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California Energy Commission

FINAL COMMISSION REPORT

Final 2024 Integrated Energy Policy Report Update

Gavin Newsom, Governor

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ABSTRACT

The *2024 Integrated Energy Policy Report Update* discusses the California Energy Demand Forecast and the Senate Bill 605 evaluation of feasibility, costs, and benefits of wave and tidal energy resources. It also includes a summary of the Western Electricity Markets workshop in an appendix.

Keywords: Energy policy, demand forecast, wave energy, tidal energy, Western Electricity Markets

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EXECUTIVE SUMMARY

Introduction

California continues to lead global efforts to combat climate change by setting some of the world's most ambitious policies and targets aimed at reducing greenhouse gas (GHG) emissions and promoting clean energy. The passage of landmark laws such as Senate Bill 32 (Pavley, Chapter 249, Statutes of 2016) and Senate Bill 100 (De León, Chapter 312, Statutes of 2018), the latter mandating 100 percent clean electricity by 2045, established a clear framework for the state's energy transition. These policies have paved the way for California's decarbonization strategy.

California's Climate Change Scoping Plan, authorized by Assembly Bill 32 (Nunez, Chapter 488, Statutes of 2006) and updated at least every five years, includes economywide actions to achieve the state's climate and clean energy targets through a cost-effective, equitable and technologically feasible path. (AB 32 established the goal of limiting GHG emissions to 1990 levels by 2020.)

In 2022, the California Climate Commitment took this framework further through a package of bills enacting aggressive climate measures, namely, setting new interim milestones of 90 percent clean energy by 2035 and 95 percent by 2040 through Senate Bill 1020 (Laird, Chapter 361, Statutes of 2022). Further, Assembly Bill 1279 (Muratsuchi, Chapter 337, Statutes of 2022) codified the goal of achieving net-zero emissions by 2045 and established an 85 percent emissions reduction target as part of that goal.

Electrification is an important part of California's AB 32 Scoping Plan, aiming to shift key sectors — transportation, buildings, and industry — to clean power. This plan requires a rapid expansion of the state's clean energy resources. Success will hinge on scaling up renewable and zero-carbon energy sources, such as wind and solar; adding battery storage; and ensuring the timely development of transmission infrastructure.

California has already made considerable progress. As of September 2025, 67 percent of the state's electricity was generated from renewable and zero-carbon resources. Since 2010, 16,302 megawatts (MW) of fossil fuel generation have been retired, and 22,000 MW of new clean energy resources have been added, including a remarkable expansion of battery storage, which has grown from 770 MW in 2019 to over 15,000 MW as of April 2025. In 2024, the state added over 6,800 MW of new clean energy resources (notably, this includes 2,200 MW solar and 3,600 MW of battery storage). Looking ahead, the state has ambitious goals to:

- Achieve 100 percent zero-emission passenger vehicles sales by 2035.
- Reach 100 percent zero-emission trucks and buses where feasible by 2045.
- Install 6 million heat pumps in buildings by 2030.
- Make 7 million homes climate-ready by 2035.
- Achieve 7,000 MW of load flexibility by 2030 — adjusting electricity usage to match supply — to manage energy demand efficiently.

As the state works to accelerate the clean energy transition, there are several significant challenges. First, there is an urgent need to sustain and even increase the already record-setting pace of development of new clean energy resources while making efficient connection to the grid easier. Second, California's regulators and utilities must maintain affordability as the grid undergoes this rapid expansion. Third, climate change is already impacting the grid, with heat waves, wildfires, and drought, which underscore the necessity for a resilient, safe, and reliable grid.

Since the rotating outages that resulted from the August 2020 extreme heat wave, the CEC, CPUC, and California Independent System Operator (California ISO) have worked to enhance preparedness to maintain reliability in the face of a changing climate.

Coordinated planning, increased communication, and continued growth in battery energy storage and new clean generation resources have strengthened the reliability of the grid, as demonstrated in the summers of 2023 and 2024 when the grid remained stable despite wildfires, record heat, and high levels of demand. Climate change-driven events will continue to threaten our grid. As a result, continued careful planning and forecasting of energy demand are critical to maintaining reliability, meeting climate goals, and ensuring affordability.

The Role of the Energy Demand Forecast

A cornerstone of California's energy planning is the California Energy Demand Forecast, developed by the CEC. This forecast provides critical information that informs energy planning proceedings across the state and serves as an important input into the state's comprehensive energy planning. The CEC, CPUC, and California ISO agreed that specific elements of this forecast set will be used for planning and procurement in the California ISO's transmission planning and the CPUC's integrated resource plan, resource adequacy, distribution system planning, and other planning processes.[1] The specific elements used for each planning process are documented in the forecast chapter of the *IEPR*, in the "Choice of a Single Managed Forecast Set for Electricity Planning" section. This approach ensures consistency across electricity planning processes.

Updated annually as part of the *Integrated Energy Policy Report (IEPR)* process, the forecast incorporates the latest data and continuous improvements in methods and models to predict future energy demand. The forecast assesses energy demand trends through 2040, considering a range of factors, including:

- Economic and demographic projections.
- Projected changes in utility rates and costs.
- The impacts of energy efficiency and electrification.
- Historical and projected climate and weather data.

1 Memorandum of Understanding Between The California Public Utilities Commission (CPUC) and the California Energy Commission (CEC) and the California Independent System Operator (ISO) Regarding Transmission and Resource Planning and Implementation. December 2022,
https://efiling.energy.ca.gov/GetDocument.aspx?tn=262057&DocumentContentId=98567.

Staff is dedicated to making continual improvements to forecasting methods and developing new products that best serve the planning process. The *2024 IEPR Update* forecast uses the most recent data for historical energy consumption, economic and demographic projections, and rate projections. This year's *IEPR* forecast:

- Improved the behind-the-meter (BTM) photovoltaic and storage historical data and forecast. BTM refers to the consumer-side of the utility meter and includes, for example, rooftop PV generation that is first used to meet the consumer's load.
- Improved characterization of the expected growth of data centers.
- Updated the transportation forecast to reflect growing electrification.
- Updated the building electrification forecast based on the latest information about zero-emission appliance standards.
- Made improvements to the hourly forecast method to improve model performance.

Draft load modifier forecast results were presented at the November 7, 2024, workshop, and overall draft forecast results were shared at the December 12, 2024, workshop. The CEC commissioners adopted the final forecast results at the January 21, 2025, CEC Business Meeting.

The *2024 IEPR Update* forecast is higher than previous forecasts primarily due to the growth of data center load to support AI technology development and deployment and reduced behind-the-meter distributed generation due to revised assumptions about PV system costs and generation. Baseline electricity sales in 2040 are forecast to be more than 338,000 gigawatt-hours (GWh) in the mid case and 347,000 GWh in the high case, which is respectively a 13 percent or a 16 percent increase over what was projected for 2040 in the *2023 IEPR.* Managed sales, which includes the impacts of additional achievable energy efficiency, fuel substitution, and transportation electrification, reach 411,000 GWh in the Planning Scenario (used for resource adequacy and integrated resource planning) or 420,000 GWh in the Local Reliability Scenario (used for local studies).

The same drivers also increase the forecast of hourly electricity demand. The *2024 IEPR Update* Planning Scenario peak forecast for the California ISO reaches almost 66,800 MW by 2040 and the Local Reliability Scenario peak is 68,500 MW by 2040. The Planning Scenario peak forecast provides a benchmark for system resource adequacy obligations for compliance year 2026. The peak forecast for the California ISO is approximately 1 percent higher in 2026 than the forecast adopted during the *2023 IEPR* cycle.

Senate Bill 605 Evaluation of Feasibility, Costs, and Benefits of Wave and Tidal Energy Resources

Developing new sources of renewable energy is critical to achieving California's climate and energy goals. One potential avenue for renewable energy resources examined in the *2024 IEPR Update* is wave and tidal energy. Senate Bill (SB) 605 (Padilla, Chapter 405, Statutes of 2023) required the CEC to evaluate the feasibility, costs, and benefits of using wave energy and tidal energy as forms of clean energy in the state in consultation with appropriate state agencies, including the California Coastal Commission, Department of Fish and Wildlife, Ocean Protection Council, and State Lands Commission.

The feasibility report in this *2024 IEPR Update* covers:

- The evaluation of factors that may increase the use of wave and tidal energy resources.
- Findings on the latest research, technology, and economics of deploying these resources.
- Evaluation of transmission, permitting requirements, and workforce development needs.
- Identification of near-term actions and investment needs.
- Identification of monitoring strategies to evaluate the impacts of wave and tidal energy resources to marine environments.

The feasibility report finds that both wave and tidal energy resources face challenges to commercial-scale deployment, although significant research, development, and demonstration have been completed. There could be an opportunity to host small-scale and pilot projects as distributed energy resources to serve nearby ports, remote communities, and military installations. Some challenges to developing marine energy resources include gaining a better understanding of resource variability, grid integration, environmental impacts, and cost competitiveness with other renewable resources. Further, project permitting and licensing processes are complex and lengthy.

Wave and tidal energy resources could become more commercially viable with cost reductions through increased electricity production (improved performance of a device to operate at peak production over a wider range of conditions) and project testing and demonstration. Commercial-scale deployment, considered to be multiple devices in arrays that are grid-connected, could occur with market mechanisms such as tax credits and other incentives that bring capital costs down.

While commercial-scale marine energy projects in California have not been implemented to date, the state's abundant wave resources and supportive policy environment present opportunities for further research, development, and demonstration to support large-scale deployment of marine energy technologies. Deployment opportunities include exploring the potential for colocation of wave energy projects with floating offshore wind energy projects. Continued efforts in this field could contribute to California's clean energy goals and promote sustainable development along its coastline.

Senate Bill 605 also requires the CEC to produce an additional report that will include identification of suitable sea space for offshore wave energy and tidal energy projects in state and federal waters. That report will include a monitoring strategy that will contain measures to avoid, minimize, and lessen adverse environmental impacts and use conflicts, and adaptive management. A draft of that report was released in March 2025.

CHAPTER 1: California Energy Demand Forecast

Introduction

The California Energy Commission's (CEC's) California Energy Demand Forecast is a foundational component of the state's energy planning. The forecast provides a statewide and regional look at California's expected energy needs, and the resulting energy demand forecasts flow directly into various energy planning processes. Some examples of these include the California Public Utilities Commission's (CPUC's) integrated resources plan (IRP) and resource adequacy (RA) processes which direct investor-owned utility energy procurement and the California Independent System Operator's (California ISO's) transmission planning process (TPP).[2] The 2024 IEPR Update demand forecast includes:

- Annual consumption and sales forecasts to 2040 for electricity 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 photovoltaic (PV) and other self-generation technologies, battery storage, electric vehicles (EVs), energy efficiency, and electrification.

The CEC continuously updates and improves the forecast to meet the state's evolving planning needs. In recent years, the CEC has improved the forecast by adding several new elements, including scenarios to inform planning for rapid changes in transportation and building electrification strategies, and incorporation of climate data to improve accounting for increased weather variability.

Presented here is the process for developing the forecast, an update on the methods used, a description of the key drivers and trends, and planned enhancements to future forecasts.

2 See materials from the October 2, 2024, IEPR workshop on Forecast Use in Electricity System Planning for more information on how the CEC's demand forecast is used by these proceedings. https://www.energy.ca.gov/event/workshop/2024-10/iepr-commissioner-workshop-forecast-use-electricity-system-planning.

Background

Each year as part of the Integrated Energy Policy Report (IEPR) process, the CEC updates and improves its electricity demand forecast by using the most recently available data and improving the methods and models. The updates are vetted with forecast users and other interested parties through the public Demand Analysis Working Group (DAWG)[3] meetings and public workshops. The DAWG meetings and workshops held in 2024 are summarized below, followed by a summary of the major improvements implemented.

The California Energy Demand Forecast and the Forecast Update exist in a broader context of energy demand assessments and policy development frameworks. For example, the forecast is an input into the CEC's broader Demand Scenarios Project, which uses the forecast and its modeling tools and methods to evaluate longer-term energy demand possibilities and associate greenhouse gas emissions. Some scenarios from the Demand Scenarios Project are used as energy demand inputs into the Senate Bill 100 (De León, Chapter 312, Statutes of 2018) reporting process. The California Air Resources Board (CARB) also develops the Scoping Plan for Achieving Carbon Neutrality, which uses various sources to evaluate energy demand, including the California Energy Demand Forecast.

Public Engagement

The CEC seeks input into its forecast development and proposals for methodological updates through various venues, including public workshops and the public DAWG. To better understand emerging trends in electricity load growth, staff invited utilities and industry experts to a May 16, 2024, IEPR workshop to discuss data centers, electrification in the agricultural sector, manufacturing, and hydrogen production. At a July 30, 2024, IEPR workshop, staff and consultants discussed updates to the forecast method with an emphasis on the use of climate scenario data. At an August 21, 2024, DAWG meeting, staff presented the updated economic and demographic inputs to the forecast and sought feedback on proposed updates for the BTM distributed generation, additional achievable energy efficiency (AAEE) and additional achievable fuel substitution (AAFS) components of the forecast. A workshop was held October 2, 2024, to cover how the forecast feeds into other electricity system planning processes.

DAWG meetings were held October 21 and November 21, 2024, for an open and in-depth discussion on the draft forecast results. Workshops were held November 7 and December 12, 2024, to formally present draft results and receive additional stakeholder comments before the forecast was finalized and presented for adoption in January 2025. Lastly, a DAWG meeting was held December 23, 2024, to discuss the revised data center and BTM PV and storage results.

The full list of public meetings and workshops related to the forecast is shown in Table 1.

3 California Energy Commission. "Demand Analysis Working Group," https://www.energy.ca.gov/programs-and-topics/topics/energy-assessment/demand-analysis-working-group-dawg.

Table 1: 2024 IEPR Forecast-Related Public Meetings and Workshops

Date	Type	Topics
May 16, 2024	IEPR Workshop	Electricity Load Growth Areas
July 30, 2024	IEPR Workshop	Energy Demand Forecast Methodology Updates
August 21, 2024	DAWG Meeting	Updates to Economic and Demographic Forecasts, Distributed Generation, AAEE, and AAFS
October 2, 2024	IEPR Workshop	Forecast Use in Electricity System Planning
October 21, 2024	DAWG Meeting	Load Modifier Results
November 7, 2024	IEPR Workshop	Load Modifier Results
November 21, 2024	DAWG Meeting	Overall Forecast Results
December 12, 2024	IEPR Workshop	Overall Forecast Results
December 23, 2024	DAWG Meeting	Updates to Data Center and BTM PV and Storage Forecasts

Source: CEC

Forecast Framework

The *2024 IEPR Update* forecast contains one baseline demand forecast and several scenarios for load modifiers, which include data centers, behind-the-meter PV and storage, AAEE, AAFS, and additional achievable transportation electrification (AATE). The baseline forecast considers policies and programs that are approved, funded, and have an implementation plan that is detailed enough to reasonably quantify their impact. The energy demand forecast assesses demand-side (behind-the-meter) impacts.

The additional achievable scenarios for energy efficiency, fuel substitution, and transportation electrification capture a range of incremental market potential impacts, beyond what are included in the baseline demand forecast, but are reasonably expected to occur. The framework for additional achievable scenarios focuses on energy impacts from policies and programs that are reasonably expected to occur and have significant and unique effects on system load.

These additional achievable scenario variations can be summarized as follows:

- Scenario 1: Firm commitments
- Scenario 2: Scenario 1 plus "will occur but some uncertainty around impacts"
- Scenario 3: Scenario 2 plus "very likely to occur with greater uncertainty about impact magnitudes"

- Scenario 4: Scenario 3 plus "likely to occur but still in planning phases"
- Scenario 5: Scenario 4 plus "more speculative programs, perhaps in early planning phases"
- Scenario 6: Scenario 5 plus "programs that could exist in the future and would be required to meet some policy goals"

For the additional achievable load modifiers, Scenario 3 is used for the planning forecast. For general consistency in the AA scenario numbering framework, the title "AATE Scenario 3" is used despite there not being other AATE scenarios.

Sets of the baseline forecast, data centers, PV, storage, and additional achievable forecasts and scenarios are combined into a "planning forecast" and a "local reliability scenario." The constituent scenarios that make up the Planning Forecast and Local Reliability Scenario are outlined in Table 2, along with the naming convention and use cases. The CEC, CPUC, and California ISO agree to use specific combinations of this forecast set for planning and procurement, and that agreement is outlined in the section later within this chapter called "Choice of a Single Managed Forecast Set for Electricity Planning."

Table 2: Forecast Framework

Use Case/Scenario	Planning Forecast	Local Reliability Scenario
Example Use Cases	Resource Adequacy, CPUC Integrated Resource Planning	California ISO Transmission Planning Process local area reliability studies, Investor-Owned Utility distribution system planning
Economic, Demographic, and Price Scenarios	Baseline	Baseline
BTM PV and Storage Scenario	Mid	Low
Data Centers	Mid	High
AAEE Scenario	Scenario 3	Scenario 2
AAFS Scenario	Scenario 3	Scenario 4
AATE Scenario	Scenario 3	Scenario 3

Source: CEC. For the *2024 IEPR Update* forecast, only one AATE Scenario was developed. The BTM PV and Storage scenarios are cost scenarios and do not fall under the "additional achievable" definition.

The planning forecast is used for resource adequacy and integrated resource planning and assumes "mid-level" impacts from behind-the-meter (BTM) PV and storage, data centers, AAEE, AAFS, and AATE. The Local Reliability Scenario is used for planning activities with more granular geography, such as the transmission planning process local area reliability studies and distribution planning process. The Local Reliability Scenario assumes less BTM PV generation and storage, less energy efficiency, more data centers, and more fuel substitution, resulting in higher demand than the planning forecast. Using this scenario with higher demand addresses some of the increased uncertainty associated with disaggregating, or breaking down, the load to study small local regions of the state.

Analysis and Findings

As part of the IEPR process, the CEC updates forecasts of end-user electricity demand in even-numbered years.[4] For the *2024 IEPR Update*, the CEC updated its forecast of electricity demand with several improvements and expansions. The major changes to the baseline demand forecast consist of improvements to the BTM distributed generation forecast, improved projections of data center load, and updates to the hourly forecast. The AAFS and AATE components were also updated for the *2024 IEPR Update*. Each is discussed further below.

High-Level Method Overview

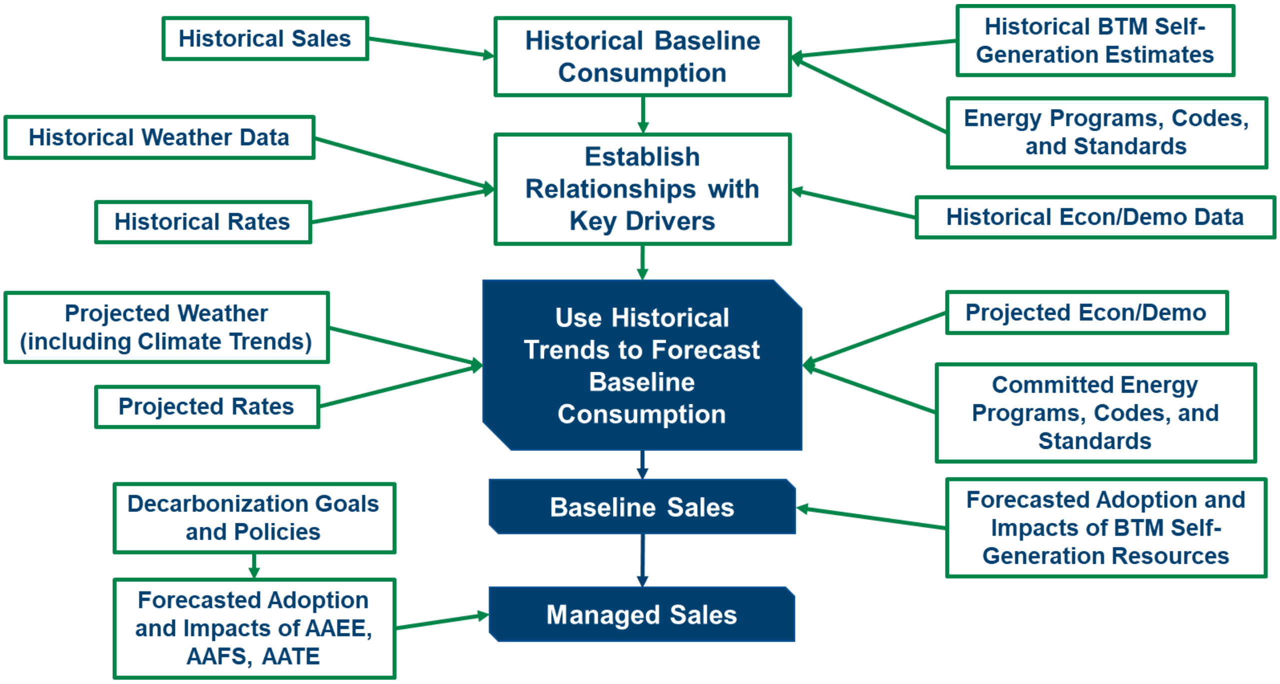
Historical energy consumption data are the foundation of the forecast and are a combination of historical energy sales data and BTM self-generation estimates. Staff establishes correlations of historical energy consumption with economic and demographic data, weather data, and rates from the same historical period. The correlations are specific to each forecast zone and economic sector. Projections for future economic and demographic trends, weather, and rates are used, along with the correlations established previously to extend the energy consumption into the future. These projections are also specific to forecast zone and economic sector.

There are several modifiers to this process. Climate trends are considered, and anticipated policy and technology changes can cause significant deviations from the historical trends and must be considered independently.

A flowchart showing the general forecast process is shown in Figure 1.

4 Recognizing the process alignment needs and schedules of the CPUC and California ISO planning, the CEC provides an update to the *IEPR* forecast in even-numbered years. The CEC completes a full refresh of the forecast in odd-numbered years.

Figure 1: Flowchart of Forecast Process



Many inputs are considered in forecasting electricity demand, including historical trends; energy programs, codes, and standards; weather and climate projections; economic and demographic data; and decarbonization goals and policies.

Source: CEC

Overview of Updates for 2024

As part of the IEPR process, the CEC develops and adopts forecasts of end-user electricity and gas demand every two years, in odd-numbered years. Recognizing the process alignment needs and schedules of the CPUC and California ISO planning, the CEC provides an update to the IEPR forecast of electricity demand in even-numbered years, in which limited changes are made.

For the *2024 IEPR Update*, the CEC updated its forecast of electricity demand that was developed for the *2023 IEPR*. The new forecast uses an additional year of historical electricity sales data, updated economic and demographic projections, and updated electricity rates projections. Other changes include improvements to BTM distributed generation (DG) and storage models, better accounting for the impacts of climate change on annual and hourly demand, adjustments for the expected growth of data centers, transportation forecast updates, building electrification forecast updates, and improvements to the hourly electricity forecast method.

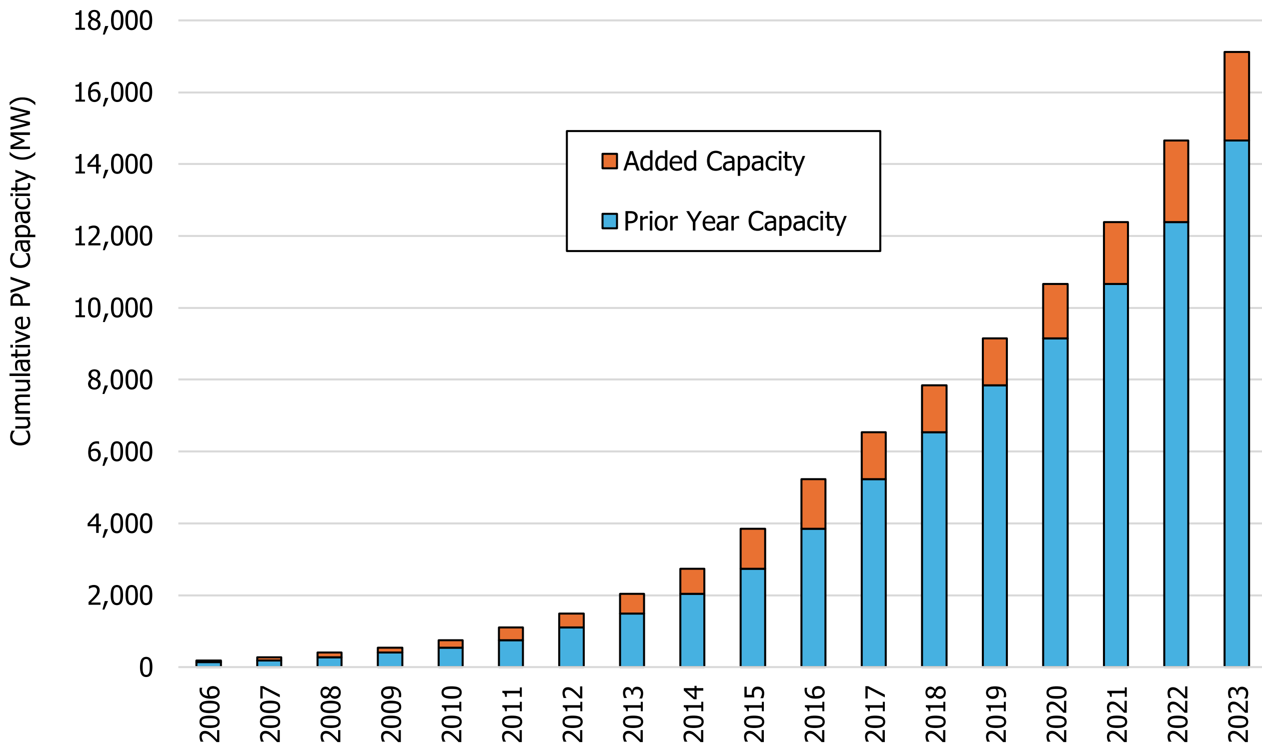
Like the *2023 IEPR*, the *2024 IEPR Update* forecast extends to 2040 in accordance with the 15-year minimum requirement established by Senate Bill (SB) 887 (Becker, Chapter 358, Statutes of 2022).

BTM Distributed Generation and Storage Updates

For the *2024 IEPR* forecast, staff updated historical BTM DG capacity through 2023 and included improved interconnection data from several utilities. Enhanced data resulted in about a 4 percent (500 megawatts [MW]) increase in cumulative statewide BTM PV capacity for 2022 compared to the historical BTM PV capacity used for the *2023 IEPR* forecast. Historical capacity for 2007 to 2021 rose by 4 to 10 percent compared to the historical capacity used for the *2023 IEPR* forecast. Staff also updated historical BTM PV capacity factors, used to estimate generation, in the *2024 IEPR Update* forecast using metered generation data from a large real-world sample. The new capacity factors are lower than those used for the *2023 IEPR* forecast, resulting in lower electricity generation estimates.

BTM PV adoption has accelerated recently with about 54 percent of BTM PV capacity interconnected from 2019 to 2023. Staff estimate 2.3 gigawatts (GW) of BTM PV capacity was interconnected in 2022 and a record 2.5 GW in 2023. By the end of 2023, staff estimates there was 17.2 GW of BTM PV capacity in California, as shown in Figure 2.

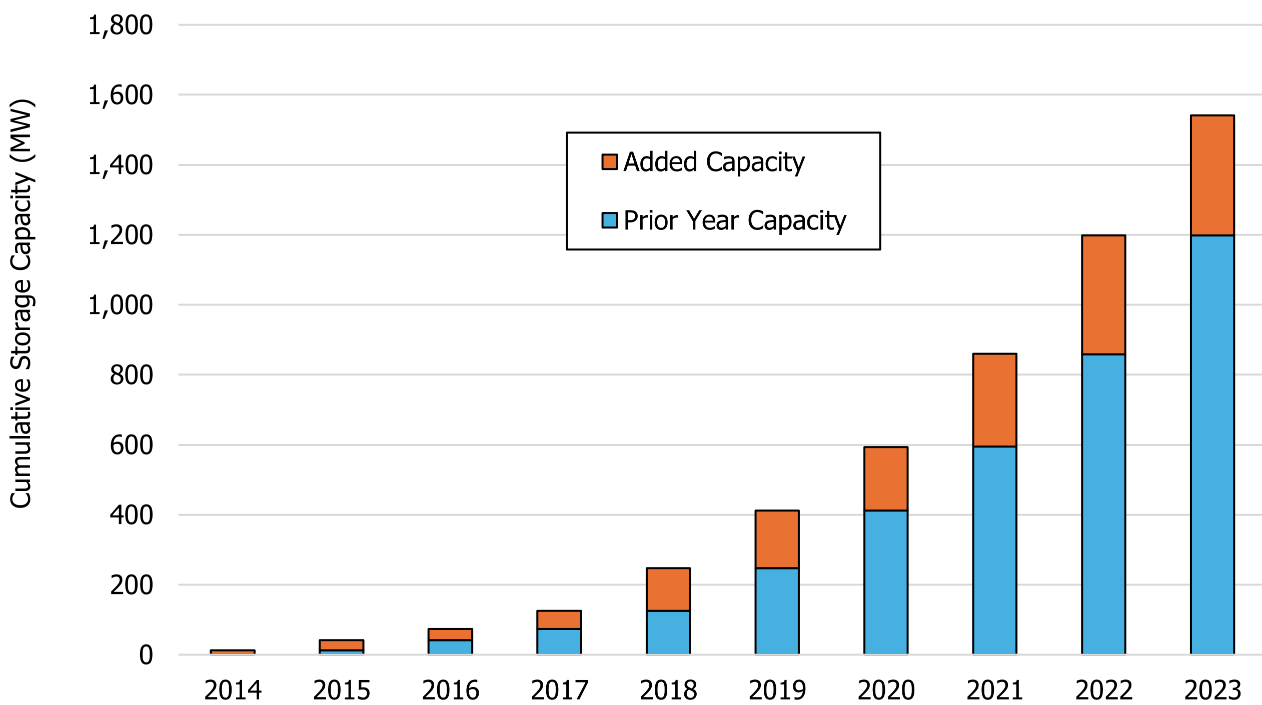
Figure 2: Cumulative BTM PV Capacity in California



Source: CEC analysis of Title 20 1304(b) interconnection data

BTM energy storage adoption is increasing in California, with about 84 percent (1.3 GW) of nameplate capacity interconnected in the last five years. In total, about 343 MW nameplate capacity was interconnected in 2023 (Figure 3).

Figure 3: Cumulative BTM Storage Capacity in California



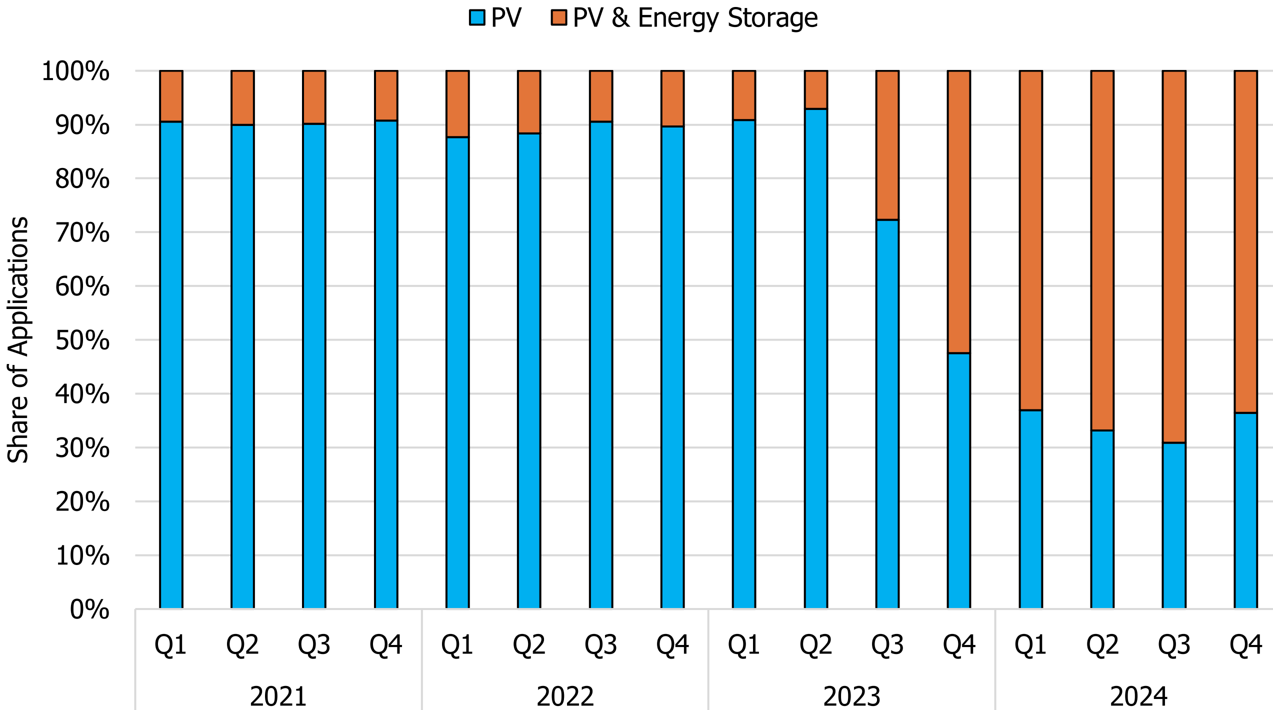
Source: CEC analysis of Title 20 1304(b) interconnection data[5]

According to the most recent CPUC interconnection data, BTM PV paired with energy storage systems increased to 69 percent of residential net billing tariff (NBT) interconnections in the first 10 months of 2024, the most recent data available at the time of finalizing the forecast, due to the incentive design of the NBT that went into effect in April 2023 (Figure 4).[6] Staff expects the share of paired systems to remain at roughly that proportion or above. Before NBT was implemented, roughly 10 percent of interconnection applications included paired BTM PV with energy storage. The retail export compensation of the NBT is higher during evening hours, when there is more demand on the electric grid and lower during hours when there is less demand and abundant solar generation already on the grid. This retail export compensation structure, combined with the NBT's requirement to enroll in a highly differential time-of-use electricity rate, encourages PV adopters to also install energy storage. This allows them to offset their grid electricity use and export excess electricity to the grid when evening electricity prices are higher.

5 Find more details on the CEC's California Energy Storage System Survey web page, https://www.energy.ca.gov/data-reports/energy-almanac/california-electricity-data/california-energy-storage-system-survey.

6 For more information on interconnected application data, visit CPUC's California Distributed Generation Statistics web page, https://www.californiadgstats.ca.gov/downloads/.

Figure 4: Pacific Gas and Electric Company (PG&E) and Southern California Edison Company (SCE) Residential BTM DG Interconnection Trends by Quarter for 2021 Through 2024



Source: CEC analysis of CPUC interconnection data. Only systems interconnected under NBT are included post-April 15, 2023, to illustrate directional trends. Data current through November 30, 2024. San Diego Gas & Electric is excluded because paired systems are not detectable in its interconnection data.

For *the 2024 IEPR Update* forecast, staff revised BTM PV capacity factor[7] assumptions, which are used to estimate the electricity generated. Updated historical capacity factors were sourced from a large sample of metered BTM PV data procured by the CEC. The data include samples by residential and nonresidential customer sectors and CEC forecast zones. Staff calculated historical capacity factors from 15-minute average power measured at the alternating current (AC) side of the inverter and total installed inverter AC active power. The data were then aggregated to produce capacity factors for each hour by zone and sector.

The annual historical capacity factors for the California ISO region are roughly 3 to 4 percentage points lower than those in the *2023 IEPR* for 2018 to 2022 (Table 3). This reduction corresponds to a 1,400 to 2,400 GWh reduction in annual BTM PV electricity generation during these years (Figure 5).

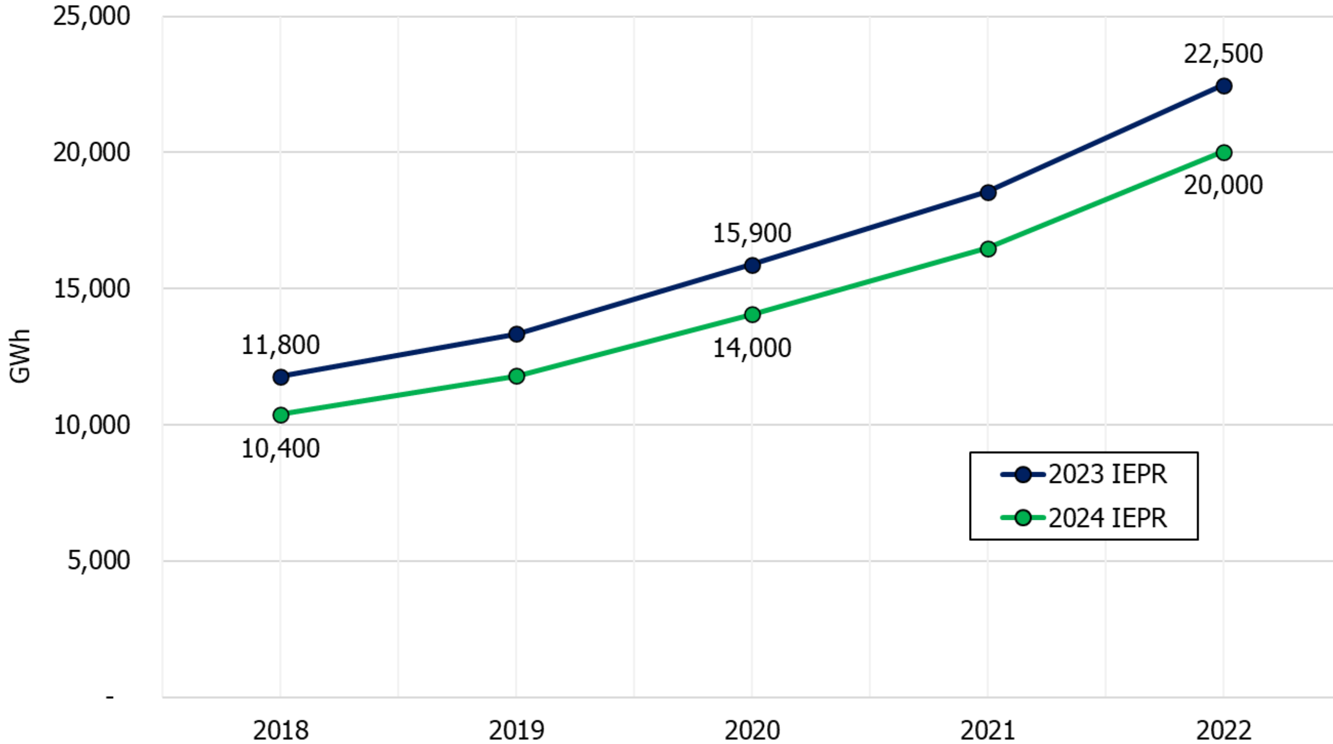
7 The *capacity factor* is the ratio of actual electricity generated relative to the total electricity that would be produced if operating at maximum capacity over the same period.

Table 3: California ISO Historical BTM PV Annual Capacity Factors

Source	2018	2019	2020	2021	2022
2023 IEPR	21.2%	20.3%	20.8%	21.0%	21.6%
2024 IEPR Update	18.1%	17.4%	17.8%	18.0%	18.5%

Source: CEC staff

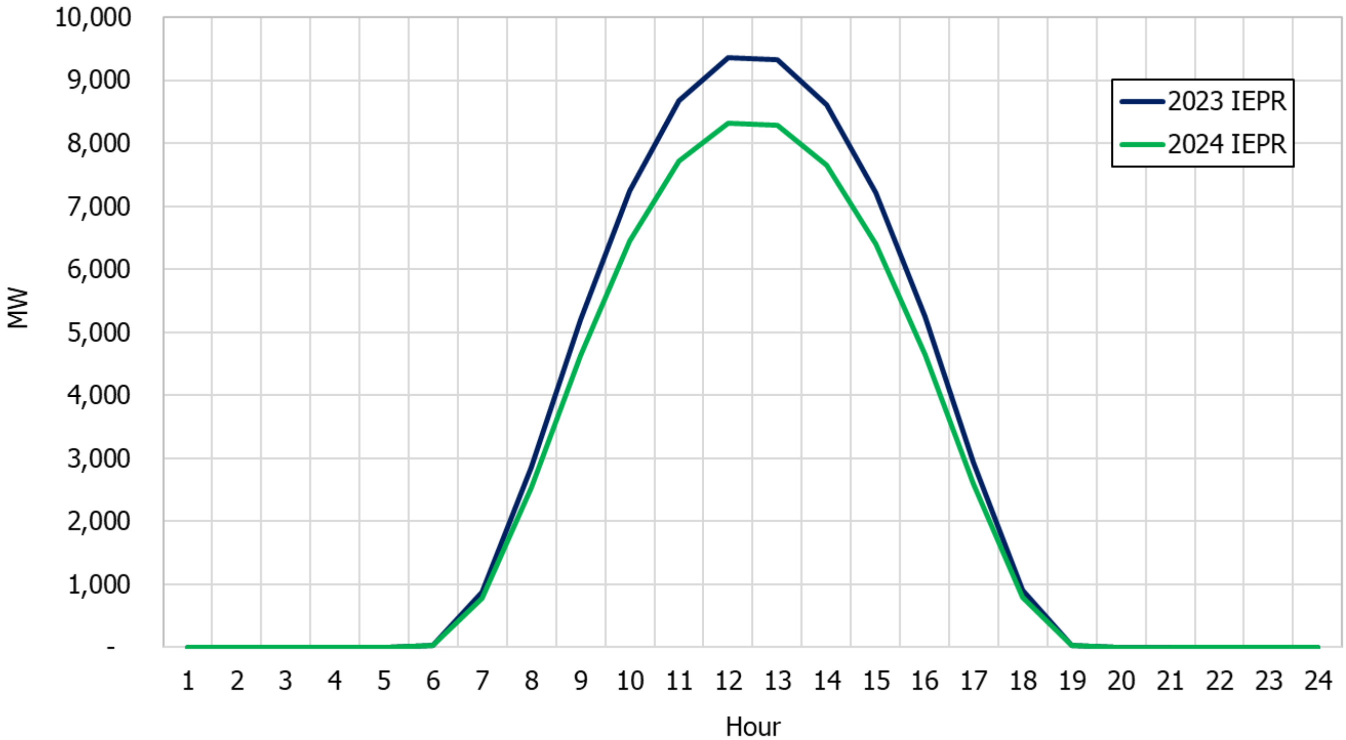
Figure 5: California ISO Historical BTM PV Generation



Source: CEC staff

The impacts of switching to the metered data to produce historical generation estimates for the *2024 IEPR Update* forecast vary by year, month, and hour. As shown in Figure 6, on an average day in the first week of September 2022, generation was 1,000 MW less during the hour of maximum generation (Hour 12) than estimated for the *2023 IEPR* forecast. Generation was 340 MW less than previously estimated during the net-peak hour (Hour 17) for the California ISO region in September 2022.

Figure 6: Average Hourly BTM PV Generation for the California ISO Region, September 2022



Source: CEC staff

Staff developed low, mid, and high BTM DG adoption forecasts to accommodate for uncertainty in future adoption. Uncertainty in future BTM DG adoption is driven by several factors, including, but not limited to, technology capital expenditure costs, electricity rates, and policies including incentives. The BTM DG adoption model uses the electricity rate forecasts discussed below and current policies such as NBT, so scenarios are distinguished by using different assumptions for capital expenditure costs and incentives (Table 4).

Table 4: BTM Distributed Generation Adoption Forecast Scenarios

Scenario	Capital Expenditure Costs	Investment Tax Credit
Low	High	Ends in 2034
Mid	Mid	Ends in 2034
High	Low	Ends in 2042

Source: CEC staff

High, mid, and low capital expenditure cost projections for PV and storage are from the National Renewable Energy Laboratory's (NREL's) 2024 Annual Technology Baseline.[8] Base-

8 Find more details on NREL's 2024 Annual Technology Baseline web pagehttps://atb.nrel.gov/electricity/2024/about. The high capital expenditure costs correspond to NREL's conservative scenario, the mid corresponds to the moderate scenario, and the low corresponds to the advanced scenario. Accessed October 2024.

year technology costs are derived from Lawrence Berkeley National Lab's 2024 Tracking the Sun data.[9] The Investment Tax Credit (ITC) expiration for the low and mid adoption scenarios align with the current expiration year, and the high scenario assumes it is renewed by Congress.[10]

For the high case, staff also included projections of energy storage adoption as customers' net energy metering (NEM) tariff service expires and they transition to NBT service. NEM tariff service expires 20 years from the standalone BTM PV interconnection date. When the NEM tariff service expires, the high case assumes some customers will choose to add energy storage to their PV system and transition to NBT. This method was originally developed for the 2025 SB 100 Distributed Energy Resources Augmentation Sensitivity analysis.[11]

Distribution-System Level Community Solar and Storage Projects

Throughout the *2024 IEPR Update* cycle, staff and leadership met with solar industry advocates and considered comments requesting that the CEC include front-of-the-meter (FTM) community solar and storage as a load modifier to reduce resource adequacy requirements for load-serving entities (LSEs). Staff also consulted with the CPUC and California ISO staff to understand the impacts to their planning and operational processes if FTM CSS projects were included in the forecast.

In D.24-05-065, the CPUC determined that FTM resources should not be credited as load modifiers to LSEs. The CPUC decision finds that community solar and storage projects are typically supply-side resources that inject 100 percent of the energy produced into the grid. These resources are operationally different than net energy metering and other BTM resources that serve onsite load before feeding energy back into the grid.[12] The CPUC decision also outlines that community solar and storage projects cannot claim RA credits without evidence that they avoid generation capacity costs.[13] In comments in the proceeding, the California ISO asserted that if the resources are not "consistently used and dispatched coincident with the hours and times of peak demand and, therefore, do not favorably reshape and modify the demand that drives [RA] requirements, then avoiding [RA] and capturing [RA] savings will not

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9 Find more details on LBNL's Tracking the Sun data and reports web page, https://emp.lbl.gov/tracking-the-sun.

10 Find more details on the Office of Energy Efficiency and Renewable Energy's Investment Tax Credit web page, https://www.energy.gov/eere/solar/homeowners-guide-federal-tax-credit-solar-photovoltaics, accessed October 2024.

11 Refer to the materials from the SB 100 webinar on August 7, 2024, for more details on the storage attachment method, https://www.energy.ca.gov/event/webinar/2024-08/senate-bill-100-demand-scenarios-staff-webinar.

12 D.24-05-065 pp. 98–99: "This decision turns to the arguments asserting the NVBT generating facilities are front-of-the-meter resources. There should be no argument surrounding this. Factually, front-of-the-meter resources are in front of a customer's meter. Behind-the-meter resources are behind a customer's meter and will address on-site load, if any, and then feed back into the grid."

13 *Id.* pp. 94-95: "Turning to avoided capacity costs, the Commission finds that without the ability of Utilities and CCAs to claim Resource Adequacy credits, proposed NVBT projects could not avoid generation capacity costs. TURN, a supporter of the NVBT proposal, cautions the Commission on the potential impact on Resource Adequacy obligations. In addition, the Commission is also concerned that the lack of a deliverability study, required in the Resource Adequacy process, could lead to the need for transmission upgrades that could result in higher costs for all ratepayers."

be realized."[14] Further, the California ISO cautioned that if community solar and storage resources send a significant amount of power onto distribution systems (as well as transmission grids) but are not visible to the California ISO, it would "create operational and demand forecasting challenges for distribution operators and the California ISO."[15] In light of the numerous challenges to California ISO and CPUC planning processes, FTM community solar and storage is not included in the *2024 IEPR Update* forecast, and staff will continue to explore this topic for the *2025 IEPR*.

Climate Change Impacts on Electricity Demand

Accounting for the impacts of climate change is critical to developing an annual and hourly electricity demand forecast out to 2040. This forecast cycle marks a continuation of staff efforts — initiated as part of the *2023 IEPR* — to leverage open, quality-controlled climate research and analytic tools to estimate climate trends and incorporate them into the forecast.

During an IEPR workshop on July 30, 2024, staff and Electric Program Investment Charge (EPIC) grant recipients[16] presented ongoing efforts to develop downscaled, bias-corrected projections over California at a 3-kilometer (km) by 3-km resolution and translate those projections into inputs that can be used directly within the CEC's forecast modeling framework.

The *2023 IEPR* forecast used hourly output from four Weather Research and Forecasting (WRF) models localized to specific weather stations used within the CEC's forecast models. Four additional downscaled, localized WRF model runs became available during the *2024 IEPR Update* cycle. The new WRF model runs and associated data sets have some additional features, such as correlated solar irradiance and wind speed projections. However, the four new model runs suggest a significantly warmer climate and, consequently, significantly higher loads if used in the CEC's electricity demand forecast.

Table 5 shows the specific models available during the *2023 IEPR* forecast, as well as the newly available models.

14 *Id.* p.81.

15 D.24-05-065 p. 82.

16 EPIC invests in research to accelerate the transformation of the electricity sector to meet the state's energy and climate goals. Find more details on the CEC's web page, https://www.energy.ca.gov/programs-and-topics/programs/electric-program-investment-charge-epic-program.

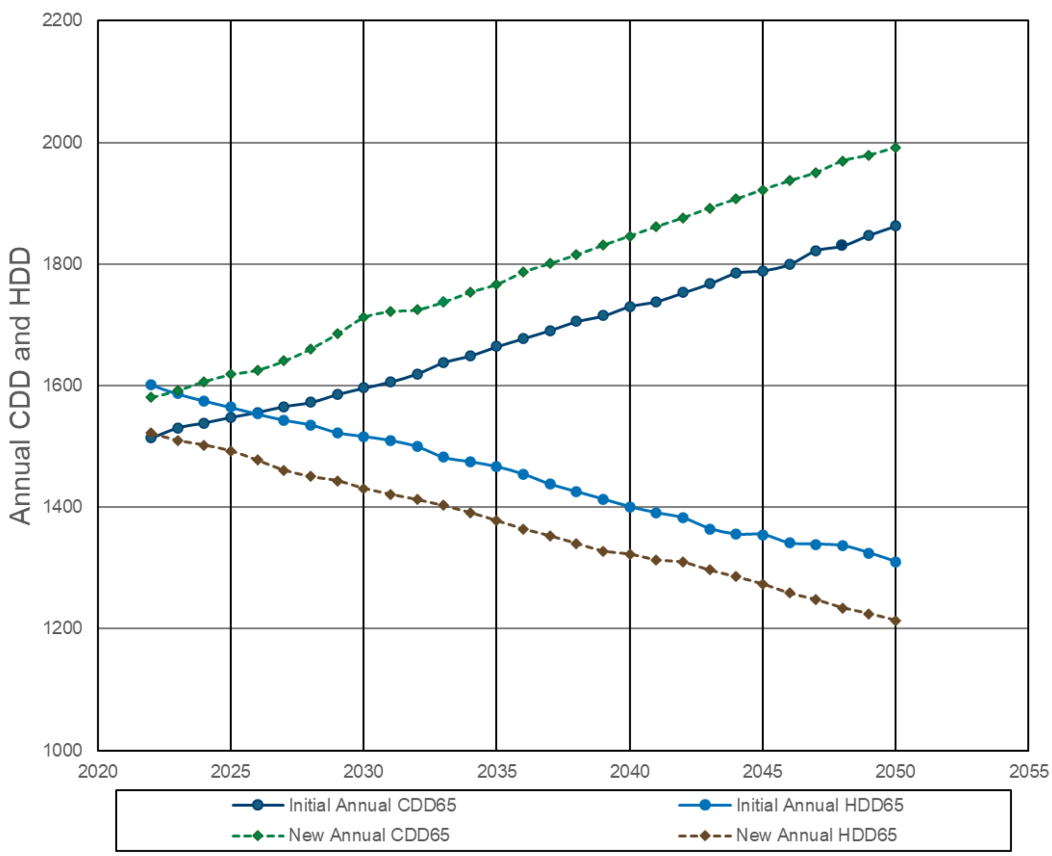
Table 5: WRF Models Used in the 2023 IEPR Forecast and the Newly Available WRF Models

WRF Models Available for the *2023 IEPR* Forecast	**Newly Available WRF Models**
CESM2 r11i1p1f1	EC-Earth3 r1i1p1f1
CNRM-ESM2 r1i1p1f2	MIROC6 r1i1p1f1
EC-Earth3-Veg r1i1p1f1	MPI-ESM1-1-HR r3i1p1f1
FGOALS-g3 r1i1p1f1	TaiESM1 r11i1p1f1

Source: CEC staff

Figure 7 compares the average level of heating degree days (HDD) and cooling degree days (CDD) from the initial WRF runs used in the *2023 IEPR* forecast and new WRF runs. The newly available projections for the California ISO region show higher annual CDD and lower annual HDD compared to the projections used in the *2023 IEPR* forecast.

Figure 7: Annual CDD and HDD From CED 2023 and CEDU 2024 for the California ISO Region



Source: CEC staff

The increased warming trend is too significant a change to implement during a forecast update and requires further review by staff and stakeholders. Staff will continue to leverage the same climate data used during the *2023 IEPR* forecast but will explore with stakeholders the potential impact of transitioning to the new WRF model output beginning with the full *2025 IEPR* forecast. At the same time, staff will explore methods for leveraging the newly available solar irradiance projections to develop PV generation estimates.

Data Center Energy Demand Forecast Updates

During the May 16, 2024, IEPR workshop, presenters from utilities and industry discussed rapid growth in new data centers that deviates from historical trends. Therefore, rather than relying on historical data to forecast data center load for the *2024 IEPR Update*, staff used information provided by utilities from applications submitted for new data center loads. Staff received data center application information from five utilities: Silicon Valley Power (SVP), City of Palo Alto, City of San Jose, PG&E, and SCE. Staff also spoke with the Los Angeles Department of Water and Power (LADWP), Sacramento Municipal Utility District (SMUD), and SDG&E and determined that data center load growth was not significant in these regions. The discussion below details the types of data received from each utility, as well as treatment of the data to forecast data center load.

Silicon Valley Power (SVP) and City of Palo Alto provided hourly forecasts for data centers. The City of San Jose[17] provided a ramping schedule of planned data center capacity (MW). Staff incorporated this information unaltered.

PG&E and SCE provided requested data center capacity from applications in any of the following stages:

- **Transmission and Distribution Planning:** Project has completed engineering studies and is close to or in the process of development. Project is included in the utility's distribution engineering process.[18]
- **Group 1:** Active application with completed or to-be-completed engineering study
- **Group 2:** Active application prior to initiating engineering study
- **Group 3:** Project inquiries that demonstrate interest, but have not materialized into an application

Given uncertainties associated with applications for new loads, including project completion date and final installed capacity, staff created three forecast scenarios for PG&E and SCE and applied confidence levels by application status and scenario. The confidence level represents the percentage of project capacity that is assumed to be completed.

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17 At the time of the draft 2024 IEPR Update forecast, the City of San Jose was becoming a municipal utility and shared applications for data centers within the city that were planned to come on-line after it became a municipal utility. CEC staff confirmed that these projects are not included under PG&E's projects. As of the publishing of this final report, the city's effort to become a municipal utility has been paused.

18 Staff has received data center capacity of this project type from SCE but not from PG&E.

- **Low Scenario:** Includes projects incorporated in utility transmission and distribution planning at 100-percent confidence level; Group 1 projects at 50 percent.
- **Mid Scenario:** Includes projects incorporated in utility transmission and distribution planning at 100 percent confidence level; Group 1 projects at 70 percent; Group 2 projects at 50 percent.
- **High Scenario**: Includes projects incorporated in utility transmission and distribution planning at 100 percent confidence level; Group 1 projects at 70 percent; Group 2 projects at 50 percent; and Group 3 projects at 10 percent for PG&E or the confidence level reported by SCE.

The table below summarizes the confidence level assumptions by application status for each forecast scenario for PG&E and SCE.

Table 6: Application Confidence Level Assumptions by Data Center Forecast Scenario for PG&E and SCE

	Low (% Confidence)	**Mid (% Confidence)**	**High (% Confidence)**
SCE T&D Planning	100%	100%	100%
Group 1	50%	70%	70%
Group 2	-	SCE: 50% PG&E not included*	50%
Group 3	-	-	PG&E: 10% SCE: 10 – 50%

Source: CEC staff. *Staff used slightly different methods for PG&E and SCE because 63 percent of the capacity of PG&E's potential projects had initiated or completed an engineering study, compared to 15 percent of the capacity of SCE's potential projects.[19]

Once the confidence level is applied to each project group, staff then applied a utilization factor of 67 percent[20] to estimate data center peak load from the requested capacity in the applications.

Once data center peak demand (MW) was calculated, staff then calculated annual consumption (MWh), using the following steps. Historical hourly electricity sales data for a sample of data centers were analyzed by staff. Using these data, staff calculated hourly load factors by dividing the demand in each hour of the year by the highest demand in the same

19 The method was outlined in a presentation at the December 23, 2024, DAWG meeting, https://www.energy.ca.gov/event/meeting/2024-12/revised-date-and-time-ca-energy-demand-forecast-updated-data-center-forecast.

20 SVP provided this figure based on its analysis of the energy usage of more than 60 existing data centers of various types (for example, colocators with large suites or servers in a building, hyperscalers with servers filing entire buildings or campuses) within their territory.

year. Staff averaged the hourly load factors by weekdays and weekends and then assigned those to the corresponding day-type in each forecast year through 2040. Staff then multiplied the hourly load factors by the peak data center demand in each year to estimate hourly data center load for that year. Finally, staff aggregated the hourly load in each year to derive total consumption (MWh) for the year.

Many of the stakeholders who submitted comments on the data center forecast stated that the projections may be too low. The reasons provided included that the forecast does not consider new applications, does not consider long-term growth, and does not account for the needed redundancy when a data center in another state is offline and needs to shift those functions to a California data center. Data centers will remain an area of focus for the *2025 IEPR* forecast. Staff will continue to track new information, collaborate with utilities to monitor applications for new data centers, and ask for stakeholder feedback on inputs and assumptions. Staff will adjust inputs and assumptions for the *2025 IEPR* forecast based on the most recent data.

Transportation Energy Demand Forecast Updates

The *2024 IEPR Update* includes modifications to the Transportation Energy Demand Forecast (TEDF), which forecasts demand for all transportation fuels (such as gasoline, electricity, and jet fuel) out to 2040. California's ambitious targets for light-, medium-, and heavy-duty zero-emission vehicles (ZEVs), coupled with the state's transportation electrification policies, regulations, and funding programs, are resulting in an accelerated adoption of ZEVs. As ZEV sales continue to grow with the success of these initiatives, comprehensive planning is necessary to ensure that the grid and other transportation fuel infrastructure is ready to support increased ZEV fuels.

The TEDF continues to assess the existing baseline demand for transportation energy and the changing market resulting from California's ZEV policies. The AATE framework will continue to be used and improved to refine the forecast for ZEV adoption impacts and support strategic infrastructure planning. This framework will allow for consideration of impacts of the growing number of on- and off-road ZEV regulatory activities at the regional, state, and federal levels.

California has adopted regulations that will impact travel patterns and energy demand within the transportation sector. In response, the CEC has developed a new model to assess the effects of these state policies and market trends. The latest model, the Passenger, Air, Rail, Microtransit, and Marine Model (PARMM Model), offers statewide projections of transportation activity and related energy demand. It is designed for regular updates using the latest data on and market analysis of California's transportation sector.

The development of PARMM was highlighted and discussed at the July 31, 2023, Demand Analysis Working Group meeting on passenger travel improvements.[21] The primary goal of PARMM is to project miles traveled and energy consumption across different passenger transportation modes within California, helping policy makers and stakeholders understand the effects of policies and market changes on transportation energy demand. PARMM also has the

21 July 31, 2023, DAWG meeting web page, https://www.energy.ca.gov/event/webinar/2023-07/california-transportation-energy-demand-forecast-passenger-travel-miles.

enhanced capability of developing various travel scenarios in response to various potential policies, programs, and market developments.

Staff has also sought to continually improve load profiles. Staff has worked on improving seasonal variability in fuel demand to better evaluate hourly loads during all months, including months where the peak hour is likely to fall.

Hourly Electricity Forecast Updates

The CEC's hourly demand forecast forms the basis for its annual and monthly peak forecasts, which are critical inputs into a variety of electricity system studies conducted as part of the CPUC's Integrated Resource Plan and the California ISO's Transmission Planning Process. Moreover, forecast hourly loads inform the California ISO's flexible capacity needs assessment which ensures that load-serving entities contract for sufficient resources to meet their largest expected three-hour increase in system load each month. Beginning with the 2025 compliance cycle, monthly peak-day profiles are used to set total resource adequacy system requirements under the CPUC's Slice of Day framework.[22]

At a high level, developing the hourly forecast involves applying hourly profiles to components of the CEC's annual energy forecasts. This process begins with a base profile intended to reflect normal levels of end-user electricity consumption for every hour over a typical year. These profiles are scaled according to the CEC's annual consumption forecast, with one caveat — certain high-growth elements of the forecast are first removed because they exhibit a load pattern characteristically different from the base profile. These "load modifiers" have a unique profile that is layered onto the base profile to create the final hourly forecast.

During the *2023 IEPR* cycle, staff leveraged newly available metered BTM PV generation data to update the CEC's hourly consumption history. These new data allowed staff to reestimate the base consumption profile for the first time in several cycles. Following the update, the resulting system load profiles showed improvement over previous IEPR forecasts across several key dimensions — the timing of near-term system peaks, the level of system load during PV generation hours, and the magnitude of daily system ramps that were more closely aligned with recent historical observations.

These improvements were critical for supporting 24-hour peak-day assessments of resource adequacy. However, as noted at the July 30, 2024, IEPR workshop on Energy Demand Forecast Methodology Updates, there are additional areas where alignment between the forecast and recent historical observations could be improved. These areas include, for example, the timing of the annual system peak, planning area coincidence with the California ISO system peak, and the ratio of annual consumption to system peaks.

Staff reestimated the hourly consumption profiles again, as part of the *2024 IEPR Update* forecast, following several updates aimed at improving model accuracy. Further scrutiny of BTM PV system data indicates that CEC estimates of historical and forecasted generation were overstated in previous IEPR cycles. Consequently, staff has lowered the CEC's historical and forecast estimates of annual and hourly PV capacity factors as discussed above. Staff

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22 The Slice of Day resource adequacy program requires each LSE to demonstrate that it has enough capacity to serve its load plus planning reserve margin in all 24 hours on the day of the CAISO system peak in each month.

estimates consumption by adding the estimated BTM PV generation to the electricity sales data provided by the utilities. Therefore, the lower PV generation estimates have lowered the level of consumption predicted by the CEC's hourly models during PV generation hours, as well as the level of PV generation taken off the consumption forecast to determine system loads.

In addition, staff updated the hourly model specifications to capture recently observed trends in historical hourly consumption data, including an increased load response to temperature and a gradual shift of load away from system peak hours and to early morning and midday hours. Finally, staff updated the CEC's method of assigning loads to particular hours of the forecast calendar, ensuring that monthly peak consumption days consistently fall within the same week from one forecast year to the next.

The *2023 IEPR* forecast placed the California ISO system peak in July during the early part of the forecast horizon. The *2024 IEPR Update* forecast now places the peak in September. Similarly, within the *2023 IEPR* forecast, the SDG&E planning area peak forecast for August reached as low as 82 percent. Within the *2024 IEPR Update* forecast, SDG&E coincidence is roughly 96 percent, which is more reasonably aligned with historical observations. Finally, changes to the PV impacts have reduced the annual consumption peak relative to the system peak.

Summary of Key Drivers and Trends

The energy demand forecast has numerous underlying inputs and assumptions, including economic and demographic data and climate trends that affect how the state uses energy. It also accounts for policies and goals that guide forecast assumptions for energy efficiency, building and transportation electrification, distributed generation, and battery storage technologies.

Economic and Demographic Trends

Economic projections for the *2024 IEPR Update* are lower compared to the previous IEPR forecast inputs. Personal income, gross state product, and manufacturing output are expected to grow at slower rates than previously forecasted. Demographic projections for the *2024 IEPR Update* are higher than the previous *2023 IEPR* forecast but still lower than the 2022 forecasts. The details of these projections are discussed below. An overview of economic and demographic trends was discussed at the August 21, 2024, Demand Analysis Working Group Meeting.[23]

Population and Households

Based on data from the California Department of Finance (DOF), statewide population for the *2024 IEPR Update* forecast grows at an average of 0.3 percent annually from 2024 to 2040. This growth rate is higher than the 0.2 percent annual growth rate assumed in the *2023 IEPR* forecast but lower than the 0.4 percent annual growth rate assumed in in the *2022 IEPR Update* forecast. The 2024 total population for California is 39.2 million and is projected to reach roughly 41.3 million by 2040 (5.4 percent total growth).

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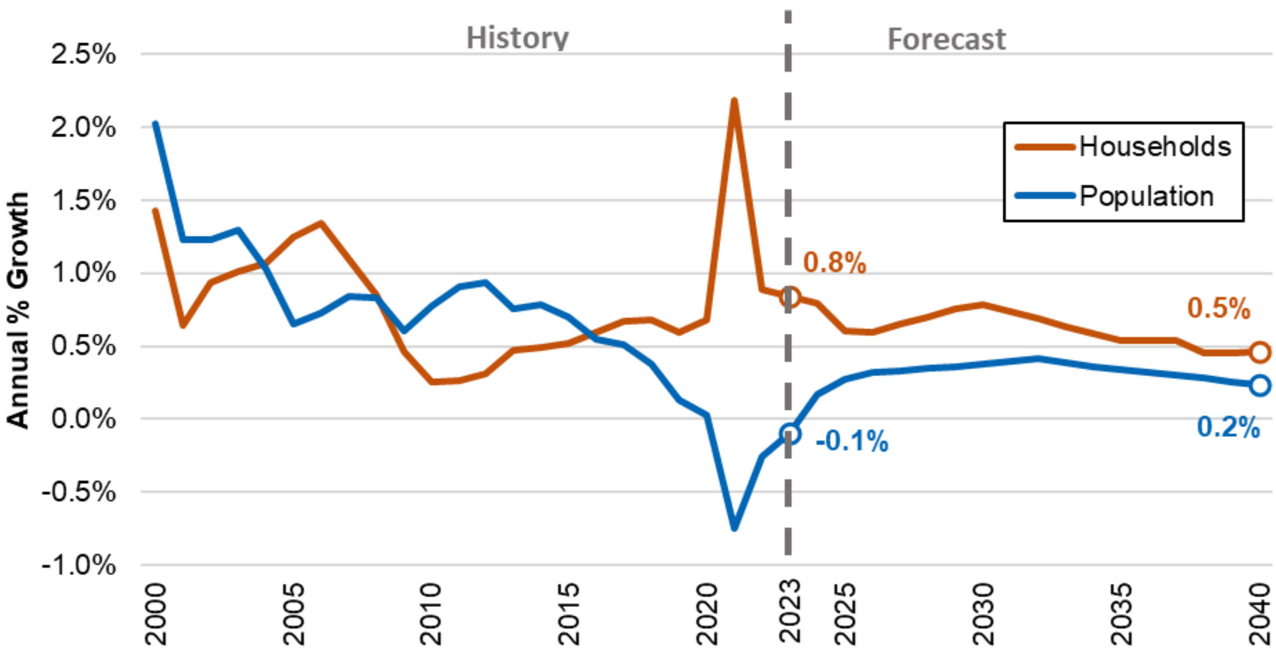
23 August 21, 2024, DAWG meeting web page, https://www.energy.ca.gov/event/workshop/2024-08/ca-energy-demand-forecast-distributed-generation-updates-economic-and.

During the period of 2020 to 2023, statewide population declined by about 1.1 percent, as noted in Figure 8. The *2023 IEPR* projected a continuation of this decline for the next few forecast years, primarily because of reduced immigration. However, data from May 2024 (used for the 2024 IEPR forecast) showed a return to normal migration patterns. The May 2024 forecast indicates a return to growth starting in 2024 and continuing past 2040.

Statewide, the number of households is expected to grow at 0.6 percent annually from 2024 to 2040, slightly above the previous projections from DOF. The last few years of historical data have also been revised upward. DOF now estimates that there are 13.9 million households in 2024 and roughly 15.2 million by 2040 (9.6 percent total growth). The high cost of living in California versus other states has largely equalized when compensating for income differences; so fewer individuals are going out of state to form households. There is also a slight decrease in rental costs over the last 18 months, which is driving an increase in household formation.

Figure 8: Statewide Population and Household Growth, 2024 IEPR Update Forecast



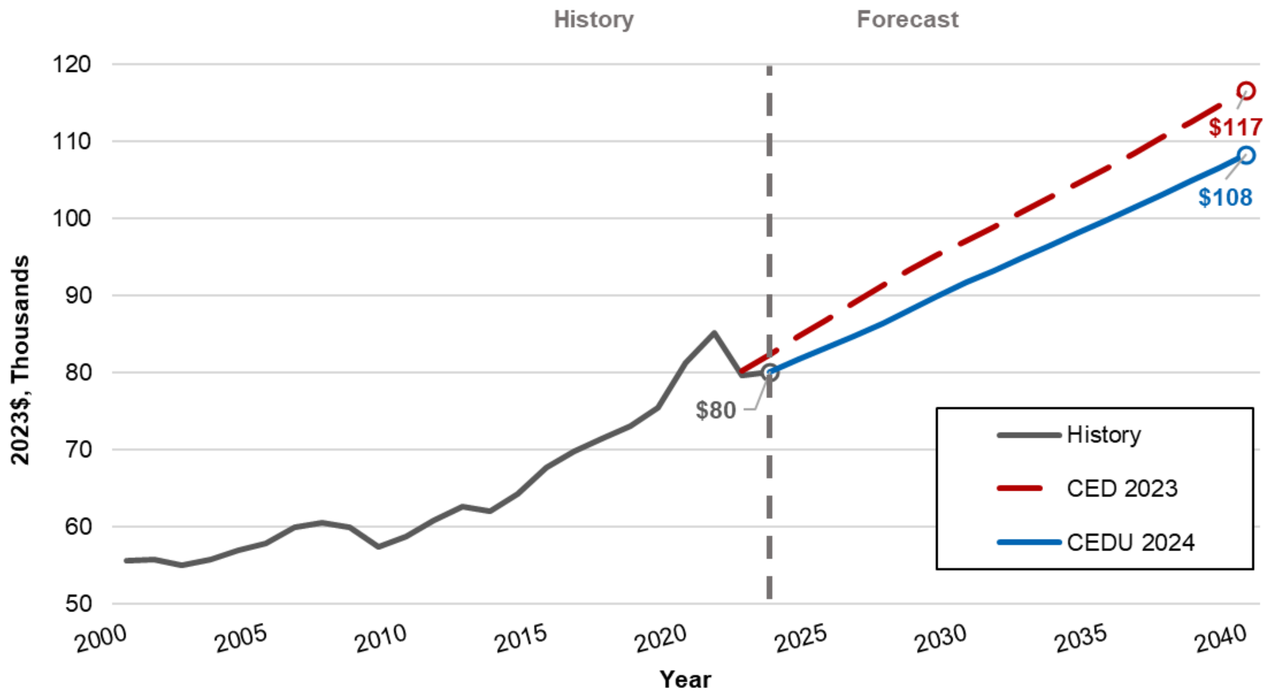
Statewide population grows at an average of 0.3 percent annually from 2024 to 2040. The number of households statewide is expected to grow at an average of 0.6 percent annually from 2024 to 2040.

Source: CEC using data from DOF

Per Capita Personal Income

Figure 9 compares baseline statewide per capita income for the *2024 IEPR Update* (also referred to as the California Electricity Demand Update [CEDU] 2024) against the *2023 IEPR* forecast (also referred to as the California Energy Demand [CED] 2023). Statewide per capita income is expected to grow at a slower rate than CED 2023, at an average annual growth rate of 1.8 percent from 2024 to 2040. Over the same period, statewide per capita income is expected to increase by 32.4 percent, reaching $108,300 by 2040.

Figure 9: Statewide Per Capita Personal Income Comparison, 2024 IEPR Update Forecast

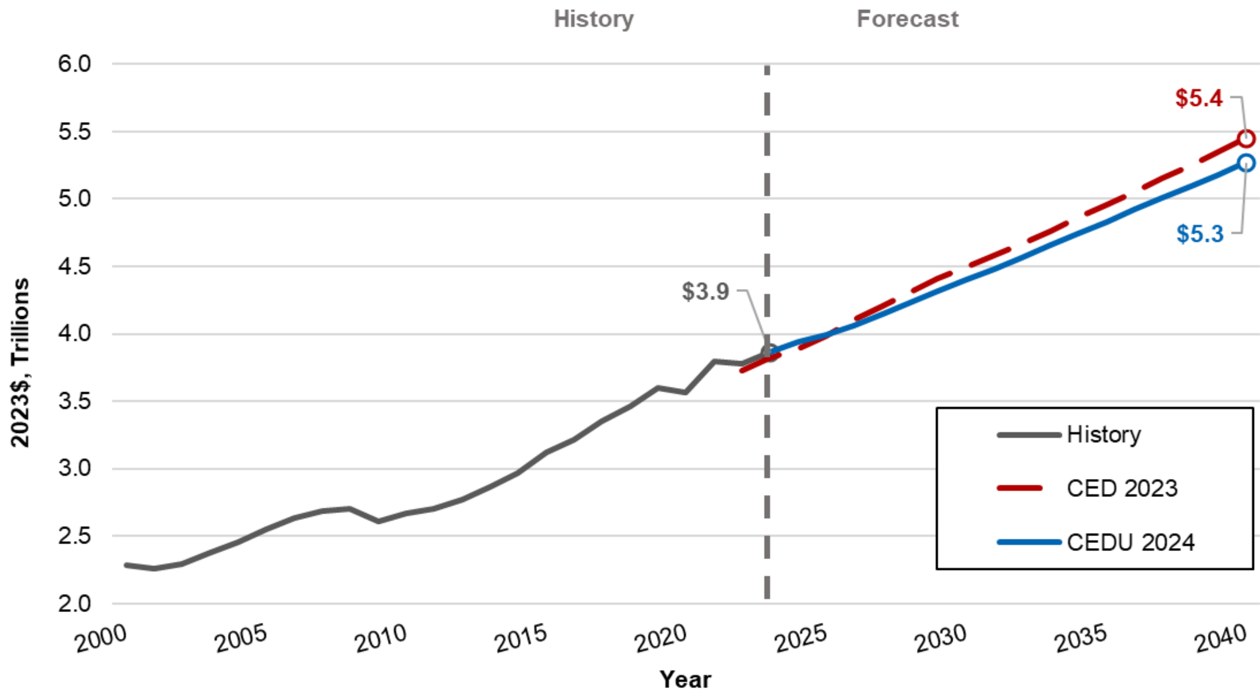


Source: CEC using data from Moody's Analytics and DOF

Gross State Product

Figure 10 compares baseline gross state product projections for CED 2023 and CEDU 2024. Gross state product is expected to grow at a slower rate in CEDU 2024 compared to the previous projection, at an average annual growth rate of 1.8 percent from 2024 to 2040. This growth is due to downward revisions to recent historical data, as well as continued inflation and uncertainty in markets. However, California's economy is still growing. Over the same period, gross state product is expected to increase by 34 percent, reaching $4.8 trillion by 2035 and $5.3 trillion by 2040. The 2024 data are from May and do not reflect any subsequent economic developments such as changes to federal monetary policy.

Figure 10: Gross State Product Comparison, 2024 IEPR Update Forecast



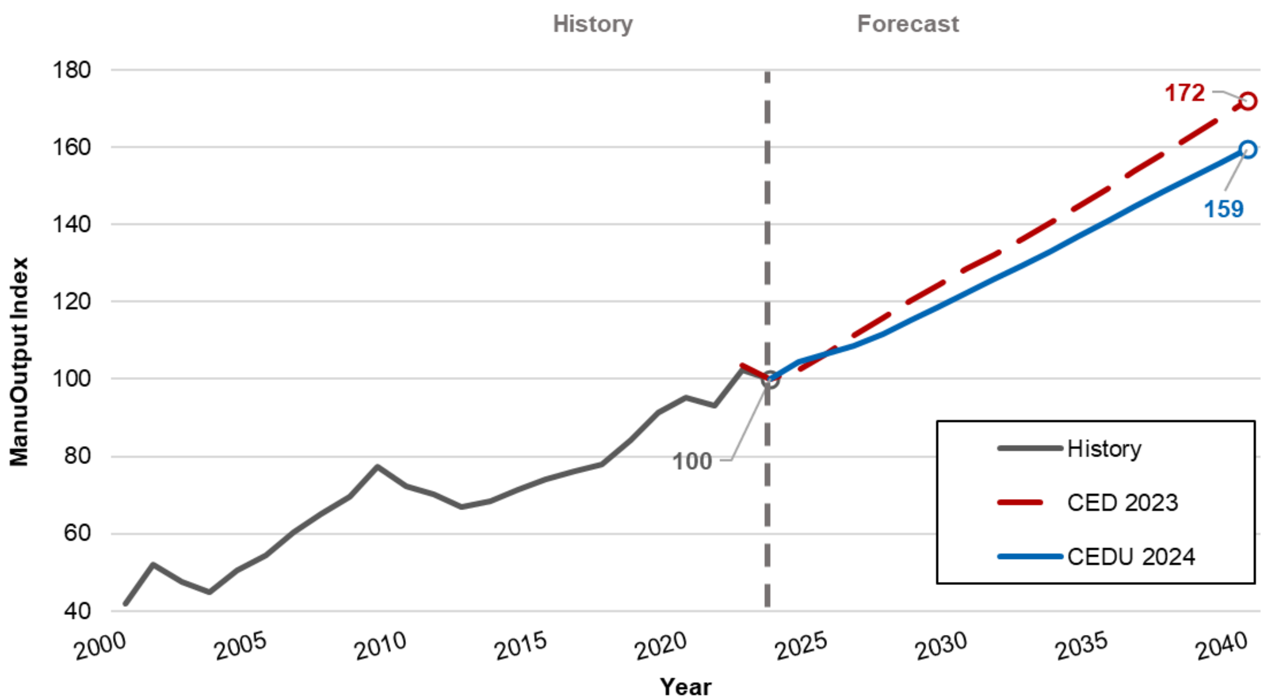
Source: CEC using data from Moody's Analytics

Manufacturing Output

Figure 11 compares gross manufacturing output projections for CED 2023 and CEDU 2024. The outputs are indexed to an arbitrary value of 100 in 2023 due to the difficulty of adjusting for inflation when comparing only a specific portion of the economy. Changes to historical data and potential alterations in methods also have resulted in discrepancies when aligning dollar amounts with previous years.

As in the previous CED 2023 forecast, gross manufacturing output in CEDU 2024 declined in 2022 and 2023 but is expected to grow again in 2024. However, the annual growth rate is slower than previous forecasts, at an average of 2.7 percent from 2024 to 2040. Over the same period, gross manufacturing output is expected to increase by 53 percent, reaching $679 billion (in 2023$) by 2040.

Figure 11: Gross Manufacturing Output Comparison, 2024 IEPR Update Forecast



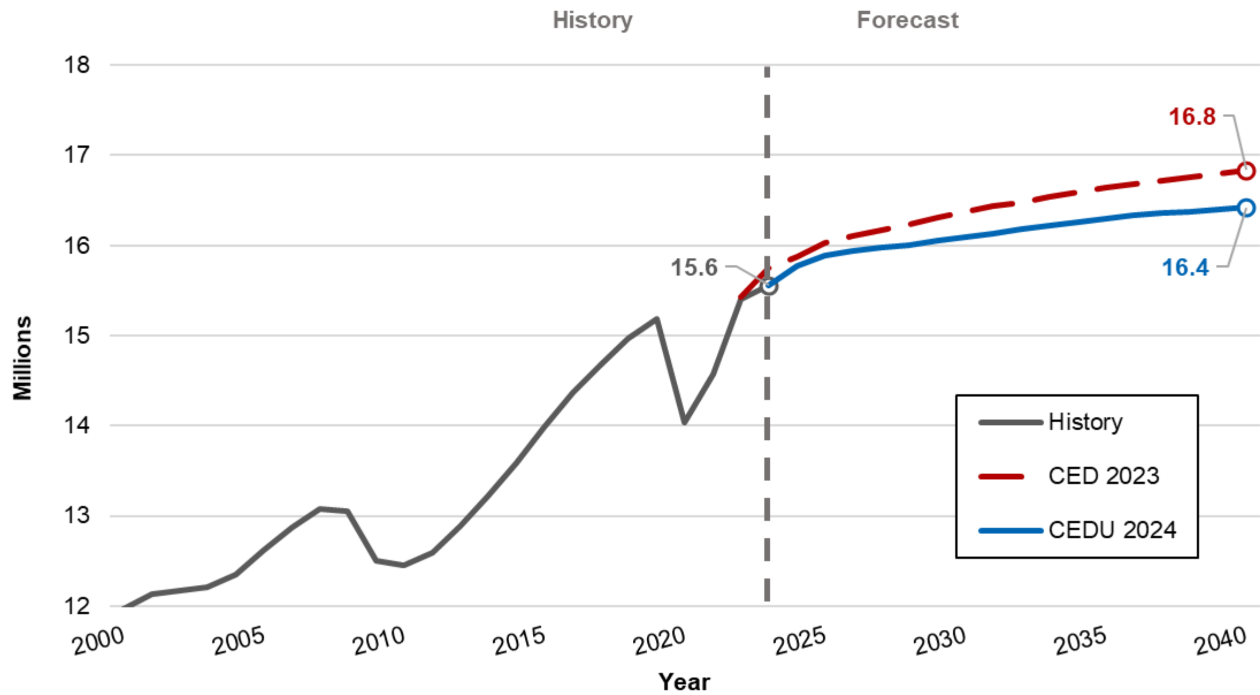
Source: CEC using data from Moody’s Analytics

Commercial Employment

Figure 12 compares commercial employment[24] projections for CED 2023 and CEDU 2024. Commercial employment is expected to grow at a slightly slower rate in CEDU 2024 compared to the previous projection, at an average annual growth rate of 0.3 percent from 2024 to 2040, resulting in a total increase of 4.1 percent. Employment trends continue back toward normalcy after the slowdown caused by the COVID-19 pandemic.

24 Commercial employment is defined as:
Commercial Employment = Total Non-Ag Employment - Construction Employment - Manufacturing Employment - Natural Resources Employment

Figure 12: Commercial Employment Comparison, 2024 IEPR Update Forecast



Source: CEC using data from Moody's Analytics

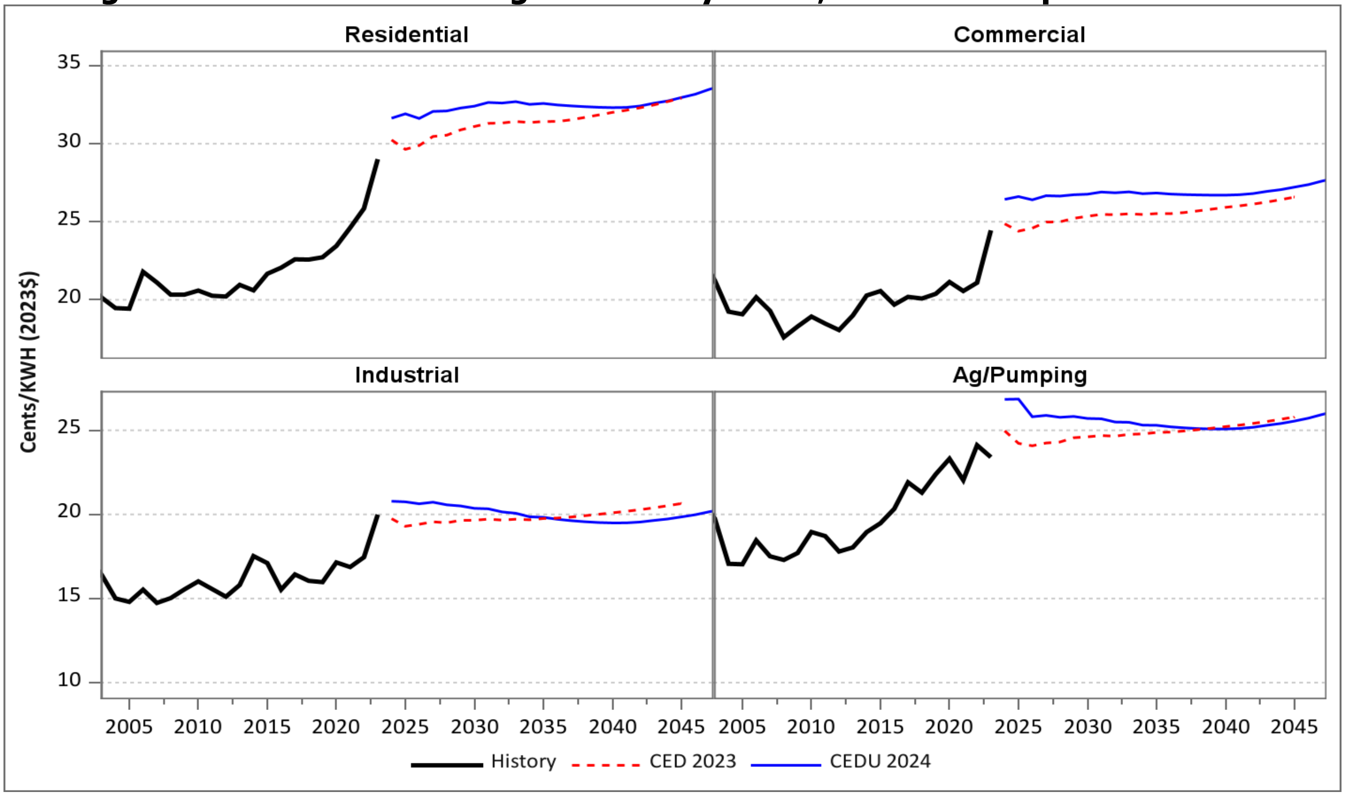
Electricity Rates

Figure 13 compares projected retail electricity rates by sector for CED 2023 and CEDU 2024.

Since 2021, electricity rates have risen significantly faster than inflation. There are several drivers for this, one of which is the costs of wildfire mitigation, such as vegetation management. Rising generation capacity prices have also contributed to higher rates, as has faster growth in utility transmission revenue requirements. NEM is causing a greater impact on rates in investor-owned utility (IOU) territories compared to publicly owned utility (POU) territories because of the disproportionately high number of rooftop solar systems in IOU territories, driven in part by a more favorable business case for solar companies and customers.

During the forecast period, as utilities continue to invest to manage climate change risk and support decarbonization, the increase in electricity sales from building and transportation electrification slows upward pressure on customer rates. However, the rate forecast is sensitive to key assumptions, such as the rate of growth in retail electricity usage and wildfire mitigation costs. For the next *IEPR*, staff will continue to assess how to improve assumptions and inputs for these rate forecasts.

Figure 13: Statewide Average Electricity Rates, 2024 IEPR Update Forecast



Source: CEC

Transportation Trends

The light-duty zero-emission vehicle (ZEV) market has grown slightly in 2024 compared to 2023. New vehicle sales are about 25 percent ZEV, and several new ZEV models introduced in the latter half of 2024 indicate that adoption in 2025 may increase already high levels. The total ZEV population of the state was more than 1.5 million as of 2023, an increase from about 1.1 million in 2022. The continued adoption of ZEVs has had an impact on gasoline demand, which has been slightly lower than in previous years.

In the medium- and heavy-duty (MDHD) vehicle sector, ZEV adoption is increasing. The CEC ZEV Stats page shows the MDHD population numbers as of 2023.[25] From 2022 to 2023, the zero-emission bus population grew by 21 percent. This growth was expected as the MDHD vehicle sector is a well-established sector that continues to work towards requirements under CARB's Innovative Clean Transit regulation. In the emerging sector of zero-emission trucks and delivery vans, the ZEV population grew by 181 percent, with many new additions expected for 2024.[26]

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25 See Medium- and Heavy-Duty Zero-Emission Vehicles in California, https://www.energy.ca.gov/data-reports/energy-almanac/zero-emission-vehicle-and-infrastructure-statistics-collection/medium.

26 The CEC counts trucks and delivery vans differently than CARB. The CEC follows the U.S. Federal Highway Administration and U.S. Census Bureau's designation of class 3 trucks to class 6 trucks (vehicles with a gross vehicle weight rating of 10,000 lbs. to 26,000 lbs.) constituting "medium-duty" vehicles. By contrast, CARB follows the U.S. Environmental Protection Agency's designation of class 2b to class 6 trucks as "medium-duty" (gross vehicle weight ratings of 8,500 lbs. to 26,000 lbs).

Transportation fuel prices, especially those for gasoline, have experienced some volatility but less than in previous years. There was a gasoline price spike in the fall of 2023, although this was not as large as the spike that occurred in the fall of 2022. In April 2024, prices again slightly spiked, but by July, they had come back down to below prices in 2022 and 2023. The rest of 2024 saw relatively stable gasoline prices, including in the September to October time frame. At the August 12, 2024, CEC Business Meeting, the CEC adopted the first Transportation Fuels Assessment, which analyzes the challenges of the state's gasoline market and offers potential actions to help address price spikes and other affordability issues in the context of continued ZEV adoption.[27]

In a more consistent pattern than seen with gasoline, retail hydrogen prices at the pump have more than doubled since 2021, averaging more than $34/kg in October 2024. This sustained increase is due to increased costs of fuel production, fuel transportation, delivery, and retailing. Light-duty fuel cell electric vehicle adoption has declined to less than 0.2 percent of all new ZEV registrations. Some medium- and heavy-duty fuel cell electric vehicles have been newly registered, but they were primarily transit buses. Staff will continue to monitor medium- and heavy-duty fuel cell electric vehicle deployment.

Policy uncertainty at the federal level may affect ZEV adoption, but the impacts are unclear. No changes can be made to the 2024 forecast, but staff will pay close attention to the policy landscape to guide future forecasts.

Building Electrification Trends

California continues to take actions to position itself to achieve its building decarbonization goals of 6 million heat pumps by 2030, 3 million climate-ready and climate-friendly homes by 2030, and 7 million climate-ready and climate-friendly homes by 2035.[28] Fulfilling these goals sets the pace for the state's residential and commercial sectors in achieving the respective 2030 and 2045 GHG emission mandates required by SB 32 (Pavley, Chapter 249, Statutes of 2016), Assembly Bill (AB) 3232 (Friedman, Chapter 373, Statutes of 2018), and AB 1279 (Muratsuchi, Chapter 337, Statutes of 2022).[29]

As of 2023, more than 1.5 million heat pumps are estimated to have been installed in California. Officially launched in May 2024, the CEC joined a public-private partnership with the major heat pump manufacturers called the California Heat Pump Coalition.[30] The CEC awarded a three-year, $9 million contract authorized by AB 102 (Ting, Chapter 38, Budget Act of 2023)

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27 For more information on the Assessment, see the CEC's "Assessment Web Page," https://www.energy.ca.gov/publications/2024/transportation-fuels-assessment-policy-options-reliable-supply-affordable-and

28 Newsom, Gavin. July 22, 2022. "Letter From Governor Newsom to CARB Chair Liane Randolph," https://www.gov.ca.gov/wp-content/uploads/2022/07/07.22.2022-Governors-Letter-to-CARB.pdf.

29 Kenney, Michael, Nicholas Janusch, Ingrid Neumann, Mike Jaske. August 2021. *California Building Decarbonization Assessment*. CEC. Publication Number: CEC-400-2021-006-CMF, https://www.energy.ca.gov/publications/2021/california-building-decarbonization-assessment.

30 Building Decarbonization Coalition. May 30, 2024. "New Public-Private Partnership Forms to Accelerate Heat Pump Adoption in California," https://buildingdecarb.org/new-public-private-partnership-forms-to-accelerate-heat-pump-adoption-in-california.

to the Building Decarbonization Coalition, which will provide assistance to consumers and contractors in accessing federal and state rebate opportunities, in addition to addressing other barriers to accelerated heat pump adoption. The partnership represents more than 90 percent of the heat pump market, utilities, and other market actors working to accelerate California's achievement of the 6 million heat pump goal. The partnership builds on a previous agreement signed at the November 2023 Building Electrification Summit hosted by the CEC and Electric Power Energy Institute, where the top global building appliance manufacturers and distributors committed to helping California achieve the 6 million heat pump goal. The partnership promotes the rapid scaling of California's heat pump market and will assist with tracking local heat pump installations to help staff forecast impacts on the electric grid.

California continues to lead the way in advancing equitable building decarbonization and driving heat pump adoption across the state. Established programs such as the $120 million Technology and Equipment for Clean Heating (TECH) Initiative and the $80 million Building Initiative for Low-Emissions Development (BUILD) Program offer incentives to install heat pump space- and water-heating appliances in existing homes and for all-electric new construction in low-income communities. The original funding for these two programs was derived from the revenue generated from the GHG emission allowances directly allocated to gas corporations and consigned to auction as part of the California Air Resources Board's (CARB) Cap-and-Trade Program and accrued over a four-year period, from Fiscal Year (FY) 2019–2020 to FY 2022–2023.

Due to the successful implementation, the TECH Initiative was awarded an additional $50 million as part of AB 179 (Ting, Chapter 249, Statutes of 2022), an additional $95 million as part of AB 102, and an additional $40 million as part of AB 157 (Gabriel, Chapter 994, Statutes of 2024).[31] In October 2024, the CEC and DOE announced that an additional $80 million of federal funds would be invested in TECH as part of the California launch of the Home Electrification and Appliance Rebates component of the Inflation Reduction Act. This $80 million investment will be dedicated to low- and moderate-income households. Based on the 2023 CPUC annual report to the Legislature, more than 12,000 heat pump heating, ventilation, and air-conditioning (HVAC) and heat pump water heater retrofits in single-family and multifamily homes have occurred from the TECH program.[32]

Further, the meter-based impact analysis of these installations shows significant energy and gas savings from these heat pump retrofits. About 54 percent of heat pump HVAC installations and 45 percent of heat pump water heater installations resulted in a net decrease or no significant change in annual utility bills for customers. The TECH program plans to assess the regional effect of the refined design through an analysis of participation data. In the multifamily sector, 83 percent of incentives supported affordable housing projects, underlining

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31 CPUC. February 2, 2023. Decision 23-02-005, https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M501/K931/501931113.PDF.

32 CPUC. February 1, 2024. *2023 Report on Trusts and Entities Established by the California Public Utilities Commission, Assembly Bill 1338 (Public Utilities Code 910.4), Annual Report to the Legislature*, https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/office-of-governmental-affairs-division/reports/2024/2023-ab-1338-annual-report---final-1-29-24.pdf. Pp. 60–62.

the ongoing need for financial support for affordable and market-rate projects to ensure lasting heat pump adoption.

Assembly Bill 209 (Committee on Budget, Chapter 251, Statutes of 2022) authorizes the five-year, $525.5 million Equitable Building Decarbonization Program (EBD), with appropriations set forth in AB 179 (Ting, Chapter 796, Statutes of 2022).[33] The EBD Program will include three subprograms: a Statewide Direct Install Program, a Tribal Direct Install Program, and a Statewide Incentive Program.

The Statewide Direct Install program will fund building decarbonization upgrades for low-income households in single-family, multifamily, and manufactured homes. The CEC has applied to the U.S. Department of Energy to augment state EBD funds with federal funds from the Home Energy Rebates Programs component of the Inflation Reduction Act. If approved, in total, $567.2 million in state and federal funding would be available for the Statewide Direct Install program.

The $30 million EBD Tribal Direct Install Program will fund building decarbonization upgrades for buildings owned or managed by California Native American tribes, tribal organizations, or tribal members.

The $30 million Statewide Incentive Program will be implemented through GoGreen Financing, which is a program that works with private lenders to provide low-interest rate financing and is administered by the California Alternative Energy and Advanced Transportation Financing Authority (CAEATFA). The EBD GoGreen Financing Program launched in fall 2024; the Statewide Direct Install Program will launch in 2025; and the Tribal Direct Install Program is expected to launch in 2026.

While these programs will be impactful in advancing the state goal to reduce greenhouse gas emissions from buildings equitably, sustained funding and private investment will be required to achieve the Governor's climate goal of installing 6 million heat pumps by 2030.

Lastly, the federally funded Inflation Reduction Act could support the state's Home Efficiency Rebates Program and High Efficiency Electric Home Rebate Act Program. In addition to requesting $154.3 million for the Statewide EBD Direct Install, the CEC has applied to DOE to use Home Efficiency Rebates Program for a pay-for-performance program that would provide residential rebate values based on measured energy savings. It would provide about $290 million in rebates for low- and moderate-income households to install new, efficient electric appliances. These appliances include heat pump HVAC, heat pump water heaters, electric stove/cooktops, heat pump clothes dryers, breaker boxes, electric wiring, and weatherization. The Inflation Reduction Act also provides Energy Efficient Home Improvement Tax Credits and Residential Clean Energy Tax Credits, which cover partial costs for clean electricity products; heating, cooling, and water-heating appliances; and other energy efficiency upgrades. For

33 CEC. "Equitable Building Decarbonization Program," https://www.energy.ca.gov/programs-and-topics/programs/equitable-building-decarbonization-program.

example, the tax credits can cover 30 percent of the cost, up to $2,000 per year, for heat pumps and heat pump water heaters.[34]

Upcoming zero-nitrogen-oxides (NOx) and zero-GHG emission space and water heater standards at the local air quality district and statewide level will propel California's building decarbonization transformation. The Bay Area Air Quality Management District (BAAQMD) adopted its amendments to Rules 9-4 and 9-6 on March 15, 2023.[35] These amendments vary by compliance date, equipment type, and heating capacity.

Beginning in 2027, all water heaters with fewer than 75,000 British thermal units (Btu) per hour manufactured and sold that year must adhere to the zero-NOx emission standard. The South Coast Air Quality Management District (SCAQMD) adopted, on June 7, 2024, amendments to Rule 1146.2, applicable to large water heaters, small boilers, and process heaters.[36] The district has an initial proposal to amend Rules 1111 and 1121, which will affect space and water heaters, and has postponed a board vote to June 2025.[37] The SCAQMD has stricter standards than the BAAQMD, where the space and water heaters must adhere to the zero-NOx emission standards at the point of sale rather than the manufactured date of the appliance.

The California Air Resources Board (CARB) shared updated draft concepts in 2024 for its zero-GHG emission standards for space and water heaters with compliance dates similar to the zero-NOx emission standards adopted or planned to be adopted by the BAAQMD and SCAQMD.[38] The updated draft concepts have earlier compliance dates for some equipment categories than the original proposed 2030 date listed in the *2022 State Strategy for the State Implementation Plan*.[39] The proposed compliance dates are based on the type and size of the space- and water-heating equipment. Staff modeled CARB's original 2030 date proposed for zero-GHG emission standards for space and water heaters for the California Energy Demand Forecast and showed significant energy impacts. CARB staff has not finalized the regulatory

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34 U.S. Internal Revenue Service. Home Energy Tax Credits web page, https://www.irs.gov/credits-deductions/home-energy-tax-credits. Accessed October 18, 2024.

U.S. DOE. December 20, 2022. "Making Our Homes More Efficient: Clean Energy Tax Credits for Customers." https://www.energy.gov/policy/articles/making-our-homes-more-efficient-clean-energy-tax-credits-consumers.

35 BAAQMD press release. March 15, 2023. "Air District Strengthens Building Appliance Rules to Reduce Harmful NOx Emissions, Protect Air Quality and Public Health," https://www.baaqmd.gov/~/media/files/communications-and-outreach/publications/news-releases/2023/barules_230315_2023_003-pdf.pdf?la=en&rev=73fdaf7bb91b475b9b7913c133c31737.

36 SCAQMD press release. June 7, 2024. "South Coast AQMD Approves Rule to Accelerate the Transition to Zero-Emission for Building Water Heaters," https://www.aqmd.gov/docs/default-source/news-archive/2024/1146-2-June-7-2024.pdf?sfvrsn=9.

37 SCAQMD. Proposed Amended Rules 1111 and 1121, https://www.aqmd.gov/home/rules-compliance/rules/scaqmd-rule-book/proposed-rules/rule-1111-and-rule-1121. Accessed December 11, 2024.

38 CARB. May 29, 2024. Presentation "Zero-Emission Space and Water Heater Standards." Slide 13, https://ww2.arb.ca.gov/sites/default/files/2024-05/May_2024_Workshop_Slides.pdf.

39 CARB. 2022. *2022 State Strategy for the State Implementation Plan*. Page 101, https://ww2.arb.ca.gov/sites/default/files/2022-08/2022_State_SIP_Strategy.pdf.

proposal for zero-GHG emission standards for space and water heaters and expects to bring them for Board consideration after more public workshops.

Staff has made efforts to improve the tracking and forecasting of heat pumps throughout California. Staff intends to use collected interval-meter data to estimate heat pump penetration and complement other available data to improve upon the current estimate of more than 1.5 million heat pumps in California in 2023. At the national level, according to data from the Air-Conditioning, Heating, and Refrigeration Institute (AHRI), the 2023 shipments of heat pumps and gas furnaces declined.[40] However, the AHRI shipments data suggest an encouraging trend where the national share of air source pumps has not fallen and has increased in 2022 and 2023 relative to gas furnaces. Such evidence points to the growing trend of heat pump adoption and building decarbonization.

Trends in Other Areas of Load Growth

New large loads pose a particular challenge for the forecast as there is uncertainty regarding the size, timing, and location of these loads.

Furthermore, in some cases, customers representing these potential new loads may assess grid capacity, rates, and connection timelines before committing to a specific location. This assessment leads to a "chicken-and-egg" situation, where without certainty about when and where these large new loads will appear, they are not incorporated in the forecast, potentially inhibiting the necessary transmission and distribution infrastructure from being built.

Because of the uncertainty of these projects, in the *2023 IEPR* forecast, staff made forecast adjustments only for new loads based on supplemental data provided by utilities where the customers own the land, are in the process of obtaining building permits, and are working with the utility to connect. Staff also considered whether these new loads are in addition to normal load growth in the utility's region. This approach strives to protect against overinvestment and unnecessary rate increases and prevents stranded assets.

The CEC held an IEPR workshop on May 16, 2024, in which investor-owned utilities (IOUs) and industry experts discussed areas of large load growth. The topics included:

- Data Centers.
- Agriculture Sector Electrification.
- Hydrogen Production.
- Industrial Manufacturing.

The discussion at the May 16 workshop is summarized in the following sections. Of the four topics, staff collaborated with utilities to incorporate data centers into the 2024 IEPR forecast. Staff members are considering when and how to account for the other large loads in the forecast process.

40 AHRI. "2023 Monthly Shipments," https://www.ahrinet.org/analytics/statistics/monthly-shipments.

Data Centers

The rapid growth of data centers is expected to add a significant amount of electricity demand to the grid. Data centers hold stacks of servers and can concentrate a large amount of load in a small area. The decision to construct a data center and the choice of location are also sensitive to a variety of factors that are difficult to forecast.

At the May 16 workshop, PG&E reported that most of the roughly 4,000 MW in large load applications for its service territory comes from data centers. SCE reported load growth from data centers over the next five years for its territory ranges from more than 100 MW to more than 500 MW. This growth consists of demand from several planned data centers with retail service studies underway for SCE to serve at least 50 MW of demand at each data center, as well as expansion of existing data centers. Data centers larger than 100 MW in demand are also considered possible in SCE territory.

CEC staff worked with utilities to incorporate applications for new data centers into the 2024 IEPR forecast. The methodology is outlined in the section 'Data Center Energy Demand Forecast Updates' and the results are summarized in the section 'Data Center Energy Demand Forecast Scenario Results.'

Agriculture Sector Electrification

The transportation energy demand forecast includes fuel consumed by on-road and off-road vehicles used in the agriculture sector.

For demand from on-road medium- and heavy-duty EVs, under the adopted and Advanced Clean Trucks regulations, increasing ZEV requirements will result in more EVs for drayage and in agriculture freight fleets. All drayage trucks must be 100-percent zero-emission by 2035, and in 2036, all sales of new freight trucks must be zero-emission. These regulations can result in nearly all trucks being replaced by zero-emission vehicles, with impacts on energy demand, as some EV freight truck chargers can demand as much as 1 MW each.

Similarly, a new zero-emission forklift regulation, beginning in 2026, prohibits the sale of most new spark-ignition (such as propane, gasoline) forklifts. Existing forklifts are typically replaced after 13 years. This regulation would increase the deployment of electric forklifts, increasing the demand for electricity and additional forklift charging stations.

Staff has included these impacts in the current IEPR forecast, although agriculture industry representatives have indicated concerns about their ability to meet ZEV regulations. They have also noted technical challenges for the electrification of heating and drying products.

The CEC is partnering with CARB on a vehicle fleet inventory survey specific to the agricultural sector. The results will guide the electricity demand forecast, including on-road and off-road transportation. The results will be incorporated into either the *2025 IEPR* or the *2026 IEPR Update*, depending on the time frame in which the study is completed.

Hydrogen Production

CARB's 2022 Scoping Plan describes the role of hydrogen in statewide decarbonization and the clean energy transition. To support market development, California is working with public and private partners to support the energy transition with over $1 billion in investments in the hydrogen economy through the Alliance for Renewable Clean Hydrogen Energy Systems

(ARCHES). However, there are also some uncertainties on the exact trajectory of hydrogen's increasing role that make it infeasible to integrate into the current forecast. These include unknowns about hydrogen production pathways and associated grid needs, as well as hydrogen demand.

At the May 16 workshop on Electricity Load Growth areas, presenters offered different estimates for the electricity necessary for hydrogen production. Presenters offered estimates that range from 9.5 GW to 79 GW electricity demand in 2050 to produce varying amounts of hydrogen. Consistent with these broad estimates, the 2022 Scoping Plan estimated the amount of off-grid solar capacity needed to supply the quantity of electrolytic hydrogen demand modeled in the Scoping Plan Scenario in 2045 at 21 GW.

The CEC and CARB have explored and will continue to explore the technical and economic feasibility of hydrogen's role in a 100 percent clean energy system. CARB, in consultation with CEC and CPUC, is developing a comprehensive report as required by SB 1075 (Skinner, Chapter 363, Statutes of 2022) that will assess the deployment, development, and use of hydrogen across all sectors in achieving California's climate, air quality, and energy goals. Additional work will occur in a modelling study in the 2025 IEPR.

In the SB 100 process, staff put forward a new framework that will be useful for consideration of electricity system impacts associated with hydrogen production through electrolysis. During the August 7, 2024, staff webinar on Demand Scenarios for SB 100, staff presented the framework, which provides varying degrees of flexibility for electrolytic production of hydrogen.[41] Results are expected as part of the SB 100 report, and the framework will be useful for better assessment of the role of hydrogen in the state's energy system, including future IEPR forecasts.

Hydrogen vehicles are included in LD and MDHD transportation models, although the LD sector has seen a significant decline in hydrogen-powered ZEV sales for 2024. The MDHD sector has seen the introduction of hydrogen-powered vehicles, and the forecast anticipates some continued adoption.

Another area that staff is tracking is the development of fuel cell vehicles and associated power systems. Accelerated development in hydrogen supply and fuel cell economies of scale will be critical for the medium- and heavy-duty sector for fuel cell electric trucks to compete with other ZEVs, such as battery-electric vehicles. For other transportation sectors, such as oceangoing vessels, rail, and other off-road mobile applications, hydrogen has high potential either for use in fuel cells for meeting zero-emission requirements or as an intermediary step in developing renewable combustion fuels such as renewable methanol. As certainty increases around the questions of production and demand, particularly for additional sectors, staff will explore pathways for integration of scenario tools into the forecast.

Industrial Manufacturing

At the May 16 workshop, the Governor's Office of Business and Economic Development highlighted that the lack of available grid capacity can be a deterrent to potential manufacturers interested in developing plants in California. Potential manufacturers interested

41 For more information on the SB 100 Demand Scenarios webinar, see the SB 100 Demand Scenarios webinar page, https://www.energy.ca.gov/event/webinar/2024-08/senate-bill-100-demand-scenarios-staff-webinar.

in developing in California need sufficient grid capacity to support operations. As described above, the forecast incorporates economic development projections, which inform distribution and transmission system planning.

Staff is collaborating with the utilities and CPUC staff to identify possible large loads and continue to assess whether adjustments to the forecasts are warranted.

California Energy Demand Forecast, 2024–2040

Table 7 presents the final electricity forecast results.

Statewide electricity consumption was more than 276,000 GWh in 2023. Consumption is projected to reach nearly 396,000 GWh in 2040 in the mid baseline used in the planning forecast and 401,000 GWh in the high baseline used in the local reliability scenario. The baseline consumption for the planning forecast includes 27,000 GWh of data center load growth, and the local reliability scenario includes 32,000 GWh of data center load growth compared to 2023.

The baseline 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 baseline consumption forecast.

Baseline statewide sales were more than 241,000 GWh in 2023 and grow to more than 338,000 GWh in 2040 in the mid baseline used in the planning forecast and 348,000 GWh in the high baseline used in the local reliability scenario. The managed statewide sales incorporate the projected impacts of AAEE, AAFS, and AATE. For the planning forecast, managed statewide sales grow to more than 411,000 GWh in 2040. For the local reliability scenario, managed statewide sales grow to more than 420,000 GWh in 2040.

Table 7: Summary of Statewide Electricity Forecast Results in 2040

	Planning Forecast (Annual GWh)	**Local Reliability Scenario (Annual GWh)**
Baseline Consumption	395,870	400,892
Behind-the-Meter Distributed Generation and Storage[42]	57,562	53,267
Baseline Sales (Baseline Consumption — BTM DG and Storage)	338,309	347,626
AAEE	13,528	10,301
AAFS	42,288	38,777
AATE	44,053	44,053

42 Includes BTM PV, storage, and other self-generation technologies.

	Planning Forecast (Annual GWh)	Local Reliability Scenario (Annual GWh)
Managed Sales (Baseline Sales – AAEE + AAFS + AATE)	411,121	420,154

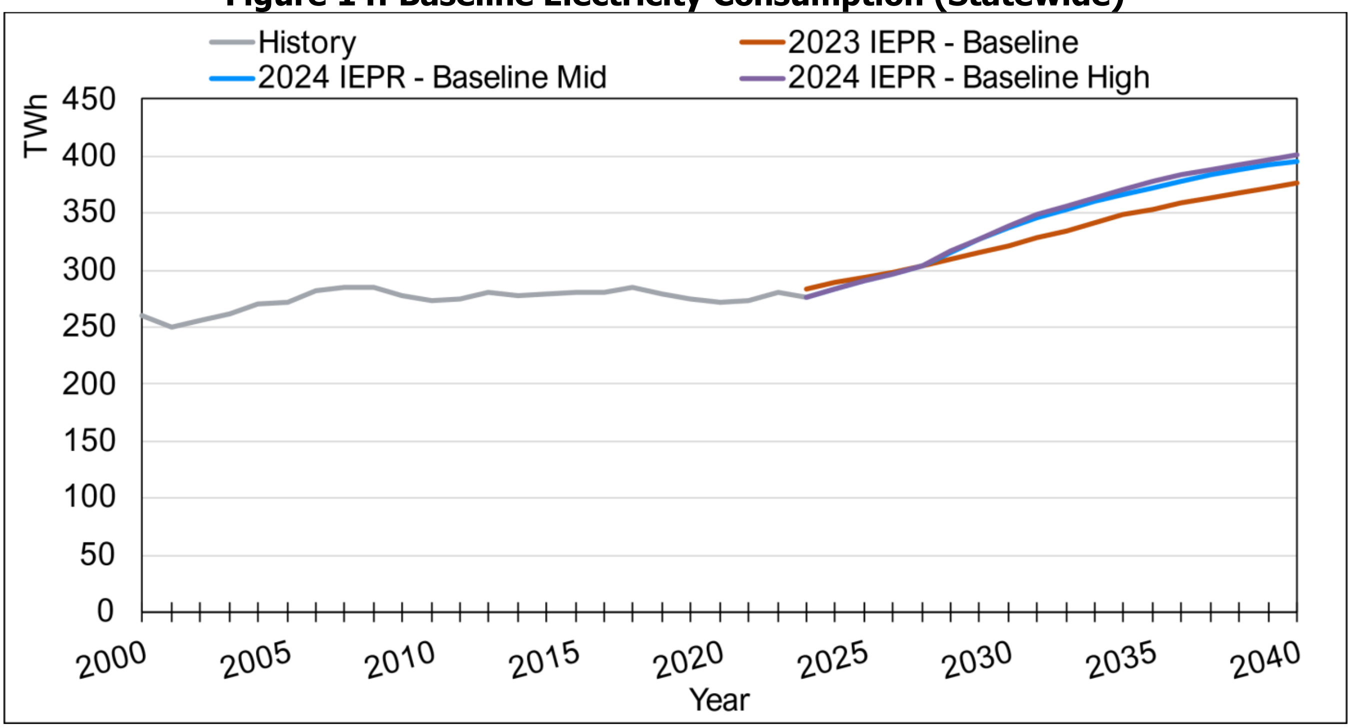
Source: CEC

The peak demand forecast is derived from the annual consumption forecast by applying hourly load profiles to projected annual consumption. Peak forecasts are developed for balancing authorities rather than for the state. The *2024 IEPR Update* Planning Scenario peak forecast for the California ISO, which manages roughly 80 percent of California's load, reaches 66,798 MW by 2040. The local reliability scenario peak forecast reaches 68,519 MW by 2040.

Annual Electricity Consumption Forecast

Forecasted baseline electricity consumption grows at 2.1 percent annually through 2040 in the mid case and 2.2 percent annually in the high case. By 2040, baseline consumption for the planning forecast is about 5.3 percent higher than the *2023 IEPR* forecast, largely due to the growth of data centers. By 2040, baseline electricity consumption will be nearly 396,000 GWh for the planning forecast and 401,000 GWh for the local reliability scenario. The difference in baseline consumption is due to using the mid case data center scenario for the Planning Forecast and the high case data center scenario for the local reliability scenario. Data center forecast results are provided in the following section.

Figure 14: Baseline Electricity Consumption (Statewide)



The 2024 IEPR forecasted baseline electricity consumption grows at a rate of 2.1 percent (mid case) or 2.2 percent (high case) annually through 2040.

Source: CEC analysis

Data Center Energy Demand Forecast Scenario Results

Staff produced three data center scenarios — low, mid, and high — based on data provided by five utilities. The values are incremental to 2023. The mid scenario is used in the planning forecast, and the high scenario is used for the local reliability scenario.

The annual growth rate of data center peak demand is roughly 15 percent from 2024 to 2030 in the low case, 19 percent in the mid case, and 20 percent in the high case. A January 2023 McKinsey study has forecasted U.S. data center demand to grow by some 10 percent per year until 2030.[43] A survey of U.S. data center growth from various sources by Energy + Environmental Economics (E3) also indicates that projected annual growth can range from roughly 9 to 16 percent.[44] California is the state with the third most data centers in the United States (behind Virginia and Texas),[45] and based on applications submitted to Palo Alto, PG&E, San Jose, SCE, Silicon Valley Power, and SMUD for new data centers, staff expects the growth rate in California to be higher than the average growth rate in the United States. Nearly 63 percent of the load growth by 2040 is in PG&E territory. Staff presented detailed results at the December 23, 2024, DAWG meeting.[46]

Figures 15 and 16 show data center peak demand and annual electricity projections, respectively. Note that the data center peak demand is the estimated maximum demand for data centers during the year. Data center load profiles are fairly flat (with minimal seasonal and daily variability), however the data center peak demand is not necessarily coincident with the California ISO coincident peak hour. Load growth flattens after 2035 because staff did not incorporate a long-term growth rate for data centers due to the high uncertainty and limited information about data center growth after 2030. Staff will revisit this for the *2025 IEPR* forecast.

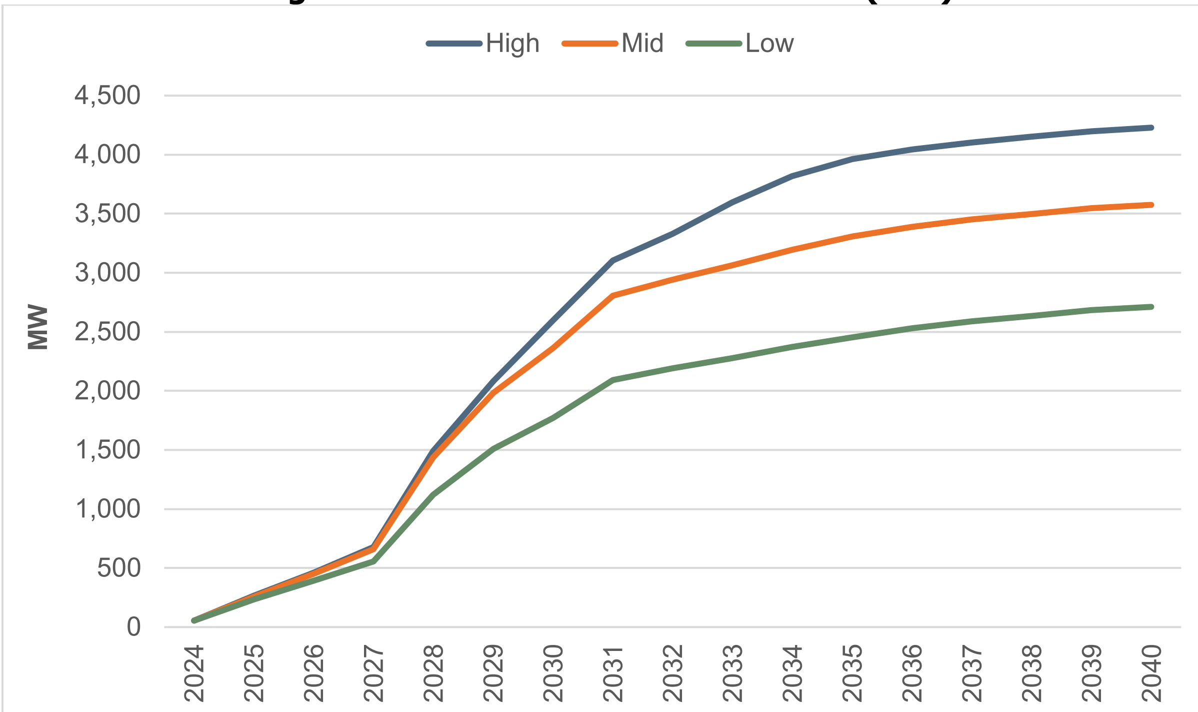
43 Bangalore, Srini, et al. January 17, 2023. "Investing in the Rising Data Center Economy." Exhibit 1, https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/investing-in-the-rising-data-center-economy.

44 Energy + Environmental Economics. E3's Data Center Demand Projections Using Various Public Sources. "Load Growth Is Here to Stay, but Are Data Centers?" Appendix 1. pp. 30.

45 Energy Policy Research Foundation. November 13, 2024. "Chart of the Week #2024-45 U.S. Data Centers: A Provisional Summary in Two Tables," https://eprinc.org/wp-content/uploads/2024/11/EPRINC-Chart2024-45-DataCenterDevelopmentSummary.pdf.

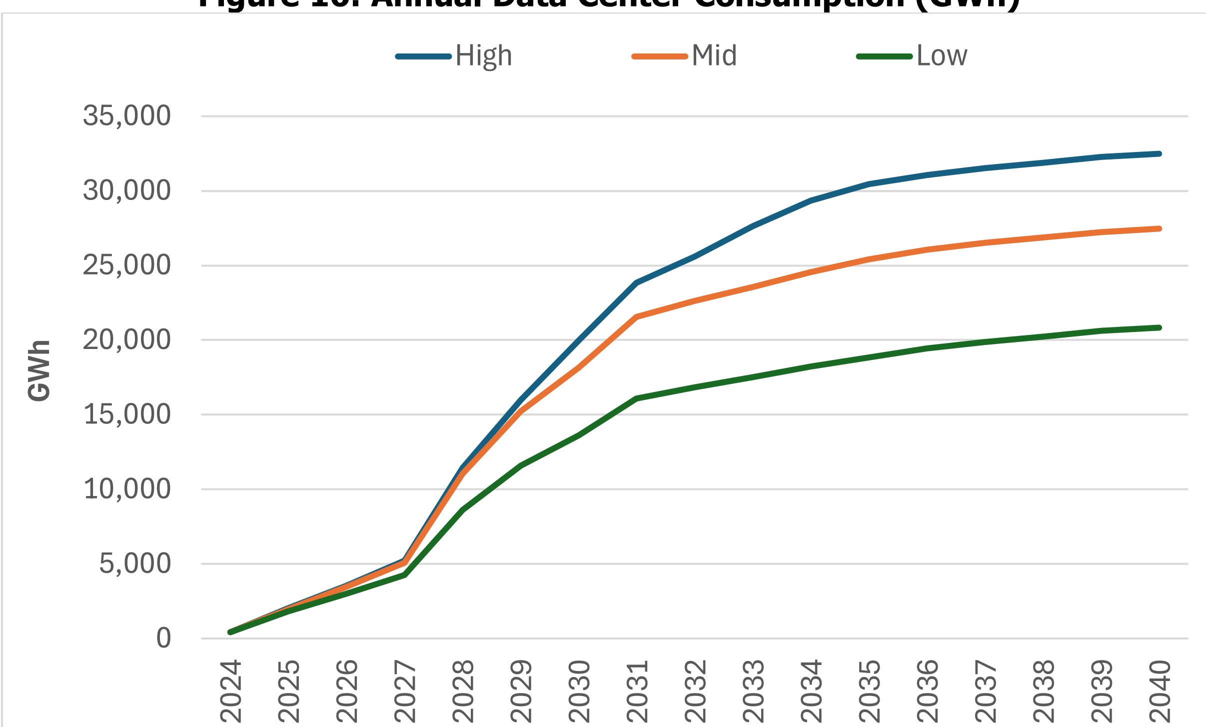
46 CEC December 23, 2024. "Demand Analysis Working Group Meeting," https://www.energy.ca.gov/event/meeting/2024-12/revised-date-and-time-ca-energy-demand-forecast-updated-data-center-forecast.

Figure 15: Data Center Peak Demand (MW)



Source: CEC

Figure 16: Annual Data Center Consumption (GWh)



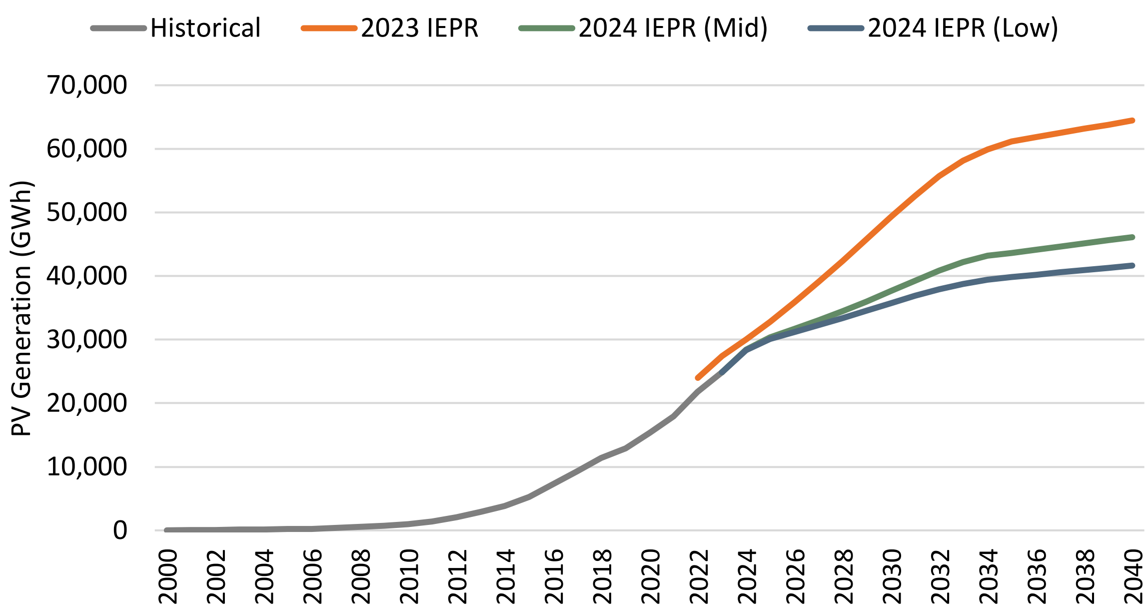
Source: CEC

Electricity Sales Forecast

The 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 incremental BTM distributed generation (including PV, storage, and other self-generation technologies) added each year reduces annual growth relative to consumption. Most BTM DG impacts are from PV generation. From 2023 to 2030, BTM PV generation grows by 6.1 percent annually in the mid case and 5.3 percent in the low case.

From 2030 to 2040, annual growth slows to 2.1 percent in the mid case and 1.6 percent in the low case. By 2040, annual PV generation reaches 46,044 GWh in the mid case and 41,641 GWh in the low case. (See Figure 17.) The CEC's PV forecast incorporates policy changes through mid-2024, meaning the new income graduated fixed charge[47] and 2025 Building Energy Efficiency Standards are reflected in the capacity and generation numbers. Further, the ITC is modeled out to 2034, based on the 2022 credit extension; the leveling off toward the end of the forecast period is due to the ITC expiration.

Figure 17: Annual Behind-the-Meter PV Generation



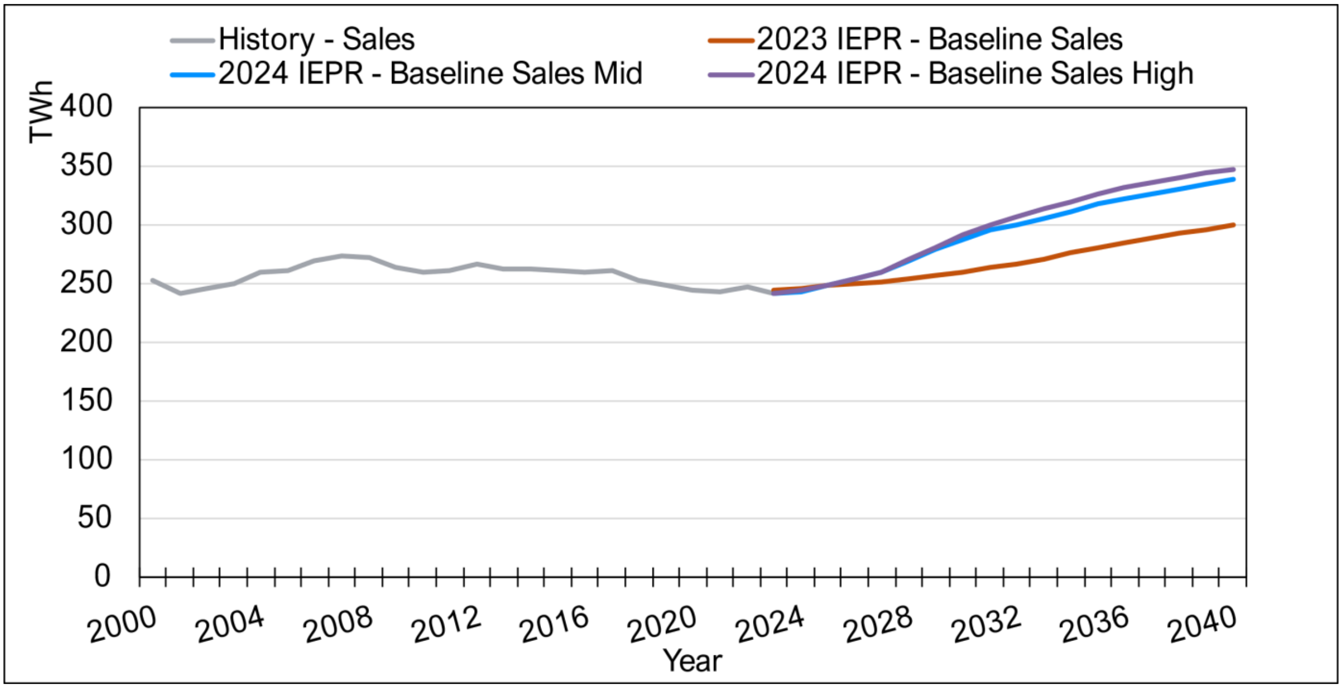
By 2040, annual PV generation reaches 46,044 GWh in the mid case and 41,641 GWh in the low case.

Source: CEC staff

47 The income-graduated fixed charge is a new billing structure for the investor-owned utilities that includes a flat rate bill component to cover a portion of the fixed infrastructure costs. For more information see CPUC's information sheet at https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/demand-response/demand-flexibility-oir/ab205_factsheet_050824.pdf.

Between 2023 and 2040, the growth rate in baseline sales is about 2.0 percent annually in the mid case and 2.2 percent annually in the high case. By 2040, baseline sales reach more than 338,000 GWh for the planning forecast, about 13 percent higher than the *2023 IEPR* forecast. (See Figure 18.) Baseline sales are higher than the *2023 IEPR* forecast largely due to the growth of data centers and decreases in BTM PV generation compared to previous assumptions. The baseline sales for the Local Reliability Scenario incorporates the high case for data centers and low case for BTM DG, and sales reach nearly 348,000 GWh by 2040, about 16 percent higher than the *2023 IEPR* forecast.

Figure 18: Baseline Electricity Sales (Statewide)



By 2040, baseline sales reach more than 338,000 GWh (mid case) or 347,000 GWh (high case) in the *2024 IEPR Update* forecast.

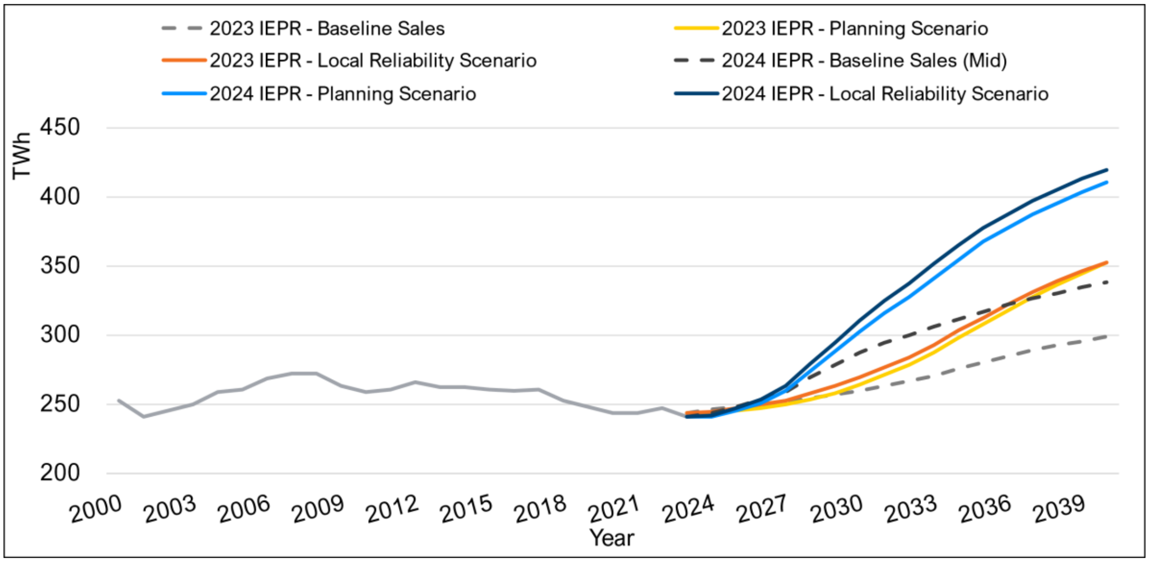
Source: CEC analysis

Managed Electricity Sales Forecasts

The *2024 IEPR Update* electricity sales forecast — combined with AAEE, AAFS, and AATE scenarios — creates managed sales forecasts. The planning forecast is a managed forecast that is a combination of the baseline sales forecast, AAEE Scenario 3, AAFS Scenario 3, and AATE Scenario 3. The local reliability scenario is a managed forecast that is a combination of a "high case" baseline sales forecast, AAEE Scenario 2, AAFS Scenario 4, and AATE Scenario 3. The high case sales forecast uses a higher data center load and lower self-generation estimates.

By 2040, the planning forecast reaches 411,121 annual GWh, and the local reliability scenario reaches 420,154 annual GWh. (See Figure 19.) As mentioned previously, the managed electricity sales are higher than the *2023 IEPR* Forecast largely due to the growth of data centers and increases in BTM PV generation compared to previous assumptions. AATE is also higher in the *2024 IEPR Update* Forecast compared to previous forecasts, as detailed in the Additional Achievable Transportation Electrification Impacts section below.

Figure 19: Managed Electricity Sales (Statewide)



By 2040, the planning forecast reaches 411,121 annual GWh, and the local reliability scenario reaches annual 420,154 GWh.

Source: CEC analysis

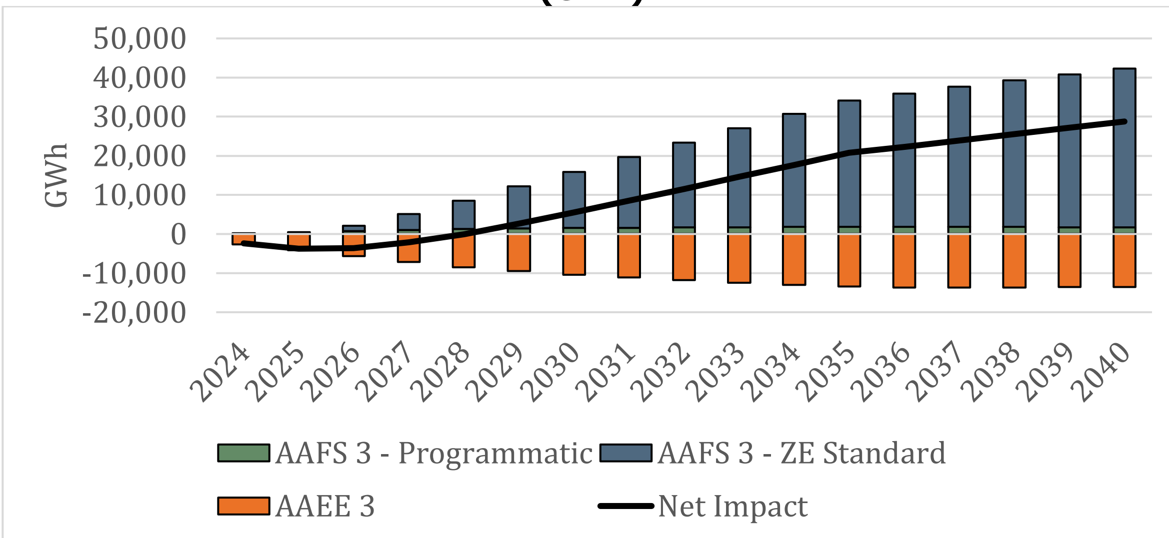
Results for AAEE, AAFS, and AATE are described below.

Additional Achievable Energy Efficiency and Fuel Substitution Electricity Impacts

The model structure of Fuel Substitution Scenario Analysis Tool (FSSAT) reports the impacts of CARB's updated draft concept for a zero-GHG emission space and water heater standard (referred to as "ZE standard" in the AAFS analysis) in the planning forecast and local reliability scenario while avoiding any double counting or overlap of AAEE and AAFS savings from incentive programs (programmatic savings).[48] Figures 20 and 21 illustrate the net electricity impacts from the AAEE, programmatic AAFS, and the ZE standard AAFS scenarios included in the planning forecast and local reliability scenario. As seen in both figures, the electricity savings from AAEE reduces but does not eliminate the added electricity from all fuel substitution activities. The black net impact lines in each figure show that the AAEE and AAFS load modifiers add more electricity than they save starting in 2029 for the planning forecast and 2027 for the local reliability scenario. For the overall energy impacts of these AAFS scenarios, the ZE standard component of AAFS has the greatest impact on added electric load for both forecast scenarios.

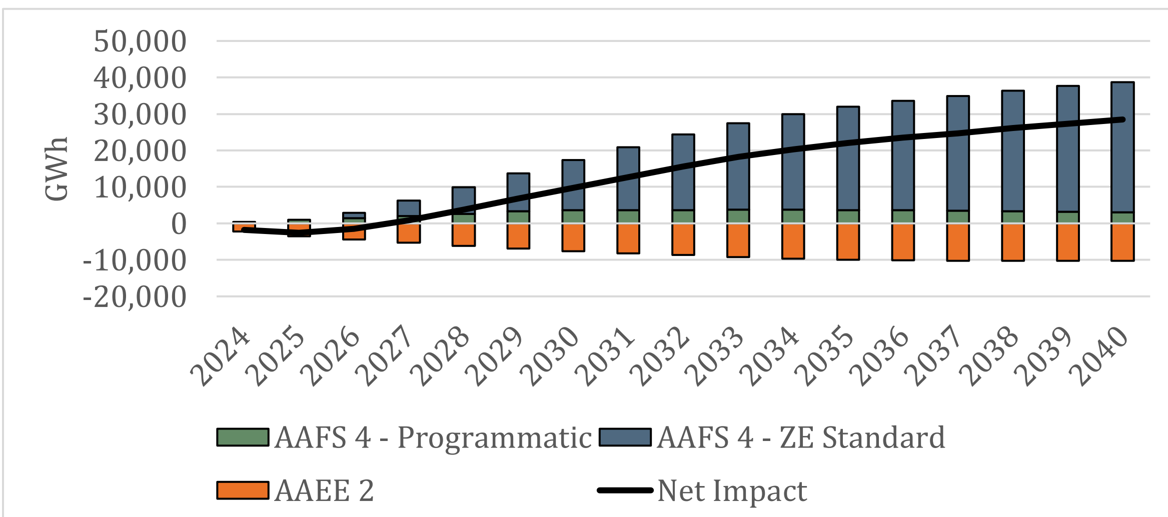
48 Note: CARB's updated draft concept of zero-GHG emission appliance space- and water-heating standards are subject to change.

Figure 20: Saved/Added Electricity from All Sectors for the Planning Forecast (GWh)



Source: CEC

Figure 21: Saved/Added Electricity From All Sectors for the Local Reliability Scenario (GWh)



Source: CEC

For the electricity impacts of the planning forecast (Figure 20), which includes the impacts from the residential, commercial, industrial, and agricultural sectors, the ZE standard AAFS 3 adds around 25 times more electricity than programmatic AAFS 3 by 2040. AAEE 3 does save around 13,500 GWh of electricity but is still about a third of the size of the load added from the ZE standard.[49] Combining all these factors, the planning forecast has a net increase in electric load of around 28,800 GWh in 2040. For the local reliability scenario (Figure 21), the

49 The *2023 IEPR* reported programmatic AAEE 3 impacts of 11,800 GWh, reflecting the impacts from strictly the residential and commercial sectors. The reported 13,500 GWh value reflects AAEE impacts from all sectors, including the agricultural and industrial sectors.

ZE standard AAFS 4 adds around 12 times greater electricity than programmatic AAFS 4 by 2040. AAEE 2 does not save as much electricity by 2040, having around 10,300 GWh of electricity savings from all sectors.[50] After reducing the added electric load from AAFS with the impacts of AAEE, the local reliability scenario has a net increase in electric load of around 28,500 GWh in 2040.

Considering the combined AAFS results in Figures 20 and 21, the electricity impacts are larger in the planning forecast than in the local reliability scenario. Three major effects explain this difference. The first is that the programmatic fuel substitution impacts in AAFS 4 are larger than in AAFS 3, reducing the impacts from the ZE standard AAFS 4 compared to ZE standard AAFS 3. As a result, the second impact is that the additional programmatic impacts from AAFS 4 add more efficient appliances (for example, heat pumps rather than less expensive and less efficient electric resistance heaters) than those that would have been added if the full impacts of the ZE standard AAFS 4 were achieved. More efficient appliances result in less increased electricity demand from fuel substitution.[51] The third major effect that helps explain the difference is how the modeling framework accounts for the savings decay from the programmatic AAFS impacts.

Based on the CEC analysis of the forecasted electric heat pump installations (from programmatic and ZE Standard AAFS) and the more than 1.5 million estimated number of existing installed heat pumps in California reported in the *2023 IEPR*, the planning forecast and local reliability scenario appear to achieve the goal of installing 6 million heat pumps by 2030. As discussed at the November 7 IEPR workshop, this year's heat pump estimates improved from last year's estimates since staff updated its model using data from the 2023 CPUC Potential and Goals Study and 2019 Residential Appliance Saturation Study (RASS), which assume higher unit energy consumption (UEC) values for existing gas equipment stock. Staff will continue to explore data sources, including AMI data, that can be used to help track heat pump installations and market trends in California and improve fuel substitution and efficiency modeling.

For the *2025 IEPR*, staff will continue consulting with CARB and CPUC staff to improve the characterization and assumptions used to model the ZE standard. Staff will seek to improve the characterization of the technologies available, the share of adoption of various competing technologies, the modeling of low-income households, and the modeling of the decarbonization potential of the industrial and agricultural sectors.

Additional Achievable Transportation Electrification Impacts

The results of AATE Scenario 3 show a higher light-duty ZEV population than the baseline forecast. For example, in 2035, the baseline forecast shows 7.4 million light-duty ZEVs, while AATE Scenario 3 shows 14.6 million ZEVs. Figure 22 below shows the light-duty ZEV population results for the two scenarios.

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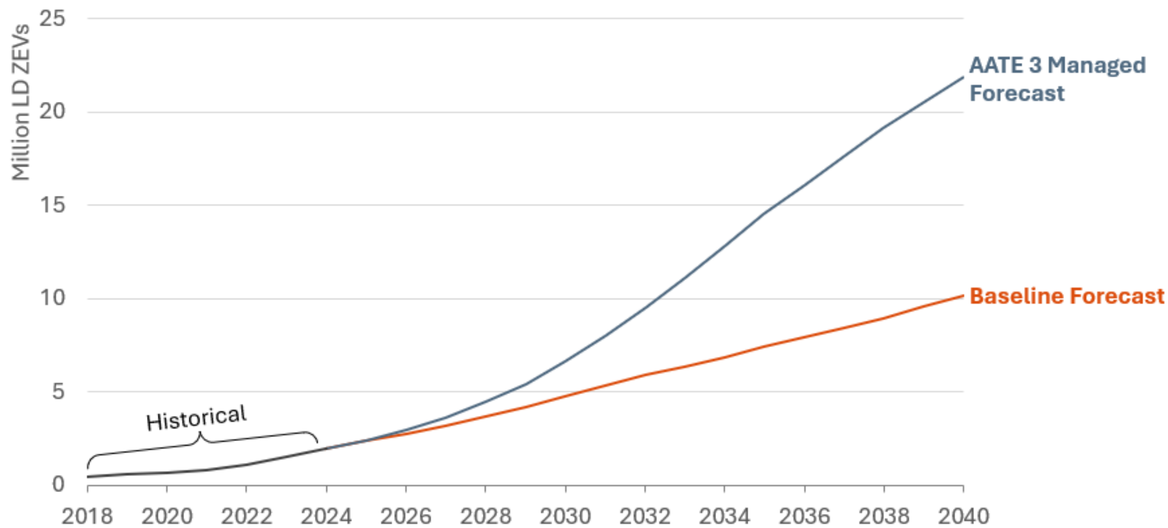
50 About 8,700 GWh savings from AAEE 2 are attributed to the residential and commercial sectors.

51 Staff acknowledges that emerging alternative lower-voltage technologies that are not included in CEC's modeling framework could potentially have different load profiles and impact future forecasts. Staff intends to investigate the potential impacts of these alternative technologies further.

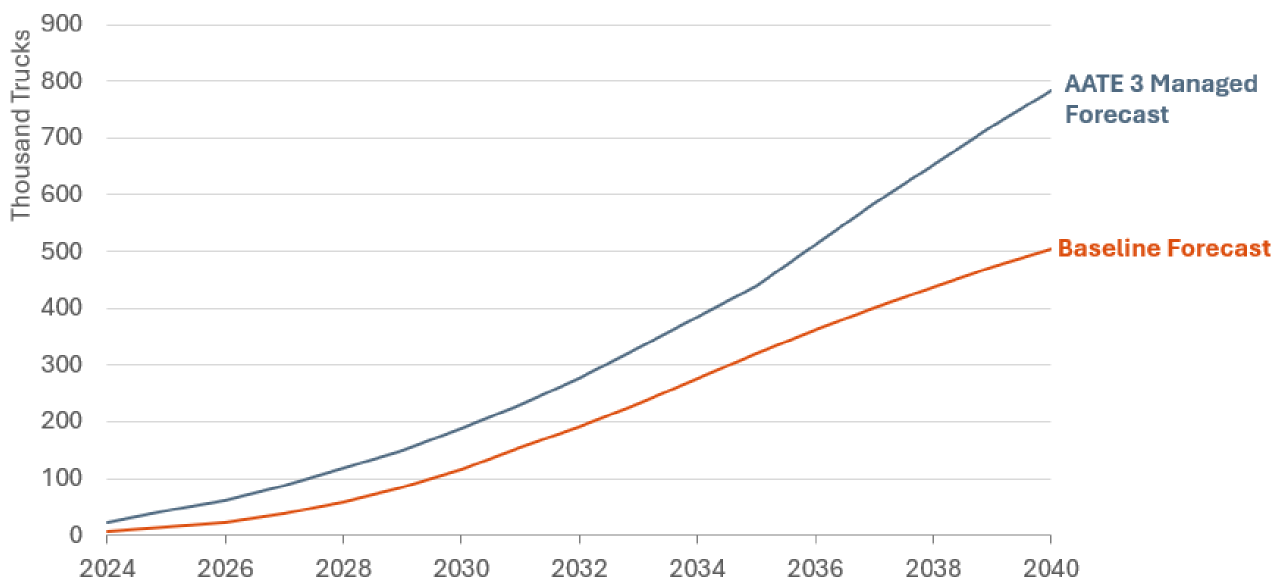
Figure 22: AATE 3 and Baseline Forecast Light-Duty ZEV Populations



Source: CEC analysis

A similar relationship holds for the medium- and heavy-duty truck population. Figure 23 below shows the medium- and heavy-duty ZEV population increasing to about 440,000 ZEVs in 2035 for AATE Scenario 3.

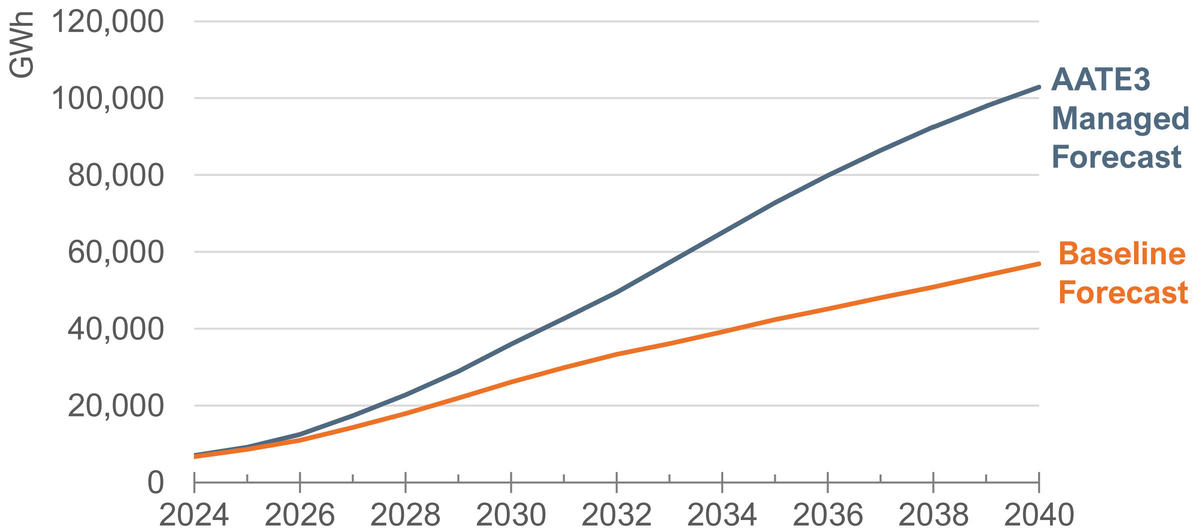
Figure 23: Medium- and Heavy-Duty ZEV Populations for AATE 3 and Baseline Forecast



Source: CEC analysis

Likewise, electricity demand from increasing plug-in electric vehicle adoption increases over the forecast period. Figure 24 below shows the transportation electricity demand from plug-in electric vehicles.

Figure 24: Transportation Electricity Demand (Light-, Medium-, and Heavy-Duty Vehicles)



Source: CEC analysis

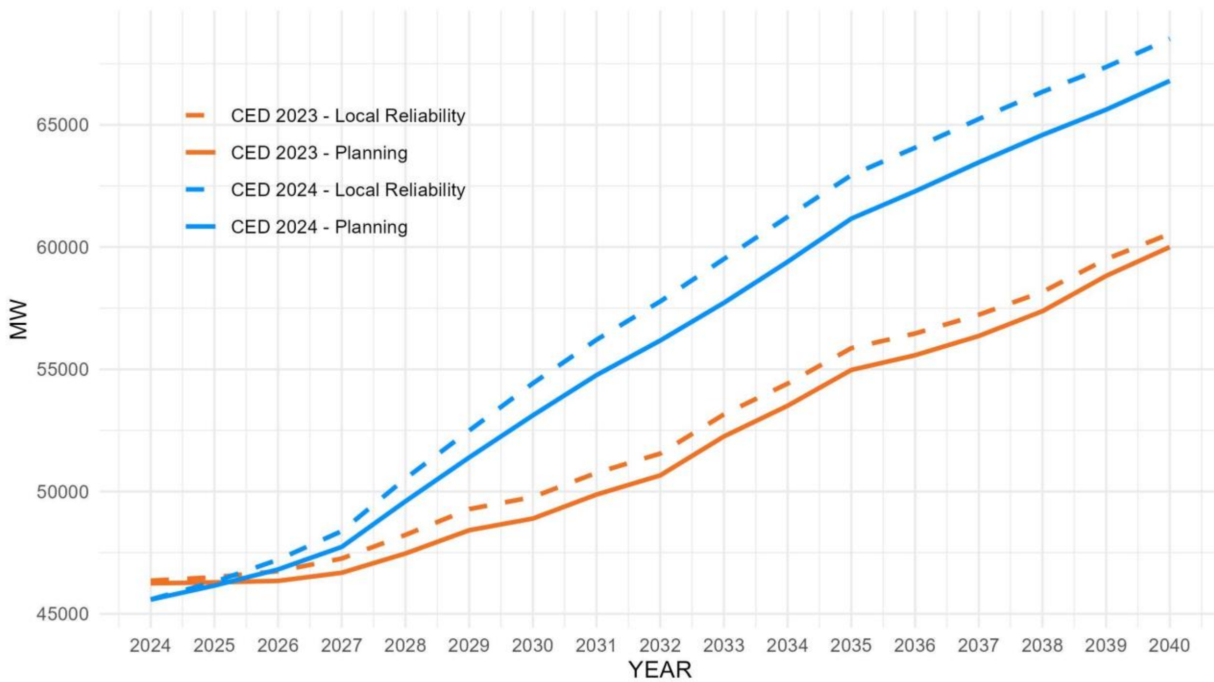
Staff presented load profiles associated with the amount of electricity demand displayed above at the December 12, 2024, IEPR workshop. A more complete, systemwide integration of hourly and peak demand that incorporates transportation electrification is presented in the next section.

Peak Electricity Demand

The peak demand forecast update is derived from the annual consumption forecast by applying hourly system load profiles to projected annual consumption. Staff benchmarks the peak forecast to weather-normalized peaks from the most recent historical year — from summer 2024, in this case. The planning forecast — combining midrange projections for behind-the-meter PV and storage, data center load, and additional achievable energy efficiency, fuel substitution, and transportation electrification — projects the California ISO system peak to grow at a rate of 2.3 percent annually, reaching 66,798 MW by 2040.

Though it starts at a lower level than previously projected, the *2024 IEPR Update* Planning Forecast for the California ISO system exceeds the *2023 IEPR* beginning in 2026. While some of the increase can be attributed to a higher baseline forecast, reduced PV impacts, and increased electrification impacts, the largest increase comes from newly added data center load. Data centers alone add more than 3,000 MW to California ISO peak demand by 2040.

Figure 25: Managed System Peak Demand (California ISO)



The California ISO managed system peak demand for the *2024 IEPR Update* Planning Forecast is higher starting in 2026 due primarily to higher baseline consumption, lower PV impacts, increased electrification, and newly added data center load. In 2040, the managed system peak demand is 11.3 percent higher than the 2023 IEPR Planning Forecast.

Source: CEC analysis

Choice of a Single Managed Forecast Set for Electricity Planning

The baseline electricity demand when combined with the following scenarios adopted as part of this IEPR, create managed electricity forecasts that constitute options for a "single forecast set" to be used for planning in CEC, CPUC, and California ISO (the joint agencies and California ISO) proceedings:

- three BTM DG scenarios,
- three data center scenarios,
- six AAEE savings scenarios,
- six AAFS scenarios, and
- one AATE scenario.

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.[52] 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 the forecast is not a single number, but a set of forecast numbers adopted as part of the *IEPR*. This set includes managed forecast scenarios that combine baseline forecasts using alternative weather variants; AAEE, AAFS, and AATE scenarios; and hourly load forecasts for transmission access charge (TAC) areas.[53] Agreement on a single forecast set includes specification on the use for each component of the set.

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

- A baseline forecast of annual energy and peak demand, with peak event weather variants (*for example*, 1-in-2, 1-in-5, and 1-in-10)
- Hourly loads for the baseline forecast for each of three IOU TAC areas
- Three scenarios of BTM DG described by annual energy and hourly load impacts
- Three scenarios of data center load growth described by annual energy and hourly load impacts
- Six scenarios of AAEE described by annual energy and hourly load impacts
- Six scenarios of AAFS described by annual energy and hourly load impacts. Scenarios 3 through 6 include the CARB May 2024 proposal for zero-GHG emission space and water heater standards,[54] and regional zero-NOx emission appliance standards[55]
- One scenario of AATE described by annual energy and hourly load impacts

The combination of the baseline forecast using a specific weather variant plus a BTM DG, data center, AAEE, AAFS, and AATE scenario depends on the use. The practices and procedures

52 Memorandum of Understanding Betweeen the CPUC, CEC, and California ISO Regarding Transmission and Resource Planning and Implementation. December 2022, https://efiling.energy.ca.gov/GetDocument.aspx?tn=262057&DocumentContentId=98567.

53 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 several publicly owned utilities using the transmission system owned by the IOU.

54 CARB's original concept in the *2022 State Strategy for the State Implementation Plan* envisioned that new space and water heaters purchased starting in 2030 would be zero-emission. At a May 2024 workshop, CARB shared a revised compliance schedule to be more staggered, with compliance dates to begin as early as 2027 for some heaters. Updates to AAFS Scenarios 3 and 4 for the *2024 IEPR Update* forecast reflect these changes. CARB will hold additional workshops in 2025 to seek public input on the regulatory proposal before taking it to the board for consideration.

55 AAFS Scenarios 2 through 6 include BAAQMD's amendments to Regulation 9, Rules 4 and 6, for space- and water-heating appliances, which was adopted in March 2023. Scenarios 2 through 4 include SCAQMD amendments to Rule 1146.2 zero-NOx emission control measures for large water heaters, small boilers, and process heaters, which were adopted in June 2024. Reflected in Scenario 4, SCAQMD is anticipated to adopt amendments to Rule 1111 and Rule 1121 for space- and water-heating appliances in February 2025.

used in electricity 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, AAEE Scenario 2 is used for local capacity studies because it is more conservative than Scenario 3, which is used in most planning studies. For fuel substitution, AAFS Scenario 4 is used rather than Scenario 3 that is used in most planning studies. For transportation electrification, Scenario 3 is used for local capacity studies and planning studies.

To account for unforeseen uncertainties, variations of adopted IEPR forecast outputs that diverge from the single forecast set may be used in planning and procurement processes under specific circumstances with consensus from the joint agencies and California ISO leadership.[56] Variations of adopted IEPR forecast outputs or CEC's long-term demand scenarios may be used for proposed portfolio and sensitivity analyses. However, lead staff agrees that planning and procurement processes will generally align with the single forecast set.

The following list describes 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 TPP economic studies:[57]
    - Baseline annual energy and annual peak demand
    - Data center mid case
    - BTM DG mid case
    - AAEE Scenario 3 annual energy and peak demand
    - AAFS Scenario 3 annual energy and peak demand
    - AATE Scenario 3 annual energy and peak demand
    - 1-year-in-2 peak event weather conditions
- California ISO TPP policy studies and bulk system studies:
    - Baseline annual energy and annual peak demand
    - Data center mid case
    - BTM DG mid case
    - AAEE Scenario 3 annual energy and peak demand
    - AAFS Scenario 3 annual energy and peak demand
    - AATE Scenario 3 annual energy and peak demand
    - 1-year-in-5 peak event weather conditions
    - Planning forecast hourly loads

56 For example, in May 2022, leadership of the joint agencies and California ISO decided to use a new scenario that reflected CARB's proposed regulations for zero-emission vehicles, given the long lead time for the types of system upgrades that could be required to support implementation of these regulations. This scenario, called the Additional Transportation Electrification scenario, was used by the California ISO for the 2022–2023 TPP.

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

    - Staff allocations of AAEE, AAFS, and AATE to load buses used in transmission studies
- California ISO TPP local area reliability studies and local capacity technical studies:
    - Baseline annual energy and annual peak demand
    - Data center high case
    - BTM DG low case
    - AAEE Scenario 2 annual energy and peak demand
    - AAFS Scenario 4 annual energy and peak demand
    - AATE Scenario 3 annual energy and peak demand
    - 1-year-in-10 peak event weather conditions
    - Staff allocations of AAEE, AAFS, and AATE to load buses used in transmission studies
- California ISO Maximum Import Capability allocation for CPUC's system resource adequacy requirements for load-serving entities (LSEs)
    - Monthly peak demand derived from the planning forecast managed sales hourly loads
- CPUC resource adequacy LSE system requirements[58]
    - Hourly loads for the monthly system peak-day demand derived from planning forecast managed sales hourly loads
    - Data center mid case hourly loads by California ISO area
    - BTM DG mid case hourly impacts by California ISO area
    - AAEE Scenario 3 hourly impacts
    - AAFS Scenario 3 hourly loads
    - AATE Scenario 3 hourly loads
    - 1-year-in-2 peak event weather conditions[59]
- CPUC IOU distribution planning[60]
    - Baseline hourly demand and hourly loads from the data center, BTM DG, AAEE, AAFS, and AATE scenarios

58 Resource adequacy under the CPUC jurisdiction shifts to using a slice-of-day approach starting in 2025, which will require hourly loads. Resource adequacy is based on annual and monthly peak demand for 2024. Non-CPUC jurisdictional load-serving entities will not shift to a slice-of day-framework. System resource adequacy obligations in the California ISO's systems and processes (which account for CPUC and non-CPUC jurisdictions) will continue to be based on annual and monthly coincident peak demand.

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

60 In October 2024, the CPUC adopted Decision (D).24-10-030 that requires large investor owned electric utilities to make various improvements to the distribution planning process. Ordered improvements include how distribution planning utilizes the CEC's forecast but does not change this joint agency and California ISO recommendation on what forecast elements shall be used in distribution planning.

    - Weather variants and AAEE, AAFS, and AATE scenarios per CPUC D. 18-02-004[61]
- California ISO flexible capacity studies for resource adequacy:[62]
    - Baseline hourly loads by California ISO area
    - Data center mid case hourly loads by California ISO area
    - BTM DG mid case hourly impacts by California ISO area
    - AAEE Scenario 3 hourly impacts by California ISO area
    - AAFS Scenario 3 hourly loads by California ISO area
    - AATE Scenario 3 hourly loads by California ISO area
    - 1-year-in-2 peak event weather conditions

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 that 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.

Long-Term Energy Demand Scenarios

The impacts of climate change and decarbonization policies have created a need to develop a set of long-term energy demand scenarios to guide planning. To meet this need, staff developed long-term demand scenarios in 2021 to identify demand-side fuel shifts, as well as GHG emission reductions from existing and near-term policies. Demand scenarios focus on a long-term horizon and include demand from all significant fuel types in various sectors. A new round of demand scenarios using the *2023 IEPR* forecast is nearing completion. Staff presented preliminary results of the major 2023 demand scenarios at a November 20, 2024, workshop. Before this workshop, staff developed a smaller, preliminary set of demand scenarios in close coordination with the CPUC and CARB for use in the 2025 SB 100 report. The smaller set used for SB 100 contained the demand scenarios standard Policy Scenario and high DER and high hydrogen use sensitivities. The complete set of demand scenarios will include more scenario sensitivities and a separate Enhanced Policy Scenario that evaluates

61 Following 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.

62 The method for assessing flexible capacity using the hourly CEC forecast was first used for flexible capacity resource adequacy planning for 2020. The joint agencies and California ISO are collaborating to evaluate this use case into the overall CEC demand forecasting work flow and the California ISO's flexible capacity projection method. The joint agencies and California ISO are evaluating and potentially modifying 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.

additional potential policies not included in the standard Policy Scenario. Staff presented the results of the early SB 100 scenarios at an August 7, 2024, webinar.

Next Steps

Each year, staff seeks to implement improvements to the forecast. To this end, staff is working on several updates for the *2025 IEPR* forecast and subsequent years.

- *2025 IEPR* forecast
    - Developing a probabilistic hourly electricity dataset to support resource planning
    - Revisiting and refining assumptions for the data center load growth forecast
    - Explore incorporating utility known load data used for distribution system planning
    - Improved geographic assignment of load for electric vehicles across existing forecast zones and other levels of geography
    - Continue discussions with the California ISO, CPUC, and industry around front-of-the meter distribution and grid interconnected solar with co-located storage
- *2026 IEPR Update* forecast and beyond
    - Assessing fuel substitution in the industrial and agricultural sectors, including the potential for hydrogen to assist with state decarbonization goals
    - Updating the commercial sector end-use model to a modern platform and incorporating the 2018–2022 Commercial End-Use Survey data
    - Incorporation of survey data from CARB's agriculture vehicle inventory survey
    - Incorporation of new data sources into EV load shape tools
    - Completing the California Vehicle Survey and integrating the information into the light-duty forecasting model
    - Exploring an increase in the geographic granularity of the forecast to support local studies
    - Exploring the possibility of new tools to better understand demand flexibility and potential interactions with the forecast

CHAPTER 2: Senate Bill 605 Evaluation of Feasibility, Costs, and Benefits of Wave and Tidal Energy Resources

Introduction

Marine energy encompasses a range of energy sources and technologies that harness marine phenomena including waves, currents (for example, tidal, ocean boundary [such as Gulf Stream], and riverine currents), ocean thermal, and salinity gradient conversion to generate electricity.[63] This chapter focuses on wave and tidal energy, as directed by Senate Bill (SB) 605 (Padilla, Chapter 405, Statutes of 2023), and summarizes the findings in the consultant report *Wave and Tidal Energy: Evaluation of Feasibility, Costs, and Benefits*.[64] This chapter concludes with recommendations to encourage and promote the technological advancement of wave and tidal technologies as they are still in the early stages of development.

Senate Bill 605

Senate Bill 605 requires the California Energy Commission (CEC) to evaluate the feasibility, costs, and benefits of using wave energy and tidal energy as forms of clean energy in the state in consultation with appropriate state agencies, including the California Coastal Commission, Department of Fish and Wildlife, Ocean Protection Council, and State Lands Commission. The evaluation is to be included in the *2024 Integrated Energy Policy Report Update* (*2024 IEPR Update*) and addresses the following:

1. Evaluate factors that may contribute to the increased use of wave energy and tidal energy in the state.
2. Provide findings on the latest research about the technological and economic feasibility of deploying offshore wave and tidal energy in the state.
3. Evaluate wave energy and tidal energy project potential transmission needs and permitting requirements.
4. Evaluate wave energy and tidal energy project economic and workforce development needs.
5. Identify near-term actions, particularly related to investments and the workforce for wave energy and tidal energy projects, to maximize job creation and economic development, while considering affordable electric rates and bills.
6. Identify a robust monitoring strategy designed to gather sufficient data to evaluate the impacts from wave energy and tidal energy projects to marine and tidal ecosystems and

63 Lee, Susan and Vida Strong. (Aspen Environmental Group). 2024. *Wave and Tidal Energy: Evaluation of Feasibility, Costs, and Benefits. SB 605 Report*. California Energy Commission. CEC Publication Number CEC-700-2024-005, https://efiling.energy.ca.gov/GetDocument.aspx?tn=257956.

64 Ibid.

affected species, including, but not limited to, fish, marine mammals, and aquatic plants, to guide adaptive management of the projects.

Furthermore, SB 605 requires the CEC to identify suitable sea space for offshore wave and tidal energy projects in state and federal waters. Identification of sea space should be done in coordination and consultation with the California Coastal Commission, Department of Fish and Wildlife, Ocean Protection Council, State Lands Commission, other state and local agencies, California Native American tribes, the offshore wave and tidal energy industry, the commercial and recreational fishing communities, and nongovernmental organizations. The sea space analysis should consider the following:

1. Existing data and information on offshore wave energy and tidal energy resource potential and commercial viability
2. Existing transmission facilities and infrastructure, and necessary additional transmission facilities and infrastructure
3. Protection of cultural and biological resources with the goal of prioritizing ocean areas that pose the least conflict to those resources

Sea space identification will be conducted outside the 2024 IEPR Update process.

California's Climate and Clean Energy Goals

As California moves toward decarbonizing the electric grid,[65] the state will need to look at integrating increasingly larger shares of renewable and zero-carbon energy resources. Offshore wave energy and tidal energy can complement other intermittent renewable energy sources such as solar and wind because of the consistent availability and predictability of waves and tides, which makes it a reliable and consistent source of power. In addition, offshore wave and tidal energy could provide geographic diversity to complement land-based clean energy resources. These advantages give wave and tidal energy the unique potential to contribute to California's clean energy transition and diversification of the state's portfolio of electricity resources.

California's electricity providers are procuring resources to meet the requirements of the Renewables Portfolio Standard and using integrated resource planning to meet greenhouse gas emission requirements and SB 100, which mandates that renewable and zero-carbon resources supply 100 percent of total retail sales of electricity to California end-use customers by 2045. The *2021 SB 100 Joint Agency Report Achieving 100 Percent Clean Electricity in California: An Initial Assessment* found that to meet the 2045 target, the state will need to roughly triple its current electricity generation capacity.[66] Wave and tidal energy may be able

65 Decarbonizing the electric grid means to reduce carbon emissions from the power sector by moving away from energy systems that produce greenhouse gas emissions.

66 Gill, Liz, Aleecia Gutierrez, and Terra Weeks. March 2021. *2021 SB 100 Joint Agency Report Achieving 100 Percent Clean Electricity in California: An Initial Assessment.* Publication Number: CEC-200-2021-001, https://efiling.energy.ca.gov/EFiling/GetFile.aspx?tn=237167&DocumentContentId=70349.

to play a role in meeting California's clean energy generation goals, pending feasibility, costs, evaluation of impacts, and the identification of suitable sea space.

Wave Energy Technology

Wave energy conversion refers to the process of harnessing the kinetic and potential energy present in ocean waves and converting it into usable electricity. Waves form as the result of wind interacting with the ocean surface. Thus, the energy of waves is highest at the surface of the ocean and decreases with depth.[67]

Along California's coastline, the estimated wave energy resource potential is 37 gigawatts (GW), generating 140 terawatt-hours (TWh) annually.[68] While this wave energy resource is theoretically available to harness, technological and environmental barriers exist in harnessing this resource. First, there is a lack of industry convergence on a single device type to harness wave power because different technologies are optimized for different resource areas and water depth. There are many wave energy converter (WEC) technologies, which can be categorized into six main device archetypes:[69]

- Attenuators
- Point absorbers
- Pressure differentials
- Oscillating water columns
- Overtopping
- Oscillating wave surge converters.

Table 8 summarizes the six main WEC device archetypes and lists examples using device name or developer name, device configuration, and optimal conditions for technology deployment. A device may fall into several archetype categories, but this table categorizes them by primary principle of operation.

67 Ibid.

68 Kilcher, L., M. Fogarty, and M. Lawson. 2021. *Marine Energy in the United States: An Overview of Opportunities.* National Renewable Energy Laboratory, NREL/TP-5700-78773, Golden, Colorado, https://www.nrel.gov/docs/fy21osti/78773.pdf.

These estimates do not consider external constraints or projected technological innovations.

69 Lee, Susan and Vida Strong. (Aspen Environmental Group). 2024. *Wave and Tidal Energy: Evaluation of Feasibility, Costs, and Benefits. SB 605 Report*.

Table 8: Summary of Six Main Wave Energy Converter Devices

Device Archetype	Example Technologies or Device Developers	Configuration	Optimal Conditions
Attenuator	Crestwing, Mocean Blue X, Pelamis, OCEANTEC	Generally floating with mooring line(s) and bottom anchor(s)	Offshore swell, tens of meters water depth (outside breaker zone)
Point absorber	AquaHarmonics, CalWave Power Technologies Inc. xWave™, Columbia Power Technologies SeaRAY, CorPower Ocean, EcoWave Power, Fred. Olsen BOLT Lifesaver, Northwest Energy Innovations Azura, Ocean Power Technologies PowerBuoy®, Oscilla Power Triton-C	Floating, semi-submerged, or submerged with mooring line(s) and bottom anchor(s)	Optimal conditions: moderate to high wave energy densities (offshore)
Pressure differential	AWS Ocean Waveswing, Bombora Wave mWave, Carnegie CETO	Submerged with mooring line(s) and bottom anchor(s)	Flexible
Oscillating water column	Ocean Energy OE, Oceanlinx, Wavegen LIMPET	Shore-based, fixed structure, or floating, moored offshore	Flexible
Overtopping	Tapchan, Wave Dragon	Shore-based, fixed structure, or floating, moored offshore	Flexible
Oscillating wave surge	Aquamarine Power Oyster, Langlee Wave Power Robusto™, Resolute Marine	Surface floating or subsurface and moored and/or bottom-mounted	Relatively shallow water depths (10-12 m)

Source: Aspen Environmental Group

WEC devices may be modular or flexible in design for use in a wide variety of environmental conditions, or they may be designed for deployment in specific locations, such as onshore, nearshore, or offshore.[70]

Onshore WECs are fixed structures that are deployed on land or in shallow water. They are integrated into breakwaters or piers or built as standalone structures. Onshore WEC devices

70 Lopez, I., J. Andreu, S. Ceballos, I. Martinez de Alegria, and I. Kortabarria. 2013. "Review of Wave Energy Technologies and the Necessary Power-Equipment," *Renewable and Sustainable Energy Reviews,* 27, 413–434, https://dx.doi.org/10.1016/j.rser.2013.07.009.

are easier to maintain but typically generate less electricity than offshore WECs because of the decrease in wave energy as waves come to shore.[71]

Nearshore WECs are installed within a few hundred meters of shore, in water depths of 10 to 25 meters. They are generally mounted directly to the seafloor; however, some devices have floating, semisubmerged, or submerged components as well.[72]

Offshore WECs are deployed in waters deeper than 25 meters. These devices may float at the surface, be near the surface (semisubmerged), or be submerged. They require moorings and anchors to hold them in place. Because of the distance from shore, these devices exploit the highest energy in waves, before breaking, and therefore must be designed to withstand large forces. Offshore devices are also more difficult and costly to maintain and require longer transmission lines to shore (if grid-connected).[73]

Tidal Energy Technology

Tidal and current energy is a form of marine renewable energy that harnesses the movement of water. This movement can be sourced from ocean circulation patterns, cyclical movement due to tides, or the flow of rivers and streams. Tidal currents are generated by gravitational forces of the Moon and the Sun on the Earth's oceans, which create bulges of water on Earth's surface, leading to the rise and fall of sea level.[74]

NREL has estimated that tidal energy resource along California's coastline exceeds 1.8 TWh annually.[75] Similar to wave energy, this resource estimate does not consider technological and environmental barriers that would constrain fully harnessing this resource. Like WECs, there is no dominant tidal energy device type in the industry. Tidal energy converter technologies come in a variety of sizes, shapes, and energy capture methods. The size may vary depending on available resource, deployment area, and mounting methods. There are six common device archetypes that could be considered for use in California:[76]

- Axial-flow turbines
- Crossflow turbines
- Oscillating hydrofoil
- Tidal kite
- Archimedes screw

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71 Lee, Susan and Vida Strong. (Aspen Environmental Group). 2024. *Wave and Tidal Energy: Evaluation of Feasibility, Costs, and Benefits. SB 605 Report*.

72 Ibid.

73 Ibid.

74 Ibid.

75 Kilcher, L., M. Fogarty, and M. Lawson. 2021. *Marine Energy in the United States: An Overview of Opportunities*. Accessed July 2024.

These estimates do not consider external constraints or projected technological innovations.

76 Lee, Susan and Vida Strong. (Aspen Environmental Group). 2024. *Wave and Tidal Energy: Evaluation of Feasibility, Costs, and Benefits. SB 605 Report*.

- Vortex-induced vibration

Table 9 summarizes the device archetypes, example technologies and developers, device configuration, and optimal conditions for technology deployment.

Table 9: Summary of Six Main Tidal Energy Current Device Archetypes

Device Archetype	Example Technologies and Developers	Configuration	Optimal Conditions
Axial-Flow Turbines	Andritz Hydro, Blue Shark Power Systems, Gkinetic Energy, Hydrokinetic Energy Corp, Magallanes Renovables, Nova Innovation, Orbital Marine Power, Sabella, MeyGen by SAE Renewables, Sustainable Marine, Verdant Power	Multiple blades attached to rotor. Can be deployed as single or multiple units on a base.	Water depths are dependent on turbine size. Can operate in systems with both tidal and unidirectional flow.
Crossflow Turbines	Ocean Renewable Power Company, GCK Technology, Marine Energy Corporation	Floating, semi-submerged, or submerged with mooring line(s) and bottom anchor(s)	When oriented horizontally, channelized flow with predictable direction. When oriented vertically, direction agnostic. Can operate in systems with both tidal and unidirectional flow.
Oscillating Hydrofoil	Tidal Sails	Fixed to sediment bed with one or multiple foils oriented perpendicular to flow direction.	Strong tidal oscillations
Tidal Kite	Minesto AB, Aquantis Inc	Submerged generating unit with cable affixed to sediment bed.	Can be optimized to meet range of tidal conditions
Archimedes Screw	Jupiter Hydro, HydroCoil Power Inc	Helix screw oriented in line with flow attached to floating platform.	Water depths are dependent on turbine size. Can operate in systems with both tidal and unidirectional flow

Device Archetype	Example Technologies and Developers	Configuration	Optimal Conditions
Vortex Induced Vibration	WITT Energy, Vortex Hydro Energy	Spherical or tubular units attached to generator.	Can be affixed to pilings or other submerged structures in turbulent areas. Can be direction agnostic depending on shape

Source: Aspen Environmental Group

Marine Energy Applications in California

Marine energy projects can be categorized as commercial-scale or distributed energy. Commercial-scale projects are deployments of multiple devices in arrays that are grid-connected. Distributed energy projects are smaller-scale deployments and pilot projects.

Although there are some commercial-scale tidal projects in the United States (such as Admiralty Inlet, Washington; Cobscook Bay, Maine; and RITE, New York), no such projects exist in California. As of late 2024, the only active wave energy projects in the United States are associated with wave energy test sites. Commercial-scale marine energy projects in California would likely use wave energy instead of tidal energy because of more abundant wave energy resources.

Smaller-scale distributed energy resource (DER) projects that serve local demand have many applications in California. For example, DER projects could be installed along breakwaters, shorelines, quay walls, or piers. Offshore devices that are installed in shallow waters, such as oscillating wave surge converters, can provide localized energy sources. Singular devices, arrays of devices, or hybrid solutions (for example, marine energy combined with solar or wind) may be integrated with microgrid networks to monitor, control, and optimize energy generation, distribution, and consumption.[77] DER marine energy applications in California include:

- **Ports and harbors**: Marine energy could help meet localized energy needs for port or harbor facilities, vehicles, or vessels.
- **Remote communities**: Marine energy could help provide a reliable and sustainable energy source in areas that otherwise lack energy generation infrastructure or redundancies.
- **Community-based initiatives**: Planning and development of marine energy projects could align with community priorities and values and help eliminate need for local fossil fuel resources that add to the air quality and health burden in communities.
- **Military installations**: Marine energy could provide a decentralized and sustainable power for military bases, installations, and operations in coastal and maritime environments.
- **Powering the “Blue Economy”**: Marine energy technologies could power ocean observation (environmental monitoring, marine research, resource management);

77 Ibid.

marine aquaculture; seabed/seawater mining; desalination; coastal resilience and disaster recovery; maritime transport and logistics; and tourism and recreation.

Other examples of DER applications include providing power and data communications for monitoring, surveying, and reporting to offshore energy. While there are many distributed marine energy applications in California, the technology is still in the early stages of development. Marine energy test sites play an important role in advancing wave and tidal technologies. These sites allow testing in real-world ocean conditions, allowing developers to assess performance and optimal deployment conditions. Existing marine energy test sites demonstrating wave and tidal energy technologies in the United States include the General Sullivan Bridge in New Hampshire, PacWave Wave Test Sites in Oregon (projected to be operational in spring/summer 2025), and the Hawai'i Wave Energy Test Site in Oahu, Hawai'i.[78]

Challenges to Developing Marine Energy

Marine energy projects have various applications in California, but the technology is still emerging and faces many challenges to reach an established industry. Current challenges to development affect the feasibility, scalability, and economic viability, and include:

- **Technology development**: Early stages of development contribute to a lack of convergence on a particular device or device archetype, which creates difficulties in project planning, including design, installation, and operation. This lack of convergence can also influence the regulatory landscape as there is little project precedent on which to base decisions. Most technologies have not reached maturity or demonstrated sufficient reliability for commercial-scale deployment. Additional challenges are related to technology durability and performance in harsh marine environments during severe weather events and storm surge.
- **Resource variability**: Marine energy resources, including waves, tides, and currents, can vary over time and location. While they are generally regarded as consistent energy sources, it is important to be able to predict and manage the various physical and environmental factors within the ocean to optimize performance and energy generation of marine energy technologies.
- **Grid integration**: There are technical and logistical challenges when integrating marine energy into existing electricity grids. These challenges include grid connection costs, grid stability, power conditioning, and regulatory frameworks for renewable energy integration.
- **Environmental impact**: Potential environmental impacts to marine ecosystems and wildlife vary from technology type/design and location of deployment. These can include habitat alteration, marine life mortality, or harm due to collision, entanglement, noise disturbance, electromagnetic fields, and other impacts.

78 Ibid.

- **Cost competitiveness**: Due to the industry being in the early stages, there are high costs associated with projects driven by upfront capital costs, operational costs, relatively low conversion efficiencies of devices, and environmental permitting costs.
- **Socioeconomic issues**: Like many energy projects, marine energy can create social issues from potential impacts on communities, livelihoods, and cultural heritage. Some examples include concern about marine organisms and marine habitats, conflicts with commercial and recreational fishing, navigation, and marine conservation areas. There are indigenous communities' concerns with cultural heritage sites, archaeological resources, and indigenous cultural practices associated with the ocean. Other general concerns include changes to landscape, coastal views, and recreational activities such as surfing.

Analysis and Findings

Factors Contributing to Increased Use of Wave and Tidal Energy in California

Below is a list of factors that could increase use of wave and tidal energy in California.

- **Market signals:** Wave and tidal energy resources could create a more diversified clean energy resource portfolio. Though clean energy sources like solar and storage have recently become cost-competitive with fossil fuel, historically the push for use of clean energy sources has been largely driven by regulatory and policy support from government. An example of this is federal tax incentives, which have been critical to deployment of clean energy resources. In California, demand for renewable energy has been driven by greenhouse gas emissions reductions required by the Renewables Portfolio Standard and SB 350, as well as through integrated resource planning coupled with the need for energy reliability. Wave and tidal energy is a zero-carbon energy source that may complement other renewable energy sources, and the resource estimate in California is relatively high. The market for wave energy is particularly attractive due to the abundance of wave energy compared to tidal, with wave energy resource estimated capacity more than 120 times the estimated tidal energy resource for the state.[79]
- **Cost reductions:** The costs of marine energy projects are expected to decrease with the convergence of technology types and increased capacity installation. Wave and tidal energy must undergo substantial cost reductions to achieve a competitive levelized cost of energy. Concentration on research and development and increased testing of devices to ensure durability against extreme weather conditions will reduce risk and help achieve cost reductions. Marine energy has applications where traditional renewable energy sources are expensive or impractical, such as in remote coastal communities. In addition, wave energy may be suited to provide baseload generation due to reliability.
- **Regional energy needs and community support and benefits**: While marine energy technology is still new and not yet well known, there are some perceived

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79 Kilcher, L., M. Fogarty, and M. Lawson. 2021. *Marine Energy in the United States: An Overview of Opportunities.*

These estimates do not consider external constraints or projected technological innovations.

benefits, such as being a low-impact, high-potential clean energy resource. Other benefits could include providing additional power supply options to remote communities, energy security by serving as an emergency power supply, coastal protection from erosive wave energy, and climate resilience.[80] However, direct engagement with coastal communities and an evaluation of site-specific marine uses are needed to determine the range of potential benefits and impacts of marine energy development in California.

- **Improved understanding of environmental effects**: As wave and tidal are emerging technologies, there is limited understanding of the potential adverse environmental effects. Scientific studies, installation and monitoring of small-scale pilot projects, and other similar initiatives are needed to help fill knowledge gaps to gain a better understanding and increase support for these technologies.

Moreover, state and federal licensing and permitting processes are lengthy and complicated, especially with the current lack of technical and environmental information. Improving the pathway to permitting with tools such as the U.S. Department of Energy's *Marine Energy Environmental Toolkit for Permitting and Licensing* that provides developers information on regulations for technology deployment could be helpful.[81] A similar, expanded planning tool for state permitting processes could provide additional information for project planning and development.

Transmission Needs and Transmission Permitting Requirements

Transmission Overview

Energy transmission feasibility and costs will be central to the viability of wave- and tidal-generated energy in California. Below is a description of transmission considerations related to wave- and tidal-generated energy:

- **Cables**: This analysis assumes that alternating current will be used for all near-term applications of wave and tidal energy projects, rather than direct current, which is used for long distances and higher-capacity projects but has not yet been fully engineered and manufactured for oceanic energy transmission. Wave and tidal energy projects will likely be connected by *array cables*, which are low- or medium-voltage cables that connect energy converters to a common point, like an offshore substation. Once the energy is gathered to a common point, it will be delivered through *export cables* to shore. Export cables are typically rated between 100 to 200 kilovolts but may be lower for lower-capacity applications. For lower-capacity (100 megawatts [MW] or less) and closer-to-shore projects (within 15 kilometers [km] or roughly 8 nautical miles), a substation may not be necessary, and array cables can run directly onshore.

80 Lee, Susan and Vida Strong. (Aspen Environmental Group). 2024. *Wave and Tidal Energy: Evaluation of Feasibility, Costs, and Benefits. SB 605 Report*.

81 U.S. Department of Energy. "Marine Energy Environmental Toolkit for Permitting and Licensing," https://marineenergy.app/. Accessed July 2024.

- **Offshore substations**: Offshore transmission will often require some form of offshore substation to collect power from the array cables and transform the voltage to export the electricity to shore. These substations are most likely required when wave and tidal projects are more than 15 kilometers (km) from shore, roughly 8 nautical miles, and greater than 100 MW of capacity. Offshore substations also stabilize the voltage and minimize the number of cables coming to shore, which could reduce permitting and costs. There are two types of offshore substations: one on the water surface that is fixed or floating, or one that is resting on the seafloor. There are also smart subsea hubs that can be used to aggregate, or collect, power from several converters into an export cable that then feeds to the grid onshore. The smart subsea hubs are a strong fit for wave and tidal energy projects since they do not require high-voltage export.

Tidal and Wave Energy Transmission Configurations

Transmission technologies can be categorized into onshore and very nearshore configurations (within several meters from shore), nearshore and offshore configurations (few hundred meters from shore), and deepwater offshore configurations for smaller distributed energy applications (hundreds of kilometers from shore). While offshore wave energy holds potential, increasing water depths and distance to shore add complexities like electrical loss and physical risk, which can increase project costs, as well as longer time frames for implementation due to the complexity of construction, operation, and maintenance.

There could be opportunities for wave energy technology to colocate with floating offshore wind energy projects for more efficient use of offshore site areas since the two technologies share similar transmission infrastructure. Colocation of wave energy and offshore wind energy can reduce project development costs through shared expenses of infrastructure, operations and maintenance, and licensing and could provide enhanced energy yield and better predictability.[82] Wave energy developers would need to explore the ability to interconnect their projects and coordinate with the offshore transmission owner.

Transmission Permitting

Any utility-scale offshore renewable energy resources, including wave and tidal, will require transmission to bring generation to shore. Wave and tidal energy resources that use a floating substation and an export cable require dynamic, or free-floating, cables between the floating offshore substation and the seabed. From the substation, the export cable can use static subsea technology and ancillary equipment to deliver power onshore. The cable would likely be buried under the seafloor or rest on the seafloor with protective equipment to minimize the potential for damage with vessel anchors or fishing gear. Transmission lines in the water would be subject to similar licensing and permitting requirements as the actual wave and tidal generation project. The permitting expectations and processes for wave and tidal resources are discussed in the next section titled "Permitting Requirements for Wave and Tidal Energy Projects."

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82 Gonzalez, N., Serna-Torre, P., Sánchez-Pérez, P. A. *et al.* August 9, 2024. "Offshore Wind and Wave Energy Can Reduce Total Installed Capacity Required in Zero-Emissions Grids." *Nat Commun* 15, 6826, https://doi.org/10.1038/s41467-024-50040-6.

Permitting of land-based transmission infrastructure in the state generally depends on the type of entity developing the transmission infrastructure. In California, there are three types of transmission developers:

- Investor-owned utilities (IOUs) such as Pacific Gas and Electric Company, Southern California Edison Company, and San Diego Gas & Electric Company (SDG&E)
- Publicly owned utilities (POUs) such as Sacramento Municipal Utility District and Los Angeles Department of Water and Power, joint powers authorities (JPAs) such as the Transmission Agency of Northern California, other public agencies
- Nonutility, private developers

Developers go through different processes for planning and determining whether transmission upgrades or new transmission lines are needed, as well as for permitting and environmental reviews. Offshore renewable energy developers will need to determine how they deliver generation to the shore.

The CPUC serves as the lead agency for California's environmental review under the California Environmental Quality Act (CEQA) for proposed electrical infrastructure (greater than 50 kilovolts [kV]) above the mean high tide line. Other state agencies may have CEQA requirements depending on infrastructure and project location. For larger transmission projects, an IOU must obtain a certificate of public convenience and necessity (CPCN) from the CPUC, and a permit to construct (PTC) is required for smaller projects.[83] The CPUC may run the processes concurrently and perform the environmental review for a private transmission developer project.

The project proponent (IOU or private independent transmission developer) files an environmental analysis with the CPUC called the Proponent's Environmental Assessment. The CPUC, as the permitting agency, then prepares its own assessment of the environmental impacts of the project. The assessment includes input from several state agencies, plus any cities, counties, or tribes that a proposed transmission line might impact. This process includes the preparation of an environmental impact report (EIR) under CEQA for the portions affecting state lands. The planning and permitting process for transmission projects under the California ISO and CPUC approval process can take several years.

POUs and Joint Power Agreements (JPAs) act as both the project developer and the lead agency for the permitting of their transmission facilities. POUs and JPAs as public utilities are directly responsible to their customers and not investors or shareholders. Presumably, POU and JPA decisions are made in the best interests of their customers; thereby, there is no CPUC

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83 Senate Bill 529 (Hertzberg, Chapter 357, Statutes of 2022) requires the CPUC, by January 1, 2024, to update its General Order 131-D to allow IOUs the use of the PTC process or claim an exemption, rather than a CPCN, for extension, expansion, upgrade, or other modification to their existing electrical transmission facilities. These facilities include electric transmission lines and substations within existing transmission easements, rights-of-way, or franchise agreements, even if the facility is above a 200-kilovolt voltage level.

or other oversight permitted.[84] POUs and federal agencies have their own approval processes for transmission projects, which differ by agency. POUs or JPAs are required to consider the environmental impacts and are the lead agency following CEQA.

For any transmission project that impacts federal lands, coordination with and approval by the appropriate federal agencies are required. The federal government owns about 45 percent of the land in California, and it is likely that transmission lines from an offshore wave or tidal project could cross federally owned land (for example, U.S. Forest Service, Bureau of Land Management), requiring federal approval.[85] There could be instances where a transmission project does not cross federal land, but a federal permit is still required. For example, a federal permit could be required due to potential impacts to a federally listed endangered species in U.S. waters. A federal action, such as approving a transmission line on federal land or a federal permit, would require environmental review under the National Environmental Policy Act.

Grid Integration Challenges

Offshore energy generation has challenges for connecting to the grid. Finding suitable areas to make landfall can be challenging and require extensive ocean floor surveys. When developers find paths to shore, finding land-based transmission that is nearby and has capacity to accept additional power is further challenging. Cost-allocation and cost-recovery mechanisms for ocean transmission cables for prospective wave and tidal projects are not yet identified. Further studies on integrating offshore wave and tidal resources to the grid could consider costs and financing options.

Permitting Requirements for Wave and Tidal Energy Projects

This section identifies permitting needs for wave and tidal energy projects based on the project type and purpose. Permitting agencies consider the characteristics of the technology, examine the location of installation, and assess the type and degree of effects on the site and surrounding area. All federal agencies authorizing a discretionary action must comply with the National Environmental Policy Act.

Wave and tidal energy projects are evaluated by several government agencies with various licenses and permits. Project developers can face a complex array of permitting requirements and processes, which can take as long as 7 to 10 years.[86] This complex permitting and licensing framework can increase project uncertainty and project costs. Given the significant cost and effort of permitting, there could be opportunities and efficiencies for wave and tidal

84 Under Public Utilities Code Sections 224.3 and 10001–10303, publicly owned utilities have sole decision authority over activities including the construction, procurement, and operation of electric generation resources and transmission infrastructure.

85 More information on federal land ownership by state is available at https://ballotpedia.org/Federal_land_ownership_by_state.

86 Grantham, K. July 2024. "An Overview of Marine Energy Permitting and Licensing" [PowerPoint Slides]. National Renewable Energy Laboratory, https://pacificoceanenergy.org/wp-content/uploads/2022/09/Grantham-OREC-Regulatory-Presentation-091522-002.pdf.

energy resources to collocate with floating offshore wind projects for improved permitting processes.

Federal Agencies

Depending on the nature and location of a project, federal approvals applicable to tide and wave energy projects are likely to include most of the following:[87]

- National Environmental Policy Act compliance
- Seabed lease or seabed research lease from the Bureau of Ocean Energy Management (BOEM)
- Federal Energy Regulatory Commission (FERC) license for hydropower generation
- U.S. Army Corps of Engineers (USACE) Clean Water Action Section 401 and 404 permits for dredging and filling of waters of the United States
- U.S. Coast Guard (USCG) aid to navigation approval
- National Oceanic and Atmospheric Administration (NOAA) Fisheries for consultation on essential fish habitat, endangered species and marine mammals
- U.S. Fish and Wildlife Service for consultation on migratory birds and federally endangered species

There are four primary federal agencies involved in approving wave and tidal energy projects:

- **FERC**: FERC is the primary licensing authority and lead agency for hydrokinetic projects. FERC has authority in federal waters and state waters (3 nautical miles from shore). However, in state waters, if the generated electricity from the project is not connected to the grid, then FERC would not typically have permitting authority. For example, a demonstration project in state waters that is not delivering power to the grid would not need a FERC license. FERC maintains an up-to-date web page describing its process to obtain a license to construct and operate a hydrokinetic electric generation facility, including preliminary permits, short-term licensing to test new technologies, and licensing for facilities that will be in operation for 30 to 50 years.[88]
- **USACE**: The U.S. Army Corps of Engineers issues permits under the Rivers and Harbors Act for placing fill or objects in navigable waters under federal and state jurisdiction, administered under Section 404 of the Clean Water Act. Activities that have minimal

87 Freeman, M., O'Neil, R., Garavelli, L., Hellin, D., and Klure, J. 2022. "Case Study on the Novel Permitting and Authorization of PacWave South, a US Grid-Connected Wave Energy Test Facility: Development, Challenges, and Insights." *Energy Policy*, 168, 113141, doi:10.1016 /j.enpol.2022.113141, https://tethys.pnnl.gov/publications/case-study-novel-permitting-authorization-pacwave-south-us-grid-connected-wave-energy.

88 For more information on the FERC licensing process, see the "Hydrokinetic Projects" web page at https://www.ferc.gov/licensing/hydrokinetic-projects.

individual and cumulative adverse environmental effects can be issued general permits for no more than five years.[89]

- **USCG**: The USCG is responsible for navigational safety, including obstruction of navigational waterways in federal and state waters. USCG enforces regulations with respect to lights and warning devices, safety equipment, and other matters related to safety of life and property. Navigation and Vessel Inspection Circular No. 03-23 provides guidance on navigational safety in and around offshore renewable energy installations.[90]
- **BOEM**: The Bureau of Ocean Energy Management is authorized to issue leases, easements, and rights-of-way to allow renewable energy development on the Outer Continental Shelf in federal waters. For wave and tidal projects connected to the grid, BOEM and FERC have authority where a lease from BOEM would be a prerequisite to a FERC license for a project.

Other federal agencies involved in the permitting process are primarily responsible for resource protection. These include the NOAA Fisheries for consultations on essential fish habitat, endangered species, and marine mammals under its jurisdiction and U.S. Fish and Wildlife Service for consultations on migratory birds and endangered species under its jurisdiction.

State Agencies

For state-level project permitting, California approvals applicable to wave and tidal energy projects would likely include:

- CEQA compliance and certification.
- Section 401 Water Quality Certification.
- Coastal Zone Management Act Federal Consistency Review.[91]
- Coastal development permit.[92]
- State tidelands lease.
- California endangered species incidental take permit.
- Land and streambed alteration agreement.

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89 The U.S. Army Corps of Engineers. 2021. *Nationwide Permit 52 — Water-Based Renewable Energy Generation Pilot Projects*, https://www.swt.usace.army.mil/Portals/41/docs/missions/regulatory/2021%20NWP/2021%20nwp-52.pdf?ver=CbN57uEQ3mD97IiqOcdJAA%3D%3D.

90 USCG. 2023. "Navigation and Vessel Inspection Circular No. 03-23. Guidance on Navigational Safety in and Around Offshore Renewable Energy Installations (OREI)," https://www.dco.uscg.mil/Portals/9/DCO%20Documents/5p/5ps/NVIC/2020/2023/NVIC%2003-23_MarinerGuidance_OREI_FINAL_10_20_2023_V2_CG-5P%20SIGNED.pdf?ver=OwCdqfYvDktgp8AIzB6zZw%3d%3d.

91 For more information on Federal Consistency Review, see *Federal Consistency Program (ca.gov)*, https://www.coastal.ca.gov/fedcd/fedcndx.html.

92 For more information on coastal development permits, see *Coastal Development Permit Applications & Appeal Forms*, https://www.coastal.ca.gov/cdp/cdp-forms.html.

- Scientific collecting permit.

Like the federal process, the state agencies' permitting process would vary depending on the jurisdiction, technology, purpose, and installation location. The primary California agencies involved include:

- **State Lands Commission**: The State Lands Commission manages the state's tidelands and submerged lands under the common law Public Trust Doctrine. The commission's jurisdiction extends along the state's entire coastline and offshore islands from the ordinary high water mark, as measured by the mean high-tide line (except for areas of fill or artificial accretion, or where the boundary has been fixed by agreement or court decision) to the state/federal boundary, roughly 3 miles offshore. The commission has authority to issue leases or permits for the use and development of these lands and resources consistent with the Public Trust and in the best interests of the state. The Commission also retains broad oversight authority over Public Trust lands legislatively granted to local jurisdictions (Pub. Resources Code, §§ 6005, 6009, subd. [c], 6009.1, 6301, 6306, 6501.1.). Before issuing a lease, the Commission must comply with CEQA and make findings related to consistency with the Public Trust Doctrine and the commission's Tribal Consultation and Environmental Justice policies.
- **California State Water Resources Control Board**: The board and its underlying Regional Water Quality Control Boards, have authority over water quality, wetlands, and riparian areas under the Clean Water Act and the California Code of Regulations. A water quality certification is issued if the proposed project would comply with water quality standards.
- **California Department of Fish and Wildlife**: This department oversees the conservation, protection, restoration, and management of fish, wildlife, and native plants. Under the California Endangered Species Act, it administers the incidental take provisions as the responsible agency to take state-listed threatened, endangered, or candidate species if certain conditions are met under Fish and Game Code Section 2081 to ensure regulatory compliance. It also manages marine protected areas that limit activities undertaken within the area to conserve and protect marine life.
- **California Coastal Commission/San Francisco Bay Conservation and Development Commission**: The California Coastal Commission has jurisdiction within California's coastal zone for management of coastal resources under the California Coastal Act and the federal Coastal Zone Management Act. In waters within and near San Francisco Bay, the San Francisco Bay Conservation and Development Commission has jurisdiction for coastal resource management. Both agencies conduct federal *consistency review* within their jurisdictions, and for projects requiring a federal permit, license, or funding, the California Coastal Commission or San Francisco Bay Conservation and Development Commission review a *consistency certification*. Both agencies review projects for state-level permits, though the federal and state-level reviews can be combined into a single process. In addition, some areas of the coastal zone have certified local coastal programs for which local governments have a role in coastal development permitting outside the Coastal Commission's retained jurisdiction.

The most effective and efficient process for wave and tidal energy project permitting is one that involves all parties early and often.

Economic and Workforce Development Needs

The consultant report used the NREL Jobs and Economic Development Impact (JEDI) model for marine and hydrokinetic power to estimate economic development needs for wave and tidal energy projects. The JEDI model outputs workforce and economic development impacts during the construction and installation of a project and during project operation.

The JEDI model categorizes impacts as:

- **Direct impacts**: onsite construction and installation labor (immediate jobs and economic impacts).
- **Indirect impacts**: equipment and supply chain impacts, and local revenues.
- **Induced impacts**: effects driven by reinvestment and spending of earnings by direct and indirect beneficiaries.

Two project sizes were modeled for the study: distributed systems (10 MW) and small commercial systems (100 MW). For the 10 MW project size, most jobs required are in equipment and supply chain, followed by induced impacts. A 10 MW wave energy project will require roughly 584 job-years and generate $78.4 million in total value added to the economy. A *job-year* is defined as total full-time equivalent employment for one year. During the projects operating years, most jobs needed are in onsite labor, and the annual value added to the economy is $2.1 million. For a 10 MW tidal energy project, the total workforce impact is 243 job-years and $31.5 million of total value added to the economy.

The workforce needed for a 100 MW wave energy project is about eight times greater than that of a 10 MW project. The economic impacts are roughly eight times greater for wave energy projects of 100 MW and about five times greater for tidal energy projects of 100 MW.

To maximize job creation and economic development, it is important to incorporate training to develop a skilled workforce ready to construct, install, operate, and maintain wave and tidal energy facilities. Potential training methods include community college programs or union-led programs, apprenticeships, and transitioning workers from existing maritime industries (including oil and gas) to wave and tidal energy.[93] Wave and tidal energy could also share workforce with the offshore wind industry in California, allowing for complementary workforce training and rotation of employees between oceanic energy sectors.

Monitoring Considerations to Gather Data for Evaluation of Environmental Impacts

The deployment of wave and tidal energy projects may have environmental impacts on marine and tidal ecosystems. Few projects have been developed, so there is a lack of existing data to

93 For more information on JEDI model inputs and outputs, see *Wave and Tidal Energy: Evaluation of Feasibility, Costs, and Benefits*, https://efiling.energy.ca.gov/GetDocument.aspx?tn=257956.

understand potential impacts. It is important to identify a robust monitoring strategy to gather sufficient data to evaluate potential impacts and guide adaptive management plans.

Some monitoring considerations for wave and tidal energy projects include:

- Collision, entrapment, entrainment, entanglement, impingement, attraction, or avoidance impacts to behavior of fish, marine mammals, or birds.
- Disturbance to benthic habitats and species.
- Electromagnetic fields.
- Noise.
- Changes in flow and impacts to water quality, vegetation, soils, sediment transport, and ecosystem and biogeochemical processes.
- Water quality.
- Water temperature.
- Lighting.
- Impacts to sensitive habitats from transmission cables and anchored material on the seafloor.
- Introduction of new structures and fish aggregating devices (FAD).
- Invasive species.

Given the variation in the types and characteristics of wave and tidal energy technology and the range of marine environments in which they might be deployed, this list of considerations is not fully understood and remains uncertain. The effects of these installations will depend on the equipment used and the environment of the installation site.

Since wave and tidal energy is an emerging industry, a useful strategy for understanding likely impacts of wave and tidal energy in the ocean ecosystem would be to consider previous studies in different offshore industries, such as offshore wind energy and oil and gas, that have examined similar situations in marine environments. Furthermore, some of the monitoring results from existing wave and tidal energy installations may be applicable to assessing effects in California's marine environment.

In 2024, the CEC published the *Assembly Bill 525 Offshore Wind Energy Strategic Plan*,[94] which outlines the necessary steps for deploying floating offshore wind energy off the coast of California. The plan includes discussions of potential impacts and mitigation strategies for marine biological resources, Native American and Indigenous people, fisheries, national defense, and underserved communities, much of which could be applied to planning for offshore wave and tidal energy projects.

94 Jones, Melissa, Jim Bartridge, and Lorelei Walker. 2024. *AB 525 Offshore Wind Energy Strategic Plan*. California Energy Commission. Publication Number: CEC-700-2023-009-V2-F, https://www.energy.ca.gov/publications/2023/ab-525-offshore-wind-strategic-plan.

A subsequent report will identify monitoring strategies for wave and tidal projects, as discussed in the "Next Steps and Recommendations" Section.

Adaptive Management

Adaptive management strategies should be considered to ease rapid response to unanticipated impacts from wave and tidal energy projects.[95] Adaptive management is an iterative process with sequential phases of planning, doing, and evaluating outcomes that results in modifying operations based on what has been learned. It is a tool that aids decision-making and incorporates knowledge to reduce uncertainty. A broad adaptive management framework has clear metrics and thresholds, timescales for baseline data collection and evaluation, and a process for adjustment of management based on evaluation of monitoring results. While adaptive management seems straightforward, it can be hindered during interpretation of monitoring results and communication of findings to decision makers.

A comprehensive monitoring strategy is needed to inform the mitigation of impacts from wave and tidal energy projects and guide adaptive management strategies. Ultimately, avoidance and minimization measures for reducing adverse effects on marine ecosystems and wildlife should be prioritized within a mitigation framework.

Next Steps and Recommendations

Offshore wave and tidal energy present an opportunity for California to continue advancing the state's clean energy and climate goals by complementing other renewable energy sources, such as wind and solar, and supporting the state's transition to a low-carbon energy future.

Marine energy infrastructure can be leveraged to enhance coastal resilience and climate adaptation efforts in California. Renewable energy installations can provide decentralized power solutions for coastal communities vulnerable to sea-level rise, storm surges, and extreme weather events, ensuring reliable and resilient energy supply and supporting disaster response and recovery efforts. California's marine energy sector can contribute to the growth of the Blue Economy, supporting sustainable economic development and job creation in coastal regions. Marine energy projects can create opportunities for innovation, entrepreneurship, and workforce development in areas such as technology development, manufacturing, installation, operations, and maintenance.

Next Steps

Per SB 605, the CEC will submit a written report to the Governor and Legislature that includes a summary of this IEPR chapter on wave and tidal energy. This report will include considerations that may guide legislative and executive actions to address barriers and support the development of feasible wave and tidal energy technologies, infrastructure, and facilities in California.

A subsequent report will identify suitable sea space for offshore wave energy and tidal energy projects in state and federal waters. It will also determine a monitoring strategy that will include measures to avoid, minimize, and lessen adverse environmental impacts, use conflicts,

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95 For more information and to read about examples of successful adaptive management approaches in the United States and abroad, see *Wave and Tidal Energy: Evaluation of Feasibility, Costs, and Benefits*.

and adaptive management consistent with California's long-term goals relating to renewable energy, reduction of greenhouse gas emissions, and biodiversity.

Throughout sea space identification, the CEC will conduct outreach with California state agencies, California Native American tribes, the offshore wave and tidal industry, fishing communities, nongovernmental organizations, and other stakeholders. Meaningful engagement with coastal communities, Indigenous peoples, and other interested parties is important to ensure that projects are developed collaboratively, transparently, and equitably.

Recommendations

Offshore wave and tidal energy could help advance California's clean energy goals and diversify its renewable generation mix. Projects will need to be developed in a way that protects the state's underserved communities, California Native American tribes, tribal cultural resources, ratepayers, and coastal resources, including marine wildlife, habitat, commercially and recreationally important fisheries. The recommendations below would support the responsible and timely development of wave and tidal energy projects.

- Promote further research on wave and tidal energy devices; generation profiles to determine potential value as a clean, firm resource; potential environmental and ocean-use impacts from projects; and value cost modeling of wave and tidal energy to quantify resource costs.
- Explore the potential development of market policies to support investment in wave and tidal energy technology, such as the development and investments in technology research, demonstration, and deployment.
- Develop, to the extent possible, clear regulatory processes for deploying marine energy projects off the California coast. Support a coordinated permitting approach to improve permitting efficiency.
- Encourage project permits for wave and tidal energy to include monitoring and adaptive management measures to gather baseline environmental data and better assess, avoid, minimize, and address environmental effects.
- Continue coordination and collaboration among state governments, California Native American tribes, commercial and recreational fishing groups, coastal communities, labor unions, industry, environmental justice organizations, environmental organizations, and others to ensure valuable perspectives are meaningfully considered throughout the wave and tidal energy planning process.

GLOSSARY

Additional achievable energy efficiency (AAEE) is the incremental energy savings from market potential that is not included in the baseline demand forecast but is reasonably expected to occur. AAEE includes many future updates of building standards, appliance regulations, and new or expanded energy efficiency programs.

Additional achievable fuel substitution (AAFS) refers to the substitution of one end-use fuel type for another that is reasonably expected to occur, such as changing out gas appliances in buildings for cleaner more efficient electric end uses.

The **additional achievable framework** is applied to energy efficiency, fuel substitution, and transportation electrification for the *2023 IEPR* forecast. The additional achievable scenarios capture a range of incremental market potential impacts beyond what are included in the baseline demand forecast but are reasonably expected to occur.

Additional achievable transportation electrification is additional transportation electrification beyond the baseline demand forecast that is informed by a range of policy and market conditions that are reasonably expected to occur but do not lend themselves to the traditional demand-side modeling framework of the baseline forecast.

Alternating current refers to an electric current that sometimes reverses direction and changes magnitude.

An **attenuator** is a single surface-floating body or multiple connected bodies that rise and fall with wave motion and generate electricity through mechanical turbine rotation or hydraulic pumps that are driven by the flexing motion of the device.

Behind-the-meter refers to energy activities on the consumer's side of the grid. This would include, for example, energy consumed by a home or business as well as energy generated by a rooftop photovoltaic system.

The **California Environmental Quality Act (CEQA)** requires that state and local government agencies disclose and evaluate potential environmental impacts of proposed projects and adopt feasible mitigation measures to reduce or eliminate those impacts.

The **California Independent System Operator (California ISO)** manages the flow of electricity across high-voltage, long-distance power lines that serve 80 percent of California's electricity needs. The California ISO also operates a competitive wholesale energy market and studies and identifies investments in new transmission infrastructure though an annual transmission planning process.

Capacity factor is the ratio of the actual energy produced to the amount of maximum energy that could have been produced in the same period.

Consistency determinations (CDs) are submitted to the California Coastal Commission when a federal agency activity affects the coastal zone. It is a project description and analysis of the coastal zone effects of the activity based on the policies of the Coastal Act.

Cooling degree days (CDD) refers to days in which the average temperature is above 65°F. The CDD space cooling requirements are quantified by how many degrees above 65°F the daily average temperature is.

Direct current refers to an electric current that flows only in one direction.

Distributed energy resources (DER) refers to typically smaller generation units that are located on the consumer's side of the meter or providing generation to serve nearby load.

Distributed generation (DG) refers to generation units that provide generation to serve onsite or nearby load. Rooftop PV is one type of distributed generation.

An **end user** refers to the person or entity that purchases and consumes energy. An end user differs from a user or consumer in that the end user is both the purchaser and final user of the product or service.

A **load profile** describes the changes in electricity demand over a particular interval, such as a 24-hour day or an 8760-hour year.

Level 2 chargers typically provide about 35 miles per hour of charging but can range from 12 to 70 miles, depending on the vehicle and charger. **DC fast charging** also varies by vehicle and charger, with most chargers able to restore a passenger PEV to 80 percent of full range within 30 minutes.

Floating offshore wind turbines are deployed in water depths that necessitate floating structures and are stabilized by moorings and anchors. Floating offshore wind technology allows offshore wind to be deployed in deeper waters where fixed bottom offshore wind is not feasible. Due to the nearshore drop-off of the Pacific Continental Shelf, floating offshore wind is the only feasible option for California.

Fish aggregating devices (FAD) are floating rafts in the ocean used to concentrate fish in one location to make them easier to catch.

A **gigawatt** is equal to 1 billion watts.

Grid hardening is the process of making the electrical grid more resilient to extreme weather and other potential threats. One example is moving power lines underground to reduce the possibility of downed lines starting wildfires. Another example is switching out wooden utility poles for ones made of steel or concrete; these materials better withstand high winds and are more resistant to fire.

Heating degree days (HDD) refers to days in which the average temperature is below 65°F. The associated space heating requirements are quantified by how many degrees below 65°F the daily average is.

A **hyperscaler** is a large-scale cloud service provider that allows for massive computing power and storage capacity.

Integrated resource planning refers to planning for a safe, reliable, and cost-effective electricity supply.

A **kilometer** is the equivalent of 0.62 miles.

A **load-serving entity** provides or sells electricity to customers.

A **load modifier** technology is on the demand-side (for example, behind the meter) and has a load profile that is different from the system load profile, and therefore, with large adoption, would change the system load profile. To be considered load modifying, a program or tariff should modify load on a predictable, consistent basis. Programs that modify load only during certain system conditions and/or are integrated into the wholesale market are not included in the demand forecast. For example, BTM technologies dispatched by system operators in response to system conditions, such as those used in some demand response programs, are not considered load modifiers.

A **load shape** is the hourly profile of electricity demand as a percentage of the total demand.

Levelized cost of energy (LCOE) is the average total cost of an energy generation project per unit of total electricity generated. Also referred to as the levelized cost of electricity, LCOE is a measurement to assess and compare alternative methods of energy production.

Marine energy encompasses a range of energy sources and technologies that harness marine phenomena including waves, currents (for example, tidal, ocean boundary [such as Gulf Stream], and riverine currents), ocean thermal, and salinity gradient conversion to generate electricity.

National Environmental Policy Act (NEPA) requires federal agencies to assess the environmental effects of their proposed actions prior to making decisions.

The CPUC's **net billing tariff (NBT)** sets electricity rates and other charges for investor-owned utility customers in California who submit an interconnection application for eligible renewable customer-sited distributed generation (such as behind the meter PV or storage) on or after April 15, 2023. The tariff is effective once customers receive permission to operate eligible customer-sited resources.

Oscillating water column wave energy converters generate electricity by using the oscillating motion of water within a chamber as waves pass by. These WECs typically consist of a partially submerged chamber open to the sea.

Oscillating wave surge converters consist of a buoyant structure that moves back and forth (surges) in response to the passing waves to create energy.

Overtopping wave energy converters consist of a sloping structure or a seawall with a reservoir behind it. As waves approach the structure, they climb up and spill over the crest, filling the reservoir with water. Being impounded, the water accumulated in the reservoir is at a higher elevation than the surrounding ocean. The water collected in the reservoir is then released through turbines or sluice gates. This controlled release of water drives turbines or generators, converting the potential energy of the stored water into electricity.

Point absorbers typically involve a floating buoy or platform that moves up and down or back and forth in response to the motion of passing waves. This movement, relative to a fixed structure (like an anchor), is then converted into mechanical energy using a power take-off mechanism, such as hydraulic pistons or linear generators.

Powering the Blue Economy involves using marine energy technologies to support and enhance various sectors and activities within California's rich ocean economy.

Pressure differential wave energy converter generates electricity by harnessing the difference in pressure between two points caused by the motion of ocean waves, the crest, and trough.

A **terawatt** is equal to 1,000,000,000,000 (1 trillion) watts.

Transportation electrification refers to the process of moving away from fossil-fuel powered internal combustion engines and toward cleaner fuel cell and battery-electric vehicles.

ACRONYMS

AAEE	additional achievable energy efficiency
AAFS	additional achievable fuel substitution
AATE	additional achievable transportation electrification
AB	Assembly Bill
AC	alternating current
AHRI	Air-Conditioning, Heating, and Refrigeration Institute
BAAQMD	Bay Area Air Quality Management District
BTM	behind-the-meter
BOEM	Bureau of Ocean Energy Management
BUILD	Building Initiative for Low-Emissions Development
California ISO	California Independent System Operator
CAGR	compound annual growth rate
CARB	California Air Resources Board
CDD	cooling degree days
CEC	California Energy Commission
CED	California Energy Demand Forecast
CEDU	California Energy Demand Update
CEQA	California Environmental Quality Act
CPCN	certificate of public convenience and necessity
CPUC	California Public Utilities Commission
DAWG	Demand Analysis Working Group
DER	distributed energy resources
DG	distributed generation
dGen	Distributed Generation Market Demand
DMV	California Department of Motor Vehicles
DOF	California Department of Finance
EBDP	Equitable Building Decarbonization Program
EIR	environmental impact report
EV	electric vehicle

FERC	Federal Energy Regulatory Commission
GHG	greenhouse gas
GW	gigawatt
GWh	gigawatt-hour
HDD	heating degree days
HVAC	heating, ventilation, and air conditioning
IEPR	Integrated Energy Policy Report
IOU	investor-owned utility
IRP	Integrated Resources Plan
ITC	Investment Tax Credit
JEDI	Jobs and Economic Development Impact
JPA	joint powers authority
km	kilometer
kW	kilowatt
kWh	kilowatt-hour
LCFS	Low Carbon Fuel Standard
LD	light-duty
LTPP	Long Term Procurement Plan
MW	megawatt
MWh	megawatt hour
NBT	Net Billing Tariff
NEM	net energy metering
NOAA	National Oceanic and Atmospheric Administration
NOx	oxides of nitrogen
NREL	National Renewable Energy Laboratory
PARMM	Passenger, Air, Rail, Microtransit, and Marine Model
PG&E	Pacific Gas and Electric Company
POU	publicly owned utility
PRM	planning reserve margin
PTC	permit to construct
PV	photovoltaic

RPS	Renewables Portfolio Standard
SB	Senate Bill
SCAQMD	South Coast Air Quality Management District
SCE	Southern California Edison
TECH	Technology and Equipment for Clean Heating
TEDF	transportation energy demand forecast
TOU	time of use
TPP	Transmission Planning Process
TWh	terawatt-hour
U.S.	United States
U.S. DOE	United States Department of Energy
USACE	United States Army Corp of Engineers
USCG	United States Coast Guard
VMT	vehicle miles traveled
WEC	wave energy converter
WRF	Weather Research and Forecasting
ZEV	zero-emission vehicle

APPENDIX A: Western Electricity Markets: Increased Progress Toward Integration and Coordination

As the California Energy Commission (CEC) noted in the *2022 IEPR Update*, the West is in a period of rapid change, resulting in increased integration of electricity system operations. This increased integration is enabling balancing authorities to share resources to save customers money and improve reliability. Markets in the Western Interconnection (WI)[96] continue to evolve. For example, in December 2023, the Federal Energy Regulatory Commission (FERC) approved the California Independent System Operator's (California ISO's) tariff for its Extended Day-Ahead Market (EDAM). EDAM is an expansion of California ISO's Day Ahead Market to other entities in the WI. In January 2025, FERC conditionally approved another day-ahead market tariff for the WI designed by the Southwest Power Pool: Markets+. Similar and competing with EDAM, Markets+ is a day-ahead wholesale energy market.

In July 2023, regulators throughout the WI wrote to the leadership of the Western Interstate Energy Board (WIEB) and the Committee on Regional Electric Power Cooperation (CREPC)[97], expressing a desire for broader coordination and integration of wholesale electricity markets across the West. That letter formed the basis of the Pathways Initiative (Pathways).[98] The regulators' letter articulated a collective desire to maximize the benefits of organized power markets for the WI. At its essence, Pathways would see the creation of a new regional organization (RO) that would oversee the governance of the Western Energy Imbalance Market (WEIM)[99] and the EDAM, collectively known as the Western Energy Market (WEM).

Pathways formally began in October 2023 with a launch committee (LC) representing diverse sectoral perspectives across the West. The LC's members represented 12 sectors and at least one launch committee member was based in each of the 11 states within the WI.

On April 10, 2024, the LC issued its straw proposal, which laid out an incremental approach to greater coordination and integration of western electricity markets. The approach is predicated on three steps.

Step 1 works through existing law to modify the governance of the WEM. Before Step 1, the California ISO maintained primary governance of WEM. At the core, Step 1 elevates the authority of the WEM Governing Body from "Joint Authority" to "Primary Authority." Step 1 effectively provides additional independence for governance to the WEM by shifting authority

96 The Western Interconnection is one of the major electric grids in North America. It comprises parts of 15 states and includes areas in Mexico and Canada.

97 WIEB is a collection of 11 states and 2 Canadian provinces. Its goal is to promote cooperation throughout the region. CREPC is a joint committee of WIEB and the Western Conference of Public Service Commissioners.

98 See Western Regulators Letter to WIRAB-CREPC: Microsoft Word — Letter to CREPC WIEB — Regulators Call for West-Wide Market Solution 7-14-23.docx.

99 The WEIM is a subhourly imbalance market to buy and sell electricity.

toward the WEM Governing Body rather than the California ISO's Board of Governors. On August 13, 2024, the California ISO Board of Governors and the WEM Governing Body voted and unanimously approved Step 1.

Step 2 creates a new and independent RO to "further maximize independence while leveraging existing market infrastructure to minimize costs." Step 2 establishes the new RO, which would operate the WEIM and the soon-to-launch EDAM under development by the California ISO. On November 22, 2024, the LC approved Step 2.

Step 3 could continue to expand the scope of the different market functions and regional services offered by the RO. Step 3 is beyond the scope of current electricity market offerings. Step 3 may or may not ever occur, as it will be predicated on successful implementation of Step 2, in addition to further process to determine what, if any, additional services would be offered. As of February 2025, the LC unanimously approved Step 2. To implement Step 2, legislative action in California is needed. At present, the LC has created a formation committee to undertake parallel work processes including the application for grant funding for the RO.

Pathways and Western Energy Markets: Progress Across the West

On January 24, 2025, the CEC convened a workshop on regional electricity markets and coordination to enable a public discussion on the potential benefits and risks of the Pathways Initiative for California.[100] The workshop sought to highlight an array of stakeholder groups and voices throughout the West that are engaging on these issues. These organizations represented a diverse set of interests that included labor, environmental, publicly owned utilities, investor-owned utilities, and community choice aggregators. Regulators throughout the West also participated and shared their perspectives.

Moreover, the CEC hosted a panel that shared preliminary analyses by the Brattle Group[101] and Stanford University. The Brattle Group study is a preliminary day-ahead market impacts analysis that attempts to quantify the net benefits to California from a variety of EDAM market footprints. The Stanford University study analyzes the reliability benefits to the West under different footprints subjected to varied levels of stress. CEC Vice Chair Siva Gunda hosted the workshop with CEC Commissioner Andrew McAllister. The dais also included President Alice Reynolds, Commissioner Karen Douglas, and Commissioner Darcie Houck from the California Public Utilities Commission (CPUC); President and CEO of the California ISO Elliot Mainzer; and Chair of the California Air Resources Board (CARB) Liane Randolph. Leaders from several

100 Materials from the January 24, 2025, IEPR Workshop on Regional Electricity Markets and Coordination are available at https://www.energy.ca.gov/event/workshop/2025-01/iepr-commissioner-workshop-regional-electricity-markets-and-coordination.

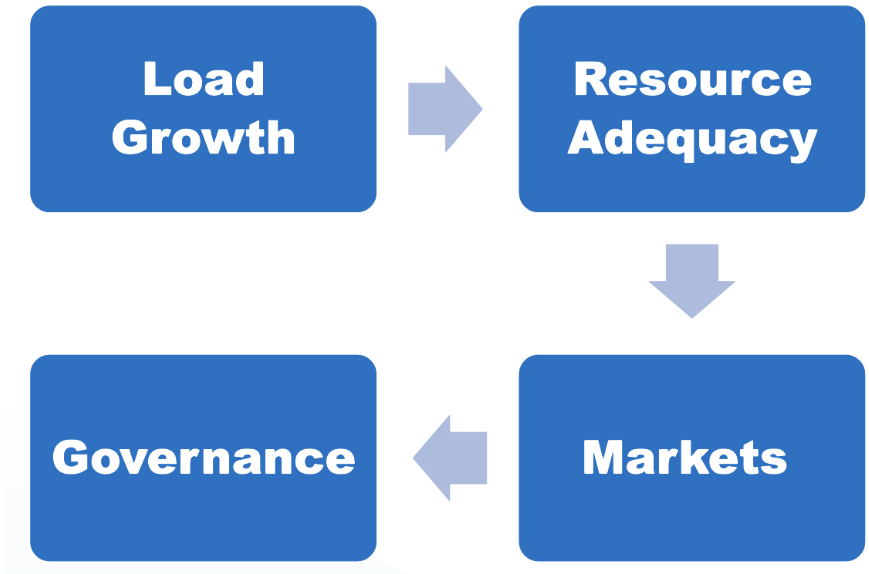
A complete recording of the event is available at https://energy.zoom.us/rec/share/fS1wetiTk5zEVByODw1Raz-Jrohl4CGrY6StojG5rpiNRZX0K7Dpuz8TPf2GEvk.9NLi975QqyXDuD5p.

101 The Brattle Group is an economic consulting firm.

western state energy regulatory agencies engaged by participating on a panel. This is a staff summary of the presentations and discussions of that workshop.[102]

Jake McDermott (with the CEC) kicked off the technical portion of the workshop with an overview of the current electricity system challenges for the western grid, addressing load growth, resource adequacy, market and governance.[103]

Figure A-1: Current Electricity System Challenges for the Western Grid



Source: CEC

Mr. McDermott described how recent trends, such as greater electrification, are creating growth in electricity demand and the need to build new generation capacity. Resource adequacy (RA) is one such paradigm that can motivate the construction of new resources such as new solar or energy storage resources. RA is a policy and compliance framework that requires load-serving entities to contract for enough capacity to meet load forecasts in addition to a planning reserve margin. Markets can optimize a collection of power plants but markets themselves are premised on having the necessary capacity in the system to meet load. The value of markets lies in their ability to efficiently optimize supply along with transmission resources.

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102 The notice, presentations, comments, and Zoom recording of the event can be accessed on the CEC event web page at https://www.energy.ca.gov/event/workshop/2025-01/iepr-commissioner-workshop-regional-electricity-markets-and-coordination.

103 Presentation by Jake McDermott with the CEC. "Western Energy Markets," https://efiling.energy.ca.gov/GetDocument.aspx?tn=261266&DocumentContentId=97634.

Carl Linvill (with the Regulatory Assistance Project[104]) provided a detailed primer on the Pathways Initiative.[105] Mr. Linvill described the mission of the LC, and his slides provided an overview of the initiative, including the varied steps. He detailed the ongoing work that the LC has completed since inception, including the formation of various stakeholder committees to complete different processes. Mr. Linvill provided the varied evaluation criteria created by the LC to appraise the proposal. In terms of next steps, Mr. Linvill elaborated on the creation of a formation committee. The formation committee will focus on preparations in advance of any legislation enactment and any implementation needs after possible legislative action.

Western Regulator Perspectives

Mr. Linvill moderated a panel of western regulators. The regulators included Commissioner Letha Tawney (Oregon), Commissioner Milt Doumit (Washington), Chair Kevin Thompson (Arizona), and Chair Pat O'Connell (New Mexico). The panel sought to understand perspectives from across the West. Each regulator was a signatory to the July 2023 letter that formally started Pathways.

Mr. Linvill invited the commissioners to describe what led to their involvement in Pathways. Throughout the panel, a few key themes emerged. They are summarized below:

- Increased value to consumers: The commissioners each discussed how Pathways can provide financial value to the consumers in their states. Commissioner Tawney highlighted the studies that have shown Oregon customers benefitting from the largest market footprint possible and noted, "There's so much clear value to Oregon customers in being in a market, together with their western colleagues." Chair Thompson described many mutual benefits from a larger western market footprint and specifically mentioned Arizona's ability to provide power for its neighbors during the winter and then relying on hydroelectric imports from the northwest during the hot summer.
- Preservation of state autonomy and the public interest: The panel discussed the importance of each state maintaining their autonomy over key energy policy choices. Furthermore, the commissioners discussed the various public interest provisions within the operating charter of the new RO.
- Connectivity and diversity of loads and resources: Commissioners mentioned that a benefit of Pathways and western market expansion is the increased transmission connectivity among states. Commissioner Tawney described how the 2000 and 2001 energy crisis revealed just how tied together each jurisdiction in the Western Electricity Coordinating Council (WECC) is, asserting that customers are better off in Oregon when the state is in "dialogue" with other states and is working collaboratively across the region.
- Stronger together: Throughout the panel, each commissioner discussed their appreciation for their colleagues throughout the West and how valuable many of their

104 The Regulatory Assistance Project is an independent NGO that is providing consultative services to the Pathways LC.

105 Presentation by Carl Linvill with the Regulatory Assistance Project. "The West-Wide Governance Pathways Initiative," https://efiling.energy.ca.gov/GetDocument.aspx?tn=261261&DocumentContentId=97629.

ongoing conversations are. During the conversation, there were consistent and repeated references to the importance of linkages between states and the benefits of increased interregional cooperation on electricity markets.

Diverse Stakeholder Perspectives

A separate panel featured representatives from different stakeholder constituencies that support the Pathways Initiative. The panel sought to ascertain why these groups (labor, environmental interests, and a publicly owned utility) support Pathways given past similar proposals that they opposed. The panel participants included Marc Joseph (with the California State Association of Electrical Workers and the Coalition of California Utility Employees), Mark Specht (with Union of Concerned Scientists), and Mark Padilla (with Los Angeles Department of Water and Power). Julie Halligan (with the California Public Advocates Office at the CPUC) moderated this panel.

Representing labor, Mr. Joseph noted that while they had previously opposed bills regionalizing the California ISO's functions, Pathways is viewed by labor as fundamentally different. Mr. Joseph referenced prior efforts that would have taken several key functions of the California ISO and delegated those responsibilities to a new regional entity. He emphasized that, instead, Pathways takes only one of those functions ("Energy Market Rules") and embeds that function within the new RO.

Mark Specht discussed the environmental case in support of a larger market footprint in Pathways, leading to reduced curtailments of renewable energy, more efficient dispatch of existing power plants, and reduced emissions and costs, respectively. While these are more short-term benefits, Mr. Specht described, how in the longer term, cooperation on transmission buildout could ease the energy transition by allowing for a more integrated and coordinated approach to infrastructure development. Mr. Specht views part of the Pathways value to be in the potential Step 3 outcomes, should stakeholders choose to move in that direction.

Mark Padilla spoke at length about governance issues for a publicly owned utility. Mr. Padilla talked about the importance of being engaged throughout the stakeholder process in addition to the incremental stepwise approach proffered by Pathways. When discussing the public interest protections put forward as part of Pathways, Mr. Joseph highlighted seven distinct protections. He mentioned that the RO's governance documents would contain provisions requiring the RO to have an obligation to respect the authority and autonomy of each state member to set its own procurement, environmental, reliability, and other public interest policies. Mr. Specht went further into some of the other public interest protections, including the creation of an office of public participation, and other provisions for state consumer advocates.

During the panel, participants also discussed the potential risks associated with Pathways and any ways stakeholders sought to address them. These risks included issues around data transparency and the public interest provisions currently embedded within the California ISO's structure. On balance, the panelists found the potential benefits to outweigh the potential risks. The panelists often pointed to the public interest provisions detailed by Mr. Joseph as a step in the right direction that could address some risks associated with the proposal. Even still, Mr. Specht noted that some of the smaller details have yet to be decided and will require additional work with the stakeholder committee.

Market Participant Roundtable

The third panel captured the feedback and views of organizations that would participate in EDAM on behalf of their customers and have an interest in Pathways because of its potential impact on EDAM, and thus, their customers. Jim Shetler (with Balancing Area of Northern California) moderated the panel, and panelists included Evelyn Kahl (with California Community Choice Association), Randy Howard (with Northern California Power Agency), and Jeff Nelson (with Southern California Edison). Moreover, each member of the panel (along with Mr. Shetler) was on the Pathways LC, and two of the panelists are on the formation committee.

The panelists highlighted thematic elements that were consistent with those of the prior panel: the incremental and phased nature of the proposal coupled with the broad stakeholder support, along with the possible impacts to affordability and increased efficiency for transactions for load. Each of these elements was considered positively by the panel. The incremental nature of the proposal allowed organizations to support relatively smaller changes without having to support whole-cloth alterations that they previously opposed. Providing smoother and more efficient transactions for buyers in the market (representing load and customers) can reduce costs and improve affordability. Finally, according to Mr. Nelson, a common belief of the initial stakeholder group was that "we are stronger together."

Furthermore, the panelists highlighted the importance of the initial regulator letter that started the Pathways process. This letter may have provided stakeholders a signal that states their regulators were serious about their collective interests in Pathways. The panelists also discussed what they see as the benefits to their ratepayers:

- Increased economic value out of resources through reduced curtailments.
- Benefits to electric sector affordability.
- A larger market footprint to aggregate resources and diverse loads.
- The ability for the West to operate under an integrated market.

Mr. Shetler noted that one of the fears about the Pathways proposal is that it could be detrimental to California's interests and autonomy. Ms. Kahl discussed this critique and how it was a key question for community choice aggregators. According to Ms. Kahl, the LC spent time on this issue and the RO will have an operating obligation to not take any actions that are directly contrary to the interests of any participating state. Ms. Kahl also referenced Mr. Joseph's comments from the prior panel that the RO would maintain authority only over the energy market rules, but that the other critical roles that the California ISO or other state institutions performs would be retained by those organizations.

Research Panel: Assessing the Benefits of Pathways for California

The last panel of the workshop included two presentations — one from The Brattle Group and the other from Stanford University.

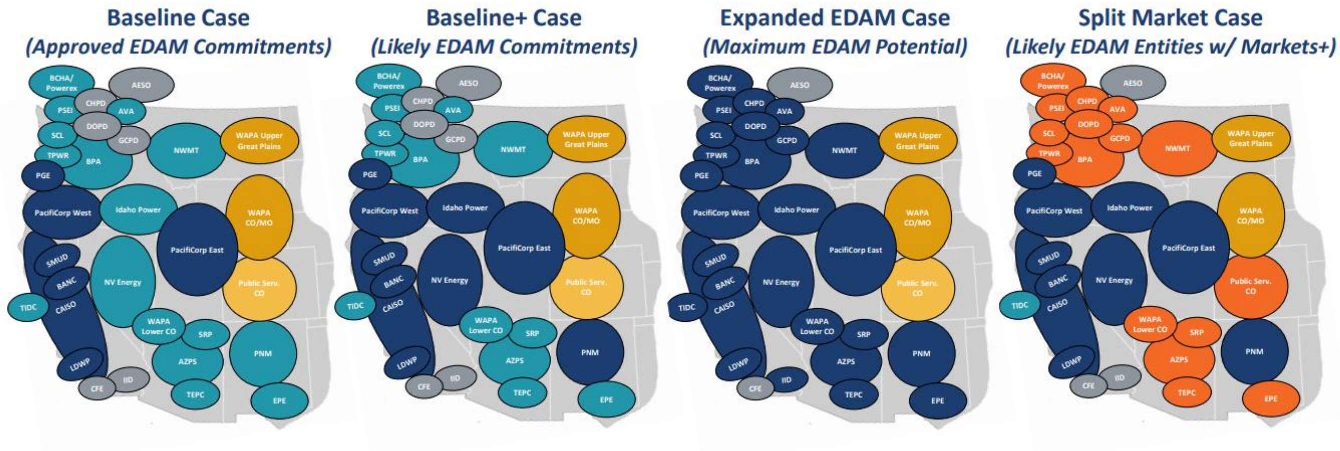
John Tsoukalis (with The Brattle Group) presented on the Preliminary Day-Ahead Market Impacts Study.[106] Brattle prepared this study for the CEC, and the goal was to provide preliminary estimates of the financial impacts to California ratepayers under different potential configurations of the market. While Brattle's primary goal was to estimate financial benefits, the study also provided greenhouse gas emissions estimates for California and the West.

Brattle used a model that they had developed through several prior studies. It is a nodal model that can calculate prices at granular locations in an electric grid. It simulates multiple aspects of the WI including physical and operational characteristics. The model used resource and transmission infrastructure assumptions from utility integrated resource plans and transmission planning processes around the West. The analysis looked at potential impacts in 2032. The year 2032 was chosen to reflect a state in which the market has already been operating for some time, and Brattle was able to model realistic changes to the resource mix and transmission infrastructure.

Mr. Tsoukalis provided an overview of the different potential market dynamics and expected outcomes, which included a larger portfolio of transmission and generation resources, reduced curtailments of renewable energy, and increased trading between partners. The bulk of the presentation was spent discussing the results from evaluating four scenarios, or cases. The four market footprints include a Baseline Case (approved EDAM commitments), Baseline+ (likely EDAM commitments), Expanded EDAM (maximum EDAM potential), and Split Market (likely EDAM entities with Markets+). Below are visuals that detail each case.

106 Presentation by John Tsoukalis with the Brattle Group. "Preliminary Day-Ahead Market Impacts Study," https://efiling.energy.ca.gov/GetDocument.aspx?tn=261300&DocumentContentId=97632.

Figure A-2: Brattle Study Footprints



Source: The Brattle Group

The three main pillars where expected benefits materialize include economic benefits from reduced production cost estimates, environmental benefits from reduced curtailments and reduced emissions, and reliability benefits. Below are Brattle's primary economic results reproduced and segmented by the respective market footprint.

Table A-1: Primary Economic Results From Brattle's Preliminary Day-Ahead Market Impacts Study

Case	CA Total System Cost ($million per year)	Savings from Baseline Case ($million per year)	Savings from Baseline+ Case ($million per year)
Baseline Case	$4,511	-	-
Baseline+ Case	$4,399	$112	-
Expanded EDAM Case	$3,721	$790	$698
Split Market Case	$4,217	$294	$182

Source: CEC

Mr. Tsoukalis discussed the top-line findings, including that the Expanded EDAM case with the largest footprint results in additional significant economic benefits for California ratepayers above the Baseline+ case ($678 million). These results are couched, however, in that they are not representative of the benefits of EDAM forming, but rather an expanded EDAM footprint with additional western participation above what is envisioned in the Baseline Case. In the Split Market case, California customers would receive about $182 million in increased benefits above the Baseline+ Case. However, this finding is driven by several assumptions. Perhaps most notably, this result is driven by Brattle's assumptions that trading between the seams of EDAM and Markets+ will be relatively efficient. To the extent that there are other factors that increase the transactional friction between markets, it would be possible to then see fewer benefits under the Split Market Case than are modeled and shown.

Michael Wara (with Stanford University) provided an overview of analysis on the reliability benefits from increased cooperation in western electricity markets. While the Brattle study focused on the economic benefits of Pathways, the Stanford study focused on the potential increased reliability benefits from additional western grid integration and coordination. Unlike the nodal model employed by Brattle, Stanford used a zonal approach. While the zonal model is less granular than a nodal one, the benefit is that Stanford is able to understand larger regional impacts to reliability. Mr. Wara discussed the benefits of increased coordination across the western grid during regional stress events from reducing the hours at risk of shedding load and the total amount of unserved energy. However, Mr. Wara emphasized that the results should be interpreted directionally rather than for any precise quantification of reliability outcomes.

The Stanford study simulated three footprints or cases. These cases are comparable to the market footprints studied by Brattle. Stanford simulated a case with entities likely to join EDAM (Case 1), one with additional entities from the Pacific Northwest (Case 2), and an entire WECC-wide footprint (Case 3). In each simulation, Stanford modeled what happens during three different stress events. Stanford simulates these stress events as extreme heat scenarios based on the September 2022 California event. For the most extreme stress level modeled (40 percent stress above baseline), Stanford computed that the total hours at risk are reduced from 25 percent in Case 1 down to 15 percent in Case 3. This result suggests that a larger westwide market is better able to meet load reliably in extreme conditions through the coordination of generation resources. Mr. Wara closed his presentation by highlighting the importance of maintaining reliable grid operations, particularly considering California’s climate and clean energy goals.