replacements in existing buildings beginning in 2030 rising to 100 percent by 2035, but no replacement prior to normal appliance burnout.[75] The FSSAT tool will be used to quantify the energy consequences of these speculative proposals.

Transportation: Analogous to the policy/compliance scenario, the mitigation scenario will assign more aggressive ZEV population proportions to align with the ZEV stock or sales goals associated with CARB's 2020 *Revised Draft Mobile Source Strategy* (2020 MSS). Due to different economic, demographic, and other differences in modeling approaches, final vehicle

75 CARB, 2022 Scoping Plan Update: PATHWAYS Scenario Modeling, December 15, 2021.

populations will differ from the 2020 MSS, but staff anticipate general alignment with it. The medium- and heavy-duty ZEV populations established in the 2020 MSS are also explicit, and staff will also use them to guide population assumptions. For off-road vehicle classes, the 2020 MSS is not explicit but establishes several guiding concepts, which will highly inform staff population assumptions. The mitigation scenario aligns with the 2020 MSS general concepts as much as possible where ZEV sales or ZEV population percentages are not explicit.

Results and Conclusions

As noted at the beginning of this chapter, the results and any conclusions from this new project are not yet available. Staff expects to conclude its initial round of analyses for this project in early 2022 and will hold a workshop to showcase the results and solicit input for consideration in future cycles of this project.

Acronyms

AAEE	additional achievable energy efficiency
AAFS	additional achievable fuel substitution
AB	Assembly Bill
ACC	avoided cost calculator
ACCII	Advanced Clean Cars II
ACF	Advanced Clean Fleets
ACT	Advanced Clean Trucks
ADM	ADM Associates, Inc.
AQMD	air quality management district
BAU	business-as-usual
BEV	battery-electric vehicle
BROs	behavioral, retro-commissioning, operations savings
BTM	behind-the-meter
BTM PV	behind-the-meter photovoltaic
BU	Beyond Utility
C&S	codes and standards
California ISO	California Independent System Operator
CARB	California Air Resources Board
CCA	community choice aggregator
CCA REN	community choice aggregator regional energy network
CEC	California Energy Commission
CED	California Energy Demand Forecast
CEDU	California Energy Demand Update
CEOP	Clean Energy Optimization Program
CMUA	California Municipal Utilities Association
CPUC	California Public Utilities Commission
CVR	conservation voltage reduction

CVRP	California Vehicle Rebate Project
DAWG	Demand Analysis Working Group
DGS	Department of General Services
DOF	California Department of Finance
ECAA	Energy Conservation Assistance Act
EE	energy efficiency
EMFAC	CARB EMission FACtor database
EV	electric vehicle
FCEV	fuel-cell electric vehicle
FPIP	Food Production Investment Program
FSSAT	Fuel Substitution Scenario Analysis Tool
GGRF	Greenhouse Gas Reduction Fund
GHG	greenhouse gas
GVWR	gross vehicle weight rating
GWh	gigawatt hour
HEVI-LOAD	Medium- and Heavy-Duty Electric Infrastructure Load, Operations, and Deployment
HLM	hourly load model
HSR	high-speed rail
HVIP	Hybrid and Zero-Emission Truck and Bus Incentive Program
ICT	Innovative Clean Transit
IEPR	Integrated Energy Policy Report
IOU	investor-owned utility
IRP	Integrated Resource Plan
kW	kilowatt
kWh	kilowatt hour
LGC	Local Government Challenge
LGO	local government ordinances
LIWP	GGRF Low-Income Weatherization Project
LDV	light-duty vehicle

MD-HD	medium-duty/heavy-duty
MSS	Mobile Source Strategy
MW	megawatt
NAICS	North American Industry Classification System
NEM	net energy metering
NO_x	oxides of nitrogen
PACE	Property Assessed Clean Energy
PEV	plug-in electric vehicle
PG Study	2021 Energy Efficiency Potential and Goals Study
PHEV	plug-in hybrid electric vehicle
PHFCEV	plug-in hybrid fuel cell electric vehicle
POU	publicly owned utility
PV	photovoltaic
RASS	Residential Appliance Saturation Study
SB	Senate Bill
SCAQMD	South Coast Air Quality Management District
SCE	Southern California Edison
SGIP	Self-Generation Incentive Program
TBD	to be determined
TOU	time of use
TPP	Transmission Planning Process
U.S. EIA	United States Energy Information Administration
WEG	Water Energy Grant
ZEV	zero-emission vehicle

APPENDIX A: Additional Achievable Energy Efficiency (AAEE) and Fuel Substitution: Overview of Methods

This appendix includes a description of the methods used to develop the additional achievable energy efficiency and fuel substitution analysis described in Chapter 2.

Overview of Method: Investor-Owned Utility (IOU) AAEE

The California Public Utilities Commission's (CPUC's) *2021 Energy Efficiency Potential and Goals Study* (*PG Study*) estimates potential energy efficiency savings of utility programs and codes and standards within the investor-owned utility (IOU) service territories for 2013–2032[76] given existing or soon-to-be-available technologies. Because many of these savings are already incorporated in the California Energy Commission's (CEC's) *CED 2021 Revised* baseline forecast, staff selected the portion of savings from the *PG Study* not accounted for in the baseline forecasts: potential program savings from 2022 onward and some codes and future codes and standards ratchets. (Code and Standards are discussed separately below.) These nonoverlapping totals become AAEE savings.

The *PG Study* presents five scenarios of load-serving entities' potential savings by year ranging from conservative to optimistic for 2022–2032. One of the scenarios presented is then adopted by the CPUC as the goals the IOUs are expected to meet. Each element of the five scenarios in the study is filtered first by technical potential, economic potential (cost-effectiveness), and finally market or *achievable* potential by netting out naturally occurring market adoption.

The CEC, CPUC, and Guidehouse Consulting staff developed six AAEE scenarios. These scenarios are designed to capture a range of possible outcomes determined by several input assumptions for each savings element. As in *CED 2019*, the reference total resource cost (TRC) scenario is the proposed goal by the CPUC for 2021. The reference TRC defines the mid-mid case (see Table 8), from which the scenario elements for more conservative and more aggressive cases are developed. The elements chosen for the final six scenarios in the IOU AAEE portfolio are shown in the design chart below.

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76 The analysis begins in 2013 because results are calibrated using the CPUC's Standard Program Tracking Database, which tracks program activities through 2013.

Table A-1: IOU AAEE Savings Scenarios

Lever	Mid-Very Low (Scenario 1)	Mid-Low (Scenario 2)	Mid-Mid (Scenario 3)	Mid-High (Scenario 4)	Mid-Very High (Scenario 5)	Mid-High Plus (Scenario 6)
Building Stock	2019 IEPR Mid Case	2019 IEPR Mid Case	2019 IEPR Mid Case	2019 IEPR Mid Case	2019 IEPR Mid Case	2019 IEPR Mid Case
Retail Prices	2019 IEPR Mid Case	2019 IEPR Mid Case	2019 IEPR Mid Case	2019 IEPR Mid Case	2019 IEPR Mid Case	2019 IEPR Mid Case
Agricultural, industrial, and mining sector emerging technologies	Reference	Reference	Reference	Average of Reference and Aggressive	Average of Reference and Aggressive	Average of Reference and Aggressive
Incentive Levels	Capped at 25 Percent of Incremental Cost	Capped at 50 Percent of Incremental Cost	Capped at 50 Percent of Incremental Cost	Capped at 50 Percent of Incremental Cost	Capped at 50 Percent of Incremental Cost	Capped at 50 Percent of Incremental Cost
Cost-Effectiveness Measure Screening Threshold	1.25	1	0.85	0.85	0.85	0.75
Marketing and Outreach	Default Calibrated Value	Default Calibrated Value	Reference = Default Calibrated Value	Increased Marketing Strength	Increased Marketing Strength	Increased Marketing Strength
Financing Programs	No Modeled Impacts	No Modeled Impacts	No Modeled Impacts	IOU Financing Programs Broadly Available to Residential and Commercial Customers	IOU Financing Programs Broadly Available to Residential and Commercial Customers	IOU Financing Programs Broadly Available to Residential and Commercial Customers
Behavioral, retro-commissioning and operational savings Assumptions	Conservative	Reference	Reference	Average of Reference and Aggressive	Average of Reference and Aggressive	Aggressive
Energy Efficiency Program Cost Adjustments	10 Percent More Than Existing Levels	No Change	No Change	No Change	10 Percent Less Than Existing Levels	10 Percent Less Than Existing Levels
Demand Response Cobenefits	Off	Off	Off	Off	On	On

Lever	Mid-Very Low (Scenario 1)	Mid-Low (Scenario 2)	Mid-Mid (Scenario 3)	Mid-High (Scenario 4)	Mid-Very High (Scenario 5)	Mid-High Plus (Scenario 6)
COVID Adjustment	On	Off, Default Assumptions	Off, Default Assumptions	Off, Default Assumptions	Off, Default Assumptions	Off, Default Assumptions
Low-Income*	Energy Savings Assistance (ESA) Decision Goals 2022-2026, PG Study Scenario 1 Base 2027-2032	ESA Decision Goals 2022-2026, PG Study Scenario 1 Base 2027-2032	ESA Decision Goals 2022-2026, PG Study Scenario 1 Base 2027-2032	ESA Decision Goals 2022-2026, PG Study Scenario 2 High 2027-2032	ESA Decision Goals 2022-2026, PG Study Scenario 3 Double 2027-2032	PG Study Scenario 3 Double 2022-2032

Sources: Guidehouse Consulting, CPUC, and CEC *Note about the Low-Income Lever: Scenario 1 (base) represents the status quo as reflected in historical program and proposed activity in the 2021-2026 IOU ESA Applications. Scenario 2 (high) takes a more aggressive growth stance than the base scenario. Scenario 3 (double) doubles the initial penetration rate of each measure by the end of the modeling period.

Retail prices and building stock remain constant across cases, pulled from the *2019 IEPR* mid case. These are external to the *PG Study* model. There are four sets of the savings in the *PG Study*:

- Agricultural, industrial, and mining sector emerging technologies (AIMs ETs)
- Rebate or financing programs
- Behavioral, retrocommissioning, and operational savings (BROs)
- Low-income programs

CEC, CPUC, and Guidehouse Consulting staff developed a range of scenarios for each. AIMs ETs and BROs are treated independently of rebate or financing programs. Financing programs, however, are influenced by marketing and outreach. They are also bounded by the levers of cost-effectiveness screening methods and thresholds as well as incentive levels.

The following list summarizes six components of staff's analysis of fuel substitution. More information is available in the *PG Study*[77] and will be available in the *2021 AAEE and SB 350 Methodology Documentation Report* upon its completion.

1. **AIMs ETs**: The *PG Study* includes emerging technologies for the agricultural, industrial, and mining sectors. Savings potentials from residential and commercial emerging technologies are no longer significant and are not included in the current *PG Study*.
2. **Incentive Level**: The incentive level is the amount or percentage of incremental cost that is offset for a targeted efficiency measure. While IOUs may vary the incentive level from measure to measure, they must work within their authorized budget to maximize savings, with incentives typically averaging about 50 percent of the incremental cost.
3. **Cost-Effectiveness Measure Screening Threshold**: For the *PG Study*, the CPUC directed[78] Guidehouse to use a TRC test based on the 2020 Avoided Cost Calculator for 2022–2023 and the 2021 Avoided Cost Calculator for 2024–2032, which was applied to each scenario. The new portfolio TRC requirement is 1.00 with a measure screening threshold of 0.85. This is more aggressive than the adopted 2019 goals scenario, which had a measure screening threshold of 1.00 and a portfolio TRC requirement of 1.25.
4. **Marketing and Outreach Effects**: The base factors for market adoption are a customer's willingness to adopt and awareness of efficiency technologies. Both are derived

77 CPUC. 2021. *2021 Potential and Goals Study*. https://pda.energydataweb.com/#!/documents/2527/view.

78 CPUC Decision 16-08-019: http://docs.cpuc.ca.gov/SearchRes.aspx?DocFormat=ALL&DocID=166232537.

from a regression analysis of technology adoption from several studies on new technology market penetration.

5. **Financing Programs**: Financing of measures is designed to break through market barriers that limit the widespread adoption of energy efficiency technologies. Financing impacts are modeled as reductions in *consumer-implied discount rates* — the effective discount rate that consumers use when making a purchase decision. It determines the perceived present value of savings in a future period. The consumer-implied discount rate is higher than standard discount rates used in other analyses because it is meant to account for market barriers that may affect customer decisions and perceptions.
6. **BROs**: In support of Assembly Bill 802 (Williams, Chapter 590, Statutes of 2015), Guidehouse assumed expanded coverage of BROs beyond what was included in the *PG Study*. The reference case is dominated by savings derived from residential home energy reports and strategic energy management potential.
7. **Low-Income Programs**: Low-income programs were modeled from the Energy Savings Assistance (ESA) decision[79] goals for 2022–2026 for most scenarios. For 2027–2032, staff used the three low-income sector scenarios included in the *PG Study*, as shown in Table 2.

Overview of Method: Publicly Owned Utility AAEE

The output from each sector model determines the incremental cumulative annual technical, economic, and market potential of energy savings for 2022–2041. Savings are characterized by sector, end use, and program name. In the assessment of economic and market potential using the TRC test, Guidehouse acquired contemporary avoided electricity costs for the cost-effectiveness screen. The avoided electricity costs are based on the CPUC-sponsored 2020 version of the avoided cost calculator.[80]

For CED 2021, CEC staff engaged Guidehouse to design scenario variations around the single scenario presented by the California Municipal Utilities Association. This single reference scenario is comparable to those developed for the CPUC programs. To create POU potential scenarios, the team calculated sector-by-sector (residential, commercial, industrial, and agricultural) ratios from the 2021 *PG Study* on IOUs. For example, if the IOU data indicated

79 CPUC. 2021. Decision on Large Investor-Owned Utilities' and Marin Clean Energy's California Alternate Rates for Energy (CARE), Energy Savings Assistance (ESA), and Family Electric Rate Assistance (FERA) Program Applications for Program Years 2021-2026. Application 19-11-003. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M386/K727/386727000.PDF.

80 Consistent with prior analyses and internal planning, select participating utilities have internally developed their own forecasts of avoided costs for use in calculating the future benefits of energy efficiency savings.

that the conservative scenario for the commercial sector resulted in 7.5 percent fewer savings than the reference case, then that same ratio was applied to derive a POU conservative case from the POU reference data.

Program projections submitted to the CEC varied in form — some POU savings were measured as gross,[81] while others included the impacts of codes and standards. For the contributions to AAEE presented here, staff converted gross savings to net (using IOU net-to-gross ratios) and removed savings from codes and standards where necessary. (These are accounted for separately, as explained below.)

Overview of Method: Codes and Standards AAEE

Codes and standards likely to be implemented were handled similarly to the *2019 IEPR*, with compliance reductions and compliance enhancements varying, as shown in Table 9. The BU analysis includes estimated statewide savings from additional ratchets for building and appliance standards through 2035. These were used in conjunction with and not overlapped with future measure savings gleaned from the *PG Study*. Savings estimates used from the *PG Study* were scaled from IOU territory savings to statewide savings using Quarterly Fuel and Energy Report sales data.[82] Next, standards savings were apportioned to POUs and then aggregated into the appropriate planning areas.

Six scenarios were created for statewide codes and standards in the *2021 IEPR* demand forecast (Table 9), with Scenario 1 being the most conservative and Scenario 6 being the most optimistic outlook for potential energy efficiency savings. The same adjustments for compliance, naturally occurring adoptions, and uncertainty factors assumed for IOUs in the *PG Study* were applied to the POUs and statewide data obtained from the Beyond Utility (BU) analysis effort. Compliance rates are based on a limited set of historical values from CPUC evaluation, measurement, and verification studies used in the *PG Study* and are reduced for more conservative scenarios. For more optimistic scenarios, compliance rates are ramped up from reference values to full compliance over a 5- to 10-year timespan.

Both new nonresidential construction and additions and alterations to existing nonresidential buildings are included for specific Title 24 code cycles in Scenarios 2 through 6. In the residential sector, however, only efficiency savings stemming from additions and alterations to

81 Includes savings from *free riders*. In 2019 average IOU net-to-gross ratios were between 0.73 and 0.90 (varied by measure). POU varied from 0.28 to 1.00.

82 Specifically, this meant multiplying the standards savings by 1 (ratio of the sum of the IOU service territory sales to total state sales). This is consistent with the method Navigant uses to apportion statewide standards savings to each of the IOU service territories, although in reverse.

existing buildings are considered. The 2019 Title 24 codes included in the baseline forecast estimate negligible AAEE savings for construction of new homes, as the code requires them to be near zero-net energy. All savings from future Title 24 code cycles are modeled according to anticipated future ratchets in energy efficiency assessed as part of the BU analysis. C&S savings reported in the *PG Study*, attributable to IOU outreach activities and advocacy, are not used for estimating AAEE savings from future Title 24 Standards here.[83]

83 The *PG Study* does include an assessment of commercial new construction as well as additions and alterations for future code cycles 2022, 2025, and 2028. Savings are however lumped into one "whole building" end use rather than the more disaggregated form found in the BU assessment. Staff chose the more disaggregated data and chose to include residential additions and alterations.

Table A-2: Beyond Utility Codes and Standards AAEE Savings Scenarios

Lever	Mid - Very Low (Scenario 1)	Mid - Low (Scenario 2)	Mid - Mid (Scenario 3)	Mid - High (Scenario 4)	Mid - Very High (Scenario 5)	Mid - High Plus (Scenario 6)
Building Stock	2019 IEPR Mid-Case	2019 IEPR Mid-Case	2019 IEPR Mid-Case	2019 IEPR Mid-Case	2019 IEPR Mid-Case	2019 IEPR Mid-Case
Retail Prices	2020 IEPR Mid-Case	2020 IEPR Mid-Case	2020 IEPR Mid-Case	2020 IEPR Mid-Case	2020 IEPR Mid-Case	2020 IEPR Mid-Case
Title 24 California State Building Energy Efficiency Standards	*none added above the baseline of the 2019 Standards*	add the 2022 Standards at a 20% compliance rate reduction	add the 2022 Standards at the reference compliance rate; add the 2025 Standards at a 20% compliance rate reduction	add the 2022 Standards at a 20% compliance rate enhancement; add the 2025 Standards at a 20% compliance rate reduction; add the 2028 Standards at a 20% compliance rate reduction	add the 2022 Standards at a 20% compliance rate enhancement; add the 2025 Standards at the reference compliance rate; add the 2028 Standards at a 20% compliance rate reduction	add the 2022 Standards at a 20% compliance rate enhancement; add the 2025 Standards at a 20% compliance rate enhancement; add the 2028 Standards at the reference compliance rate
Title 20 (California State) Appliance Energy Efficiency Standards	*none added above the baseline of standards "on the books" in 2021*	*none added above the baseline of standards "on the books" in 2021*	add possible new measures starting 2022–2024 at a 20% compliance rate reduction	add possible new measures starting 2022–2024 at the reference compliance rate; add additional possible new measures starting 2025–2030 at a 20% compliance rate reduction	add possible new measures starting 2022–2024 at the reference compliance rate: add additional possible new measures starting 2025–2030 at the reference compliance rate	add possible new measures starting 2022–2024 at a 20% compliance rate enhancement; add additional possible new measures starting 2025–2030 at a 20% compliance rate enhancement
Federal Appliance Energy Efficiency Standards	*none added above the baseline of standards "on the books" in 2021*	*none added above the baseline of standards "on the books" in 2021*	add possible new measures starting 2023–2025 at a 20% compliance rate reduction	add possible new measures starting 2023–2025 at the reference compliance rate; add additional possible new measures starting 2026-2030 at a 20% compliance rate reduction	add possible new measures starting 2023–2025 at the reference compliance rate; add additional possible new measures starting 2025–2030 at the reference compliance rate	add possible new measures starting 2023–2025 at a 20% compliance rate enhancement; add additional possible new measures starting 2025–2031 at a 20% compliance rate enhancement

Source: CEC

Savings for the Federal Appliance Standards and Title 20 Appliance Standards are modeled from data in the *PG Study* and additional measures analyzed as part of the BU assessment for more favorable AAEE scenarios. Measured savings from the *PG Study* were analyzed to capture all savings in a given IOU territory. Statewide C&S savings in POU territories were obtained by extrapolating the IOU C&S savings to the larger 16 POUs subject to integrated resource planning, as well as northern and southern POU groupings for the smaller entities. A similar method of allocating statewide modeled savings for additional appliance measures in the BU analysis is used to allocate savings to each utility territory.

Overview of Method: Beyond Utilities Programs AAEE

In 2021 AAEE, BU savings analysis includes programs not previously considered part of AAEE. Fuel Substitution was removed, as it is superseded by the new AAFS analysis discussed later in this chapter.

The BU modeling tool built in 2019 generates scenario specific savings and allocates statewide shares to each utility based on statewide retail electricity sales. Staff adjusted program-specific levers to define conservative, reference, and aggressive savings estimates. Staff also assigned a confidence level for each program based on funding certainty, program penetration, and potential for overlap with other savings programs, as well as the historical or modeled basis for the savings.

Once programs were assessed and bundled into four groups by confidence level, they were assigned to the specific AAEE Scenarios indicated in Table 10. The first three rows are established programs with historical performance data and expected future funding allocations. The next five rows contain programs with limited historical data on a pilot or other subset of programs and are based on some reasoned assumption of future funding allocations. The third cluster of seven rows are programs modeled using assumptions based on pilot or proposed program data, which are more uncertain. The final four rows are the most speculative, programs with savings based on more limited assumptions from pilot or proposed program data.

Table A-3: Beyond Utility Programs AAEE Savings Scenarios

Lever	Mid-Very Low (Scenario 1)	Mid-Low (Scenario 2)	Mid-Mid (Scenario 3)	Mid-High (Scenario 4)	Mid-Very High (Scenario 5)	Mid-High Plus (Scenario 6)
Building Stock and Retail Prices	2019 IEPR Mid Case	2019 IEPR Mid Case	2019 IEPR Mid Case	2019 IEPR Mid Case	2019 IEPR Mid Case	2019 IEPR Mid Case
Prop 39 2021, DGS 2021, and ECAA 2021	Reference EE Savings	Reference EE Savings	Reference EE Savings	Reference EE Savings	Aggressive EE Savings	Aggressive EE Savings
CCA RENs 2021 New, GGRF_WEG 2021, GGRF_LIWP 2021, LGO 2021, and PACE 2021	Conservative EE Savings	Conservative EE Savings	Reference EE Savings	Reference EE Savings	Aggressive EE Savings	Aggressive EE Savings
POU BROS 2021, LGC 2021, AssetRating 2021, SmartMeter 2021, SGIP HPWH 2021 New, CEOP 2021 New, and FPIP 2021 New	Not Included	Not Included	Conservative EE Savings	Conservative EE Savings	Reference EE Savings	Aggressive EE Savings
AQMD 2021, CVR 2021, Industrial 2021, and Agricultural 2021	Not Included	Not Included	Not Included	Conservative EE Savings	Reference EE Savings	Aggressive EE Savings

Source: CEC

Overview of Methods: IOUs AAFS

As described in Chapter 2, the CPUC's *2021 Potential and Goals Study* presents five scenarios for 2022–2032. Fuel substitution measures were included as elements of the five *PG Study* scenarios consistent with the fuel substitution decision of 2019.

CEC, CPUC, and Guidehouse Consulting staff developed five AAFS scenarios similar in concept to those developed for AAEE. These scenarios are designed to capture a range of possible outcomes determined by a host of input assumptions for each savings element. The 2021 reference TRC scenario defines the mid-mid case (Table 11), and CEC staff used variations from there to build more conservative and more aggressive variants of IOU potential savings for each AAFS scenario. The elements chosen for the final five scenarios in the IOU AAFS portfolio are shown in the scenario design chart below.

Table A-4: IOU AAFS Impacts Scenarios

Lever	Mid-Low (Scenario 2)	Mid-Mid (Scenario 3)	Mid-Mid Plus (Scenario 4)	Mid-High (Scenario 5)	Mid-High Plus (Scenario 6)
Building Stock and Retail Prices	2019 IEPR Mid Case	2019 IEPR Mid Case	2019 IEPR Mid Case	2019 IEPR Mid Case	2019 IEPR Mid Case
Agricultural, Industrial, and Mining Sectors	Reference	Reference	Average of Reference and Aggressive	Average of Reference and Aggressive	Aggressive
Incentive Levels	Capped at 25 Percent of Incremental Cost	Capped at 50 Percent of Incremental Cost	Capped at 50 Percent of Incremental Cost	Capped at 50 Percent of Incremental Cost	Capped at 75 Percent of Incremental Cost
C-E Measure Screening Threshold	1	0.85	0.85	0.85	0.75
Marketing and Outreach	Reference	Reference	Increased Marketing Strength	Increased Marketing Strength	Increased Marketing Strength
Financing Programs	No Modeled Impacts	No Modeled Impacts	IOU Financing Programs Broadly Available to Residential and Commercial Customers	IOU Financing Programs Broadly Available to Residential and Commercial Customers	IOU Financing Programs Broadly Available to Residential and Commercial Customers

Lever	Mid-Low (Scenario 2)	Mid-Mid (Scenario 3)	Mid-Mid Plus (Scenario 4)	Mid-High (Scenario 5)	Mid-High Plus (Scenario 6)
Fuel Substitution Program and Equipment Cost Adjustments	20 Percent More Than Existing Levels	No change	No change	20 Percent Less Than Existing Levels	20 Percent Less Than Existing Levels
Demand Response Co-Benefits	Off	Off	Off	On	On
IOU Low-Income Fuel Substitution Program Contributions	Low Fuel Substitution	Reference Fuel Substitution	Reference Fuel Substitution	Aggressive Fuel Substitution	Aggressive Fuel Substitution

Sources: Guidehouse Consulting, CPUC, and CEC

In Table 12 above, there are two constants for the economic and demographic drivers: retail prices and building stock taken from the previous IEPR estimates. These constants are external to the model. The *PG Study* fuel substitution impacts are contained in two basics bins: AIMs ETs and Rebate or Financing Programs, and a range of scenarios is generated for each. Financing programs are influenced by marketing and outreach and further bounded by the levers of cost-effectiveness screening methodologies and thresholds as well as incentive levels and actual equipment costs. Details summarizing the parameters and assumptions included in the levers used to construct the five scenarios can be found in the IOU contributions to AAEE above.

Separate low-income sector fuel substitution programs were not considered in the CPUC's *2021 Potential & Goals Study,* so CEC and Guidehouse Consulting staff estimated the savings. The analysis was modeled after SCE's low-income Energy Savings Assistance (ESA) program fuel substitution measures and similar programs anticipated for the remaining IOU's starting in 2024.

Overview of Methods: POUs AAFS

CEC and Guidehouse staff interviewed all willing POUs and collected data from several. Staff collected preliminary pilot program data from Los Angeles Department of Water and Power (LADWP) projected for 2021–2052 and additional data from Sacramento Municipal Utility District (SMUD), Pasadena Water and Power, and City of Palo Alto. Projections were made for costs, number of participants, or estimated future GHG reductions. To extrapolate the data to POUs across the entire state, the GDS Associates POU energy savings projections data were analyzed to determine the relative size of each POU's total energy savings potential relative to LADWP. The projected savings for each POU was then summed for the five years from 2022 to 2026 and compared to create a *savings potential multiplier*. The team finally assigned a fuel substitution delay or *head start* to each POU, relative to the LADWP fuel substitution timeline. SMUD, for example, was judged to be two years ahead of LADWP in fuel substitution implementation, while most other POUs were judged to be two years behind LADWP.

To measure the variation around the BAU forecast, the team analyzed the percentage difference among the conservative, reference, and aggressive scenarios outlined in the *PG Study* data to calculate an average *scenario factor* between the conservative and reference cases (as well as a separate scenario factor for the difference between the aggressive and reference cases). Factors were calculated based on IOU fuel substitution programs.

- Low POU FS impacts are applied to the mid-low AAFS scenario 2
- Mid POU FS impacts are applied to both the mid-mid (BAU) AAFS scenario 3 and the mid-mid plus AFFS scenario 4
- High POU FS impacts are applied to both the mid-high and the mid-high plus AAFS scenarios 5 and 6

Overview of Method: Codes and Standards AAFS

Five scenarios were created for the potential fuel substitution impacts that could be derived from the 2022 Title 24 building standards and future ratchets in the *2021 IEPR* demand forecast (Table 12). Of the five, scenario 2 is the most conservative and scenario 6 the most optimistic. The same adjustments for compliance, naturally occurring adoptions, and uncertainty factors assumed for BU C&S in AAEE were employed in this new BU analysis effort toward C&S AAFS impacts. Table 12 illustrates how each Title 24 vintage varies by compliance rate and number of assumed ratchets across the five scenarios.

Because the residential 2022 Title 24 standards strongly encourage but do not require electrification for either water heating or space heating, staff assumed the compliance option builders would choose. This option is reflected in the fuel substitution uptake lever, also shown for each vintage in Table 19. The table shows the percentage of construction complying via the appropriate end-use electrification in the prescriptive compliance path versus those opting to build under the performance pathway at higher energy efficiency levels. (The energy efficiency savings from those opting for the high energy efficiency savings in favor of electrification are counted as part of the C&S BU contributions to AAEE.) Staff included fuel substitution for residential new construction as well as additions and alterations. The more speculative assumptions about future residential code cycles are based on the possibility of encouraging both water and space heating end uses. For the more BAU AAFS scenarios (scenarios 3 and 4), this is assumed for the 2028 vintage while for the more aggressive AAFS scenarios (scenarios 5 and 6) this is accelerated to the 2025 vintage of Title 24.

Similarly, scenarios 2 through 6 include 2022 Title 24 code for new nonresidential construction and additions and alterations to existing nonresidential buildings. There are some prescriptive electrification measures in the 2022 Title 24 nonresidential code that cannot be avoided by increased energy efficiency (EE). More measures may be introduced in the future as existing technologies become more cost-effective or as new technologies are developed.

Table A-5: Beyond Utility Codes and Standards AAFS Impacts Scenarios

Lever	Mid - Low (Scenario 2)	Mid - Mid (Scenario 3)	Mid - High (Scenario 4)	Mid - Very High (Scenario 5)	Mid - High Plus (Scenario 6)
Building Stock	2019 IEPR Mid-Case	2019 IEPR Mid-Case	2019 IEPR Mid-Case	2019 IEPR Mid-Case	2019 IEPR Mid-Case
Retail Prices	2020 IEPR Mid-Case	2020 IEPR Mid-Case	2020 IEPR Mid-Case	2020 IEPR Mid-Case	2020 IEPR Mid-Case
Title 24 California State Building Energy Efficiency Standards	Adding the building electrification encouraged by the 2022 Standards at a 20% compliance rate reduction and low uptake rate	Adding the building electrification encouraged by the 2022 Standards at the reference compliance rate and reference uptake rate; adding potential updates in the 2025 Standards at a compliance rate reduction and low uptake rate	Adding the building electrification encouraged by the 2022 Standards at a 20% compliance rate enhancement and high uptake rate; adding potential updates in the 2025 & 2028 Standards at a compliance rate reduction and low uptake rate	Adding the building electrification encouraged by the 2022 Standards and potential updates in the 2025 & 2028 Standards at the reference compliance rate and high uptake rate	Adding the building electrification encouraged by the 2022 Standards and potential updates in the 2025 & 2028 Standards at a compliance rate enhancement and high uptake rate

Source: CEC

Overview of Methods: Beyond Utilities Programs AAFS

As described previously, most programs included in the 2019 AAEE forecast were included in the 2021 AAEE forecast as well. Notably, staff replaced the more speculative fuel substitution analysis from 2019 with data from the FSSAT for the 2021 aggressive AAFFS.

Some energy efficiency programs have potential fuel substitution elements that were developed separately for use in 2021 AAFS. These elements included local government ordinances (LGO), industrial programs, and agricultural programs.

As mentioned, new elements of the 2021 analysis included capturing both energy efficiency savings as well as fuel substitution impacts not accounted for in 2019. Lastly, the 2021 analysis captured the expected fuel substitution impacts from the Technology and Equipment for Clean Heating (TECH) and Building Initiative for Low-Emissions Development (BUILD) programs.

The BU modeling tool, enhanced to include fuel substitution impacts for 2021, generates scenario-specific impacts and allocates shares to each utility using the utility's proportional retail electricity sales compared to the statewide total. Program-specific levers are adjusted for each program and are grouped to define conservative, reference, and aggressive FS impact estimates. Staff assigned a confidence level for savings from each program, based on the funding certainty, program penetration, and potential for overlap with other savings programs, as well as whether the FS impact estimates are based on historical data or are modeled.

Once programs were assessed and bundled by confidence level, they were then assigned to the specific AAFS scenarios as indicated in Table 13. The first three rows are established programs with historical performance data and expected future funding allocations. The second set of three rows contain programs with limited or no historical data on a pilot or other subset of programs and are based on some reasoned assumption of future funding allocations. The final cluster of two rows are the most speculative programs, with savings based on even more limited assumptions from pilot or proposed program data.

Table A-6: Beyond Utility Programs AAFS Impacts Scenarios

Lever	Mid-Low (Scenario 2)	Mid-Mid (Scenario 3)	Mid-Mid Plus (Scenario 4)	Mid-High (Scenario 5)	Mid-High Plus (Scenario 6)
Building Stock and Retail Prices	2019 IEPR Mid Case	2019 IEPR Mid Case	2019 IEPR Mid Case	2019 IEPR Mid Case	2019 IEPR Mid Case
CCA RENs 2021 New and LGO 2021	Low Fuel Substitution	Reference Fuel Substitution	Reference Fuel Substitution	Aggressive Fuel Substitution	Aggressive Fuel Substitution
TECH-BUILD 2021 New, SGIP HPWH 2021 New, FPIP 2021 New, and CEOP 2021 New		Low Fuel Substitution	Reference Fuel Substitution	Reference Fuel Substitution	Aggressive Fuel Substitution
Industrial 2021 and Agriculture 2021			Conservative Fuel Substitution	Reference Fuel Substitution	Aggressive Fuel Substitution

Source: CEC