California Energy Commission

DRAFT COMMISSION REPORT

Draft 2024 Integrated Energy Policy Report Update

Gavin Newsom, Governor

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Stephanie Bailey
Mathew Cooper
Quentin Gee
Heidi Javanbakht
Danielle Mullany
Primary Authors

Raquel Kravitz
Project Manager

Sandra Nakagawa
IEPR Director

Drew Bohan
Executive Director

ACKNOWLEDGEMENTS

Mariko Geronimo Aydin
Onur Aydin
Aria Berliner
Lindsay Buckley
Jenny Chen
Denise Costa
Catherine Cross
Lisa DeCarlo
Bryan Early
Jessica Eckdish
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Heather Raitt
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Carol Robinson
Katerina Robinson
Ken Rider
Stacey Shepard
Sabaratnam Thamilseran
Kevin Uy
Ysbrand van der Werf
Kristi Villareal
Renee Webster-Hawkins
Susan Wilhelm
Bobby Wilson
Lakemariam Worku

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.

Keywords: Energy policy, demand forecast, wave energy, tidal energy

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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, built around electrification and clean energy.

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. California also made substantial investments to advance the adoption of zero-emission vehicles and accelerate clean energy infrastructure development.

Electrification is at the heart of California's above-mentioned decarbonization plan, aiming to shift key sectors — transportation, buildings, and industry —to clean energy. 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. By the end of 2022, 61 percent of the state's electricity was generated from renewable and zero-carbon resources, according to the most recent data. 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 more than 13,000 MW in 2024. In 2024, from January 1 through September 30, the state has added 3,993 MW of new energy resources (485 MW solar and 3,508 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 to support all-electric appliances by 2035.
- Achieve 7,000 MW of load flexibility – adjusting electricity usage to match supply – to manage energy demand efficiently.
- Develop 25,000 MW of offshore wind by 2045.

However, as the state works to accelerate the transition, it faces 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 facilitating efficient connection to the grid. 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 event, the California Energy Commission (CEC), California Public Utilities Commission (CPUC), and California Independent System Operator (California ISO) have worked to further enhance preparedness to maintain reliability in the face of a changing climate.

Better coordination has paid off, as demonstrated in the summers of 2023 and 2024 when the grid remained stable despite wildfires and record heat. However, tight electricity conditions are expected to continue in the coming years. As a result, careful planning and forecasting of energy demand — both in the near and long terms — are critical to maintain reliability, meet climate goals, and promote 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 guides energy planning proceedings across the state. 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 in the near and long terms, 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.

The forecast also serves as an important input into the state's comprehensive energy planning process. The joint agencies and California ISO have agreed that specific elements of this forecast set will be used for planning and procurement in the California ISO's transmission planning process and the CPUC's integrated resource plan, resource adequacy, distribution system planning, and other planning processes. The details of this agreement will be adapted through time as the needs of planning and procurement evolve. This agreement was also documented in a joint memorandum of understanding in December 2022.[1] This multistep approach ensures that clean energy resources are developed in a timely manner and align with the state's long-term climate goals.

The accelerating climate crisis has increased the importance of the energy demand forecast. Climate change is increasing uncertainty in long-term planning, with extreme weather events significantly influencing energy demand. Because extreme weather events are occurring more frequently, historical weather data are no longer sufficient for projections of future weather patterns. For this reason, CEC has shifted from using historical weather data to using newly available climate simulation data in its forecasts.

Staff are 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:

- Made improvements to the behind-the-meter photovoltaic and storage historical data and forecast.
- 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 regulations.
- Made improvements to the hourly forecast method to improve model performance.

Draft load modifier forecast results[2] were presented at the November 7, 2024 workshop and overall forecast results will be shared at the December 12, 2024 workshop. Final results and will be included in the final *2024 IEPR Update*.

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*

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://www.cpuc.ca.gov/-/media/cpuc-website/divisions/news-and-outreach/documents/news-office/mous/cpuc-cec-caiso-mou-december-2022.pdf.

2 Load modifiers include behind-the-meter PV and storage, and additional achievable energy efficiency, fuel substitution, and transportation electrification.

IEPR Update is wave and tidal energy. Senate Bill 605 (Padilla, Chapter 205, 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 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 (increasing capacity factor) 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.

The Senate Bill 605 statute 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. The additional report will include a monitoring strategy that will contain measures to avoid, minimize, and lessen adverse environmental impacts, use conflicts, and adaptive management. Work for this report is underway, with a draft expected in early 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 proceedings that ensure California will have an adequate electricity supply. Some examples of these proceedings 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).[3] The 2024 IEPR 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 scenario analyses to better plan for rapid changes in transportation and building electrification strategies, and accounting for more extreme weather variability. The CEC will continue to advance its forecasting capabilities as part of its focus on providing science-based planning tools needed in the transition to a clean energy future.

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.

3 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)[4] meetings and public workshops. The DAWG meetings and workshops held in 2024 are summarized below, followed by a summary of the major improvements implemented.

Stakeholder 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 data that will be used in the forecast and sought input on proposed updates for the 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. A workshop was held November 7 and another will be held on December 12, 2024, to formally present draft results and receive additional stakeholder comments before the forecast is finalized and presented for adoption in January 2025.

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

4 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	Name	Topic
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

Source: CEC

Forecast Framework

The 2024 IEPR forecast contains one baseline demand forecast and multiple scenarios for load modifiers, which include behind-the-meter PV and storage, AAEE, AAFS, and Additional Achievable Transportation Electrification (AATE). A technology is considered a load modifier if its load profile is different from the system load profile, and therefore with large adoption would change the system load profile. 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. 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, the third scenario 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.

Proposed sets of the baseline forecast, 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.

Table 2: Forecast Framework

Use Case/Scenario	Baseline Forecast	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	Baseline
BTM PV and Storage Scenario	Mid	Mid	Low
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, 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 and storage, less energy efficiency and more fuel substitution, resulting in higher demand than the planning forecast. Using this scenario with higher demand mitigates 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.[5] 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

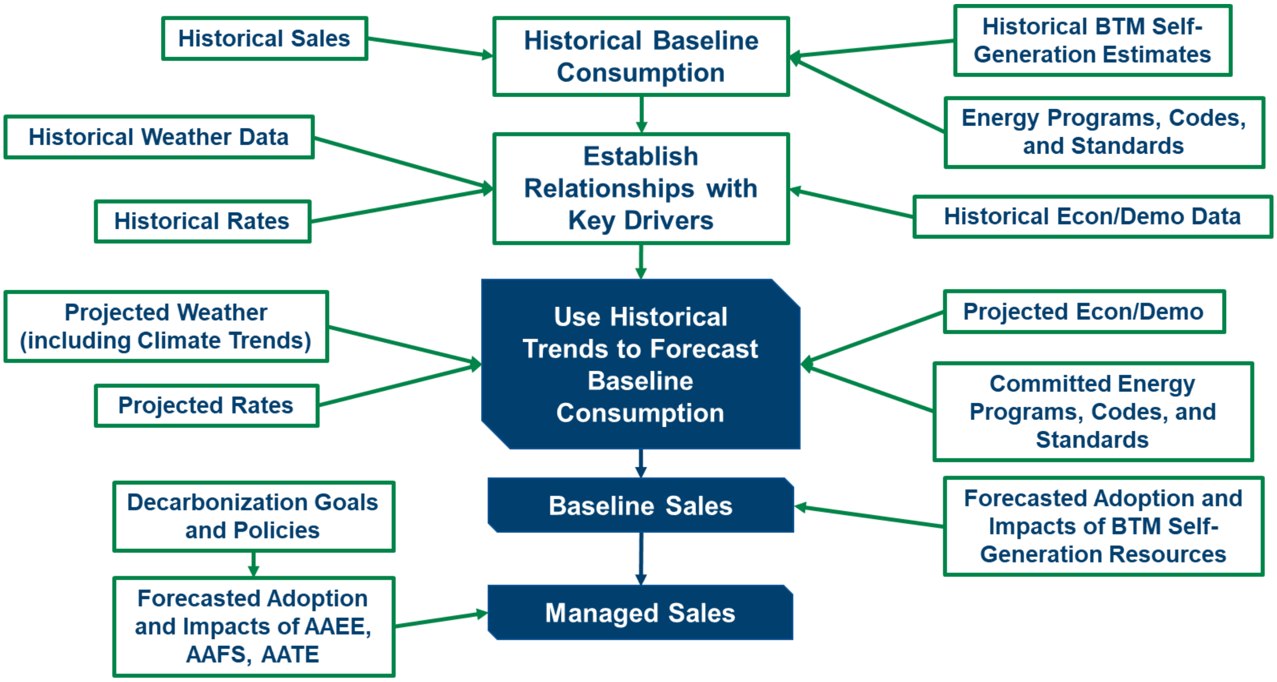
Historical energy consumption data are the foundation of the forecast and are a combination of historical energy sales data and BTM self-generation estimates. Staff establishes correlations of historical energy consumption with economic and demographic data, weather data, and rates from the same historical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

5 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.

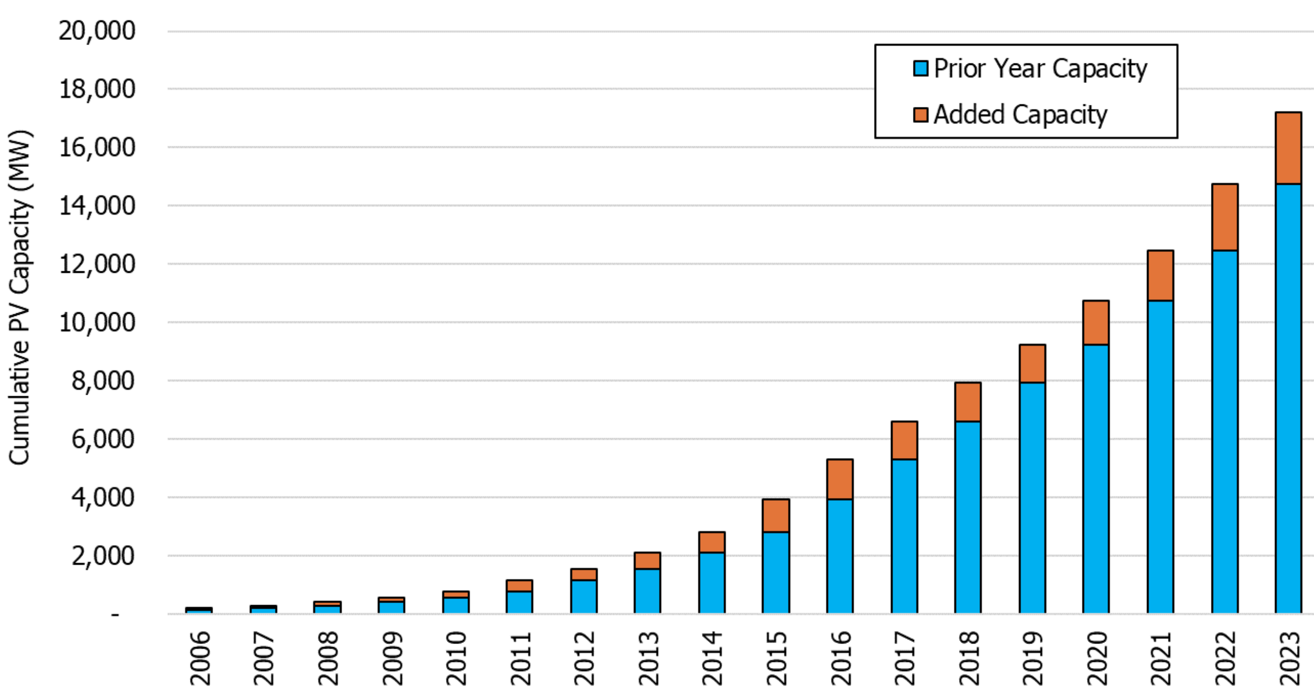
Like the *2023 IEPR*, the *2024 IEPR Update* forecast extends to 2040 in accordance with the 15-year minimum requirement established by Senate Bill 887 (Becker, Chapter 358, Statutes of 2022).

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* 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.

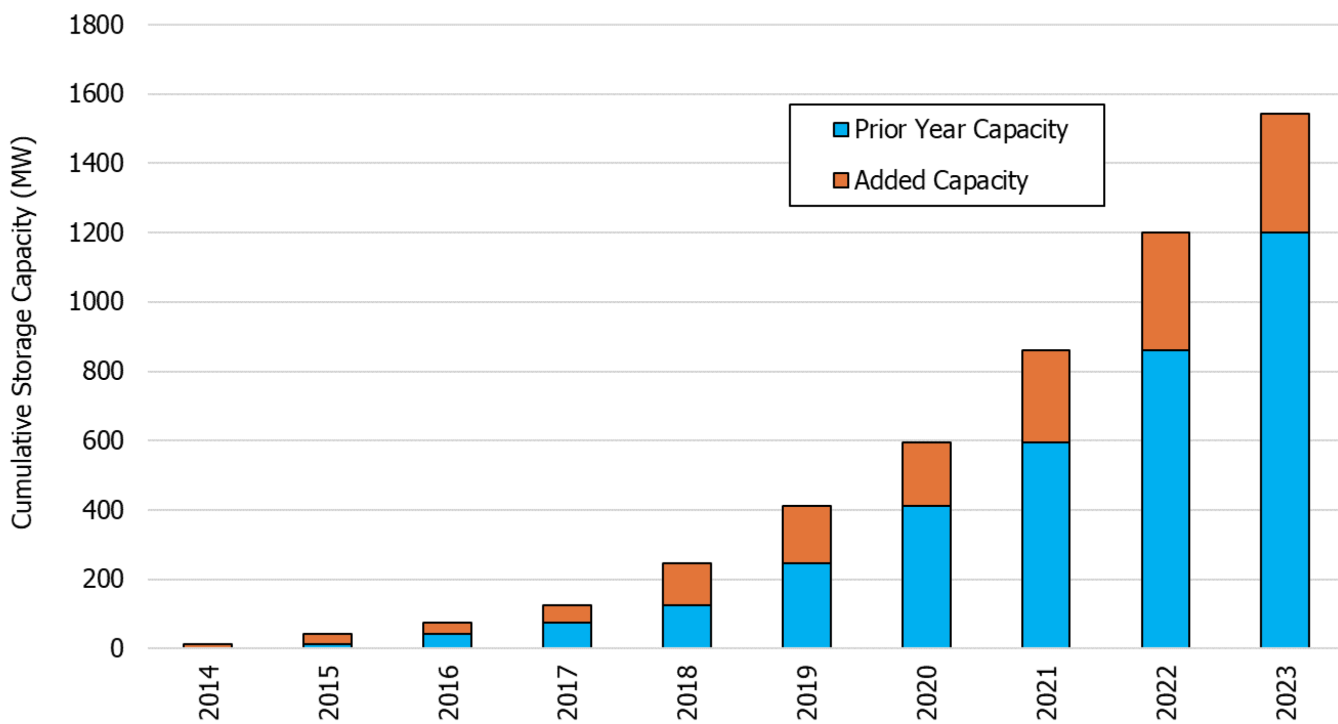
Figure 2: Cumulative BTM PV Capacity in California



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[6]

According to the most recent CPUC interconnection and pending application data, BTM PV and energy storage systems made up 49 percent of the applications in the first quarter of 2024.[7] CEC staff expects the share of paired systems to continue to rise due to the incentive design of the Net Billing Tariff (NBT) that went into effect in April 2023 (Figure 4). 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. The NBT, along with the requirement to enroll in a high differential time-of-use electricity rate, encourages PV adopters

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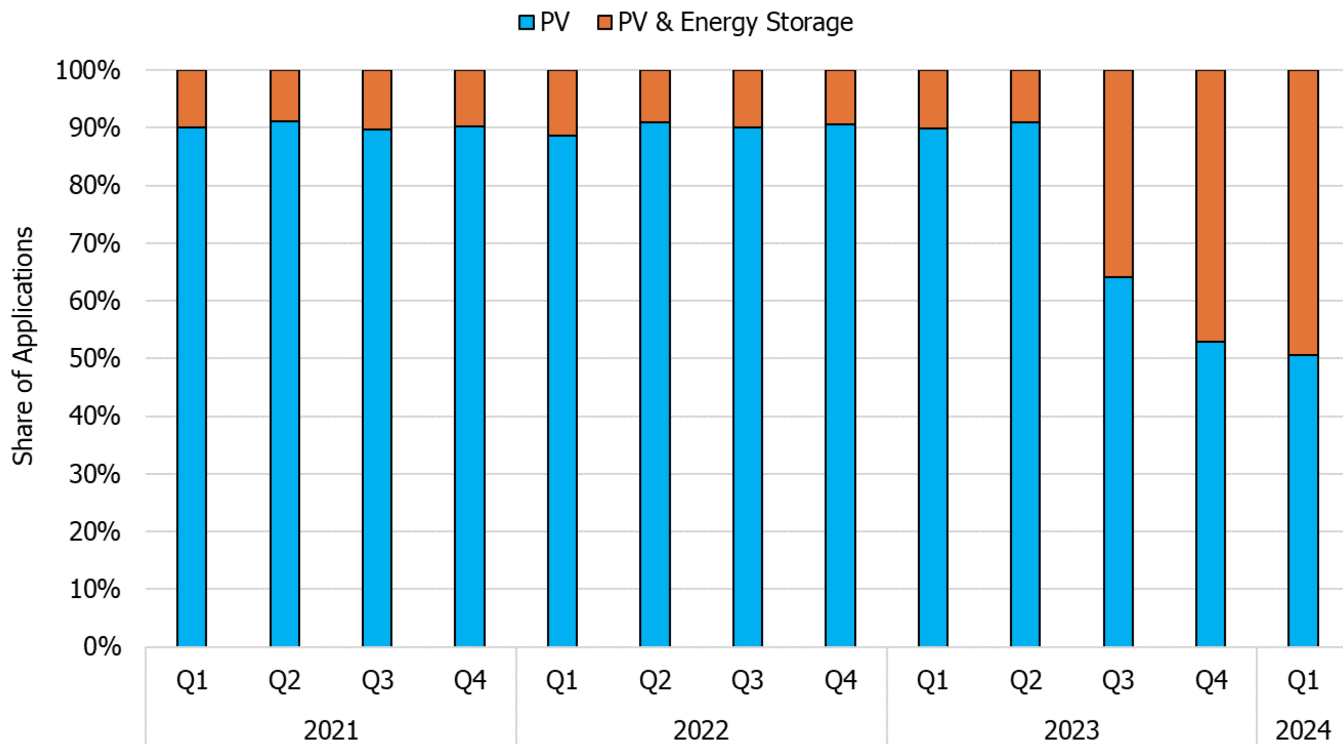
6 Find more details on the CEC's California Energy Storage System Survey web page, https://www.energy.ca.gov/data-reports/energy-almanac/california-electricity-data/california-energy-storage-system-survey.

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

to also install energy storage and offset their electricity use when prices are higher in the evening.

Figure 4: Pacific Gas and Electric Company (PG&E) and Southern California Edison Company (SCE) Residential BTM DG Interconnection Applications



Source: CEC analysis of CPUC interconnection and pending application data. San Diego Gas & Electric is excluded because paired systems are not detectable in their interconnection application data.

For the 2024 IEPR Update, staff revised BTM PV capacity factor[8] 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, or collected, to produce capacity factors for each hour by zone and sector.

8 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.

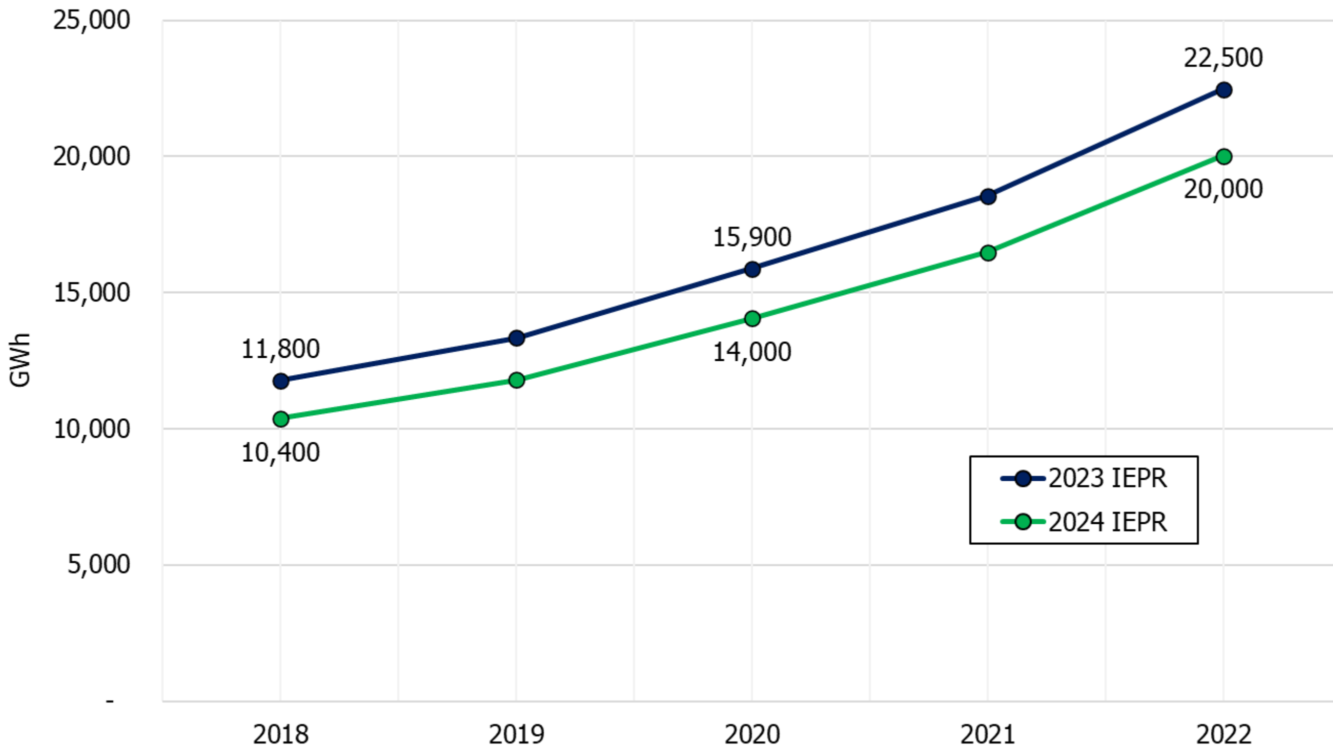
The annual historical capacity factors for the California ISO region are roughly 3 to 4 percentage points lower than those in the 2023 IEPR for 2018 to 2022 (Table 3). This reduction corresponds to a 1,400 to 2,400 GWh reduction in annual BTM PV electricity generation during these years (Figure 5).

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	18.1%	17.4%	17.8%	18.0%	18.5%

Source: CEC staff

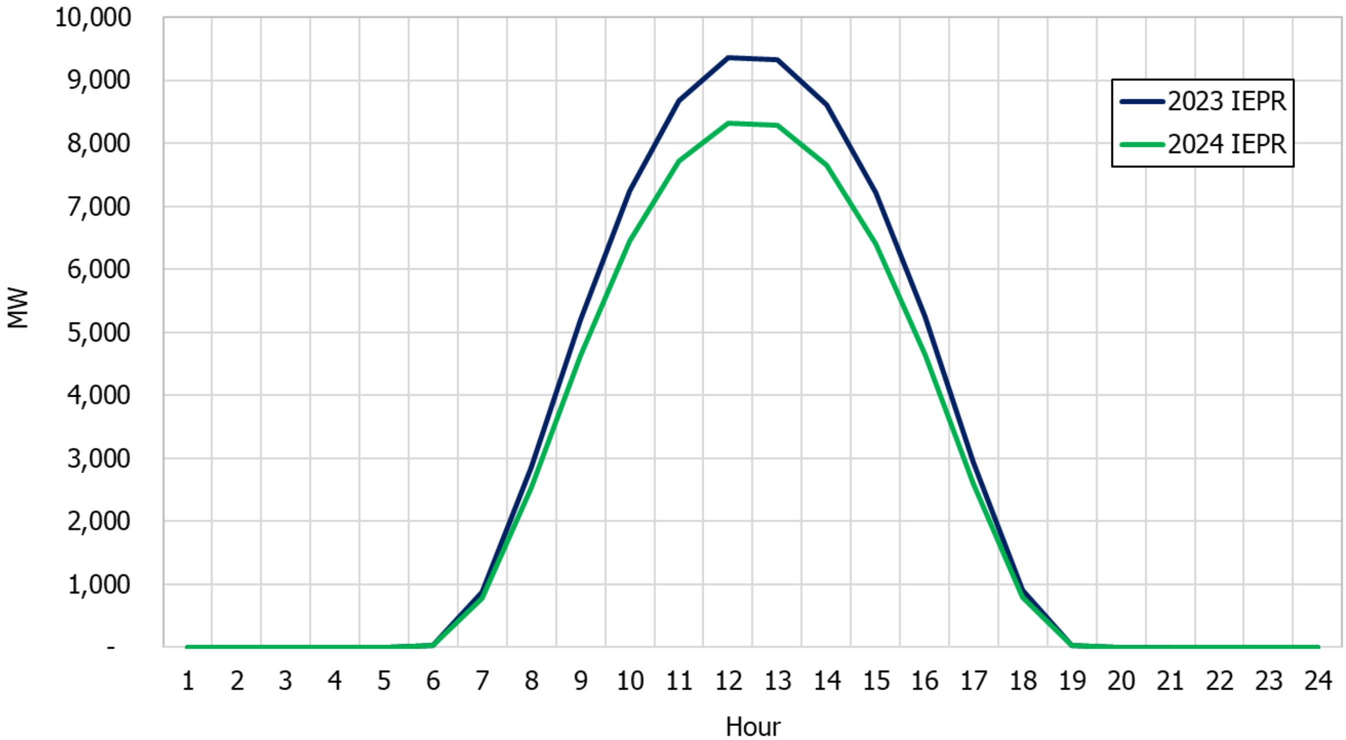
Figure 5: California ISO Historical BTM PV Generation



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

Conservative, moderate, and advanced technology capital expenditure cost projections for PV and storage are from the National Renewable Energy Laboratory's (NREL's) 2024 Annual

Technology Baseline.[9] Base year technology costs are derived from Lawrence Berkeley National Lab's 2024 Tracking the Sun data.[10] 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.[11]

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 Senate Bill 100 Distributed Energy Resources Augmentation Sensitivity analysis.[12]

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 program (EPIC) grant recipients[13] 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*

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9 Find more details on NREL's 2024 Annual Technology Baseline web page. 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.

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

11 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.

12 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.

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

Update cycle. The new WRF model runs and associated data sets have some attractive features, such as a priori bias correction, as well as 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 newly available models.

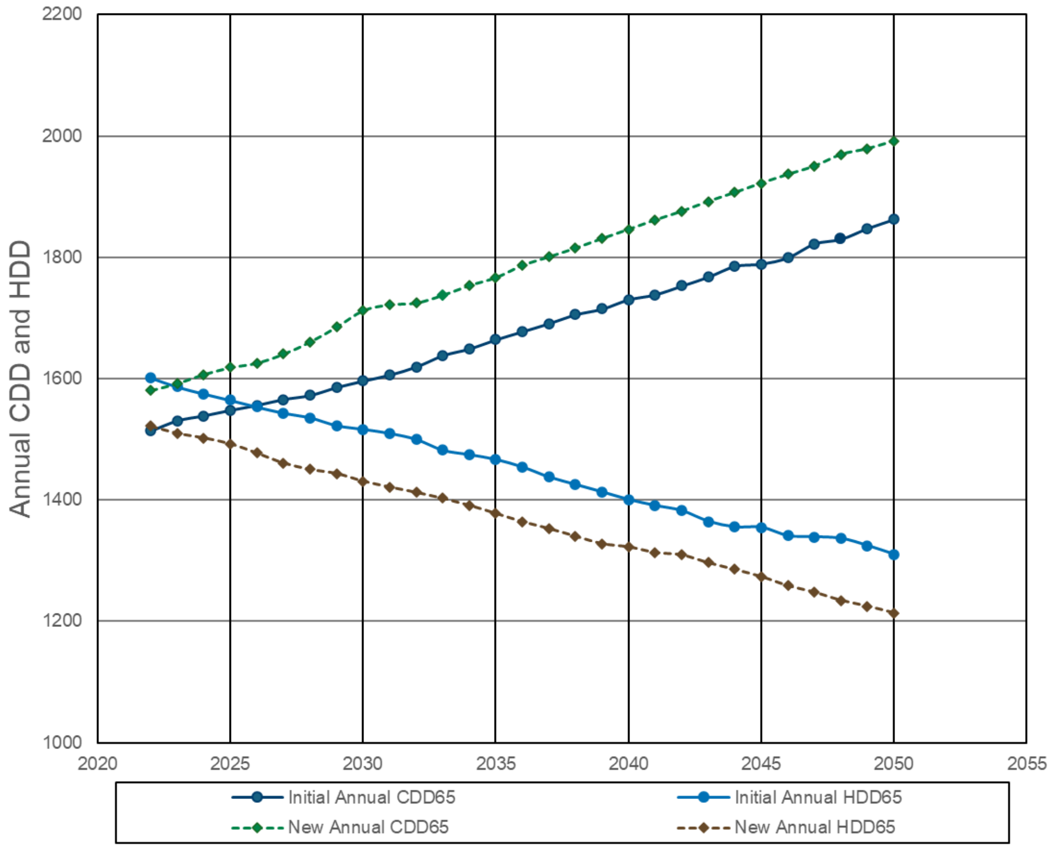
Table 5: WRF Models Used in the *2023 IEPR* Forecast and the Newly Available WRF Models

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 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

Data center energy demand is included in the commercial sector forecast. Many utilities in the state report that they are seeing an increase in the number of new load applications for data centers, and for larger data centers, as technology companies expand and build out infrastructure needs for artificial intelligence.

A January 2023 study by McKinsey & Company estimates that in the United States, demand from servers housed within data centers grew from roughly 7 GW in 2014 to 17 GW in 2022.[14] Data center demand is projected to reach 35 GW in the United States by 2030, which reflects about a 10 percent growth rate per year. Load growth is most prominent in multitenant data centers with servers in small racks or cage space dedicated to colocated but separate clients, as well as hyperscalers with a single client occupying servers in entire buildings or campuses.

The anticipated growth deviates from historical trends, warranting adjustments to the commercial sector forecast. Staff first adjusted for data centers in the *2021 IEPR* forecast based on data provided by Silicon Valley Power that listed the data center projects in its territory and construction status. Staff calculated the portion of these new loads that were not already included in the forecast, then added that portion to the forecast for this region. Staff made similar adjustments in the *2022 IEPR Update* and *2023 IEPR* forecasts based on data submitted by Silicon Valley Power. The data center adjustment for Silicon Valley Power in the *2023 IEPR* forecast resulted in an additional 570 MW during the hour of peak demand in 2040.

For the *2024 IEPR Update*, staff coordinated with five utilities expecting new data center loads, who provided data on the new loads expected in their service territories. Staff will use these data to make an adjustment to the commercial sector forecast to account for the growth of data centers.

Staff is also looking at historical growth of data centers for consideration, as well as the range of building sizes and associated energy-use intensities. Work is ongoing to gather data and develop a method for the data center component. Additional details being researched for data centers include load factors, equipment replacement rates, building decay rates, and vacancy rates. Peak-load shifting and savings from codes and standards are also being investigated.

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

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14 Bangalore, Srini, et al. January 17, 2023. "Investing in the Rising Data Center Economy." McKinsey & Company. Page 2, https://www.mckinsey.com/industries/technology-media-and-telecommunications/our-insights/investing-in-the-rising-data-center-economy.

necessary to ensure that the grid and other transportation fuel infrastructure is ready to support increased ZEV fuels.

The TEDF continues to assess both 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, Passenger, Air, Rail, Microtransit, and Marine Model (PARMM), 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.[15] 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 enhanced capability of developing various travel scenarios in response to various potential policies, programs, and market developments.

Staff has also sought to continually improve work on 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, hourly loads inform the three-hour ramp for the California ISO's flexible capacity studies, and, 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.

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

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 re-estimate 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 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 during a workshop held July 30, 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, as well as planning area coincidence with the California ISO system peak.

Staff will re-estimate the hourly consumption profiles again, as part of the *2024 IEPR* forecast, following efforts to improve model performance. 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. Staff estimate consumption by adding the estimated BTM PV generation to the electricity sales data provided by the utilities. Therefore, lower PV generation estimates will lower 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.

Staff also noted several trends in its historical hourly consumption data, including an increased load response to temperature, as well as a gradual shift of load away from system peak hours and to early morning and midday hours. Staff is testing revised model specifications for certain planning areas and hours and expects that the revised models will better reflect these trends. Staff will provide additional information at the upcoming IEPR forecast workshops, as well as in the final report.

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.[16]

Population and Households

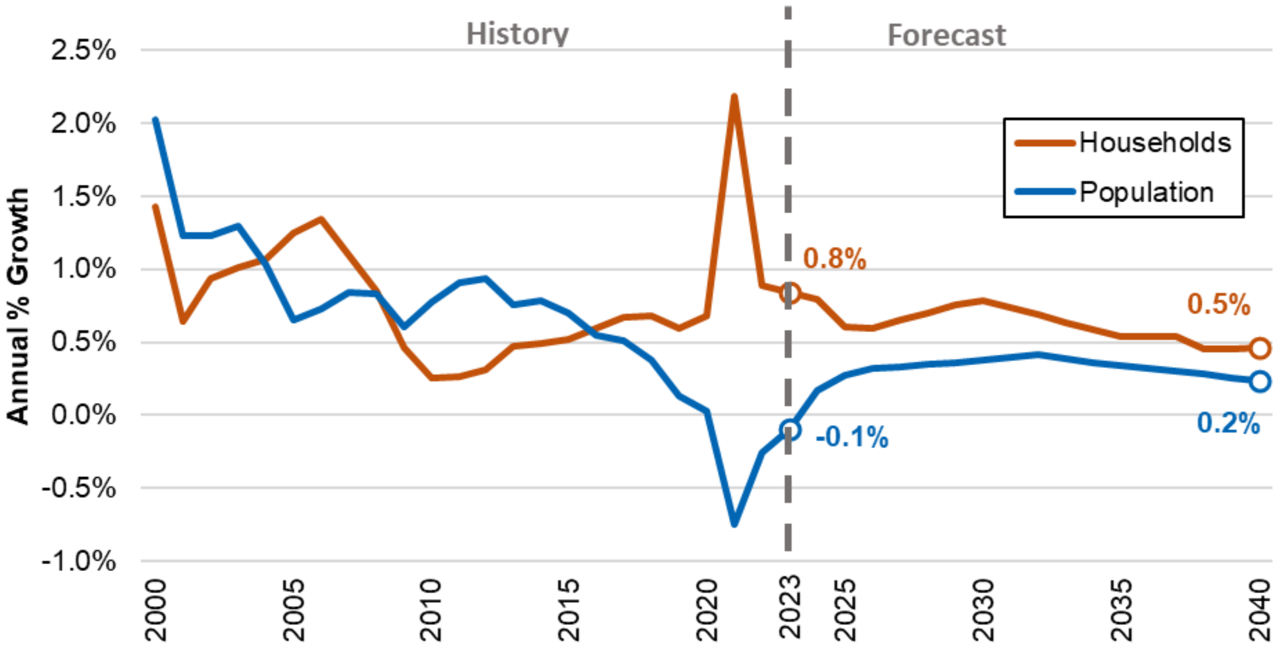
Based on data from the California Department of Finance (DOF), statewide population for the *2024 IEPR Update* forecast grows at an average of 0.3 percent annually from 2024 to 2040. This growth rate is higher than the 0.2 percent annual growth rate assumed in the *2023 IEPR* forecast but lower than 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).

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, more recent data show a return to normal migration patterns, so the 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.

16 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.

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



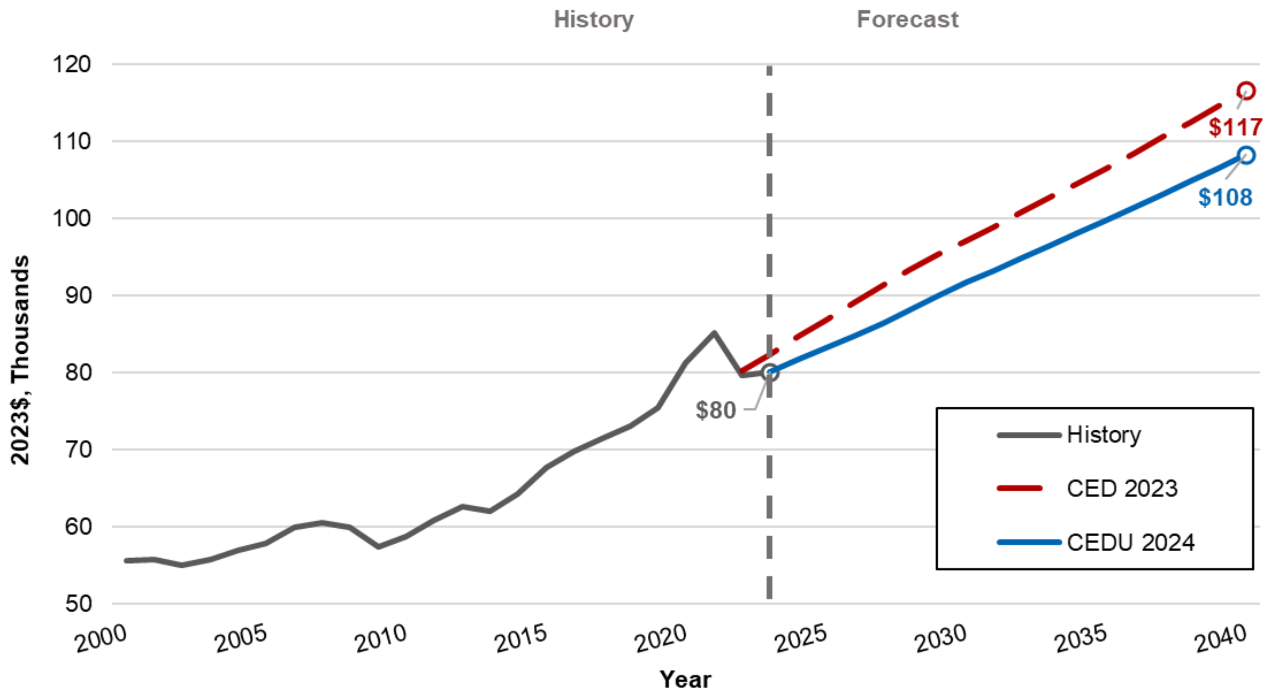
Statewide population grows at an average of 0.3 percent annually from 2024 to 2040. The number of households statewide is expected to grow at an average of 0.6 percent annually from 2024 to 2040.

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

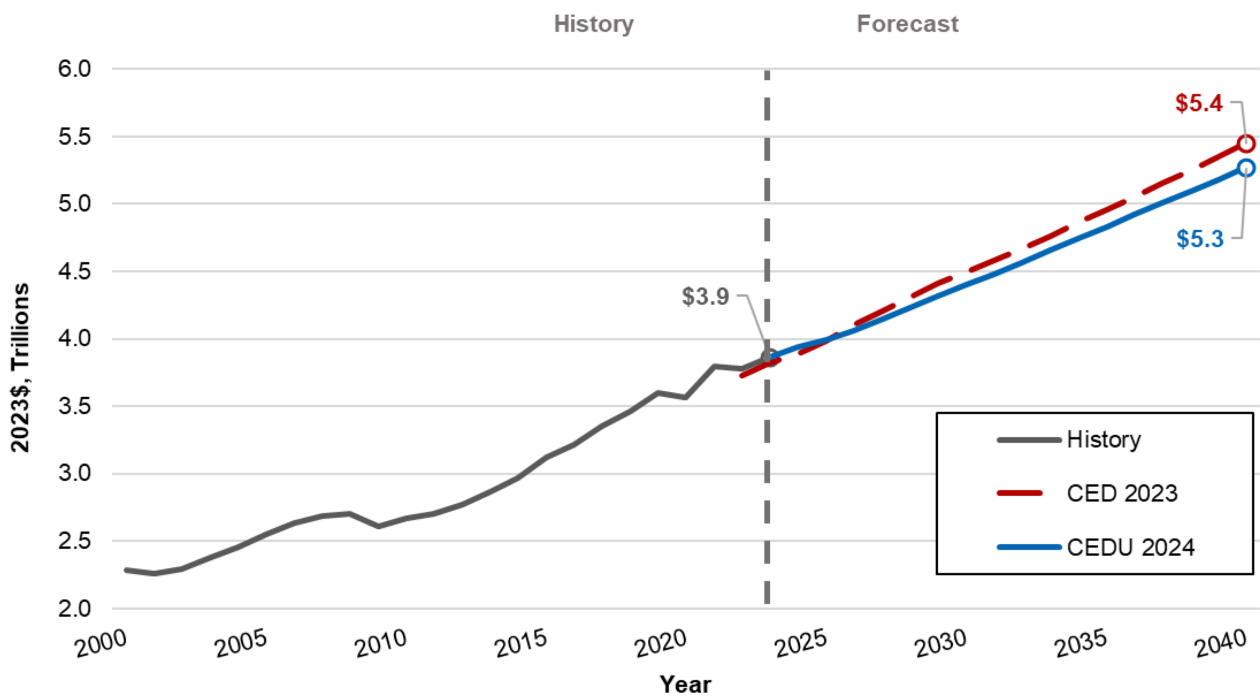


Source: CEC using data from Moody's Analytics and DOF

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



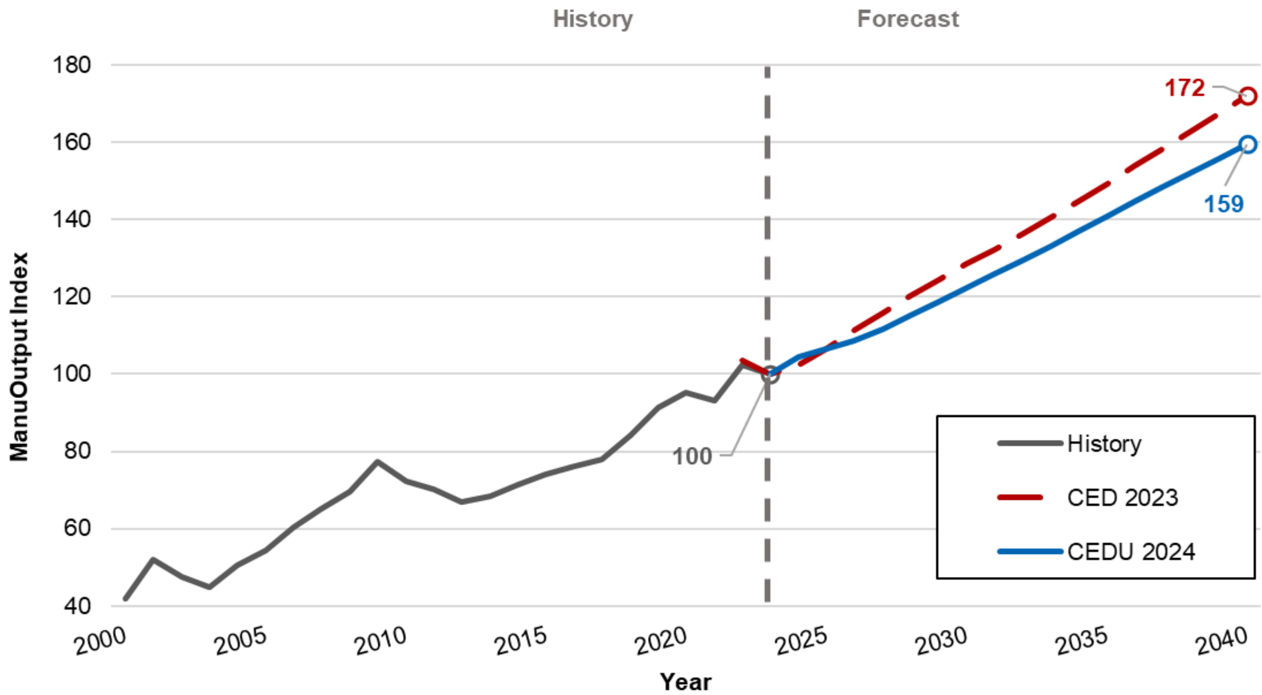
Source: CEC using data from Moody's Analytics

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 and 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



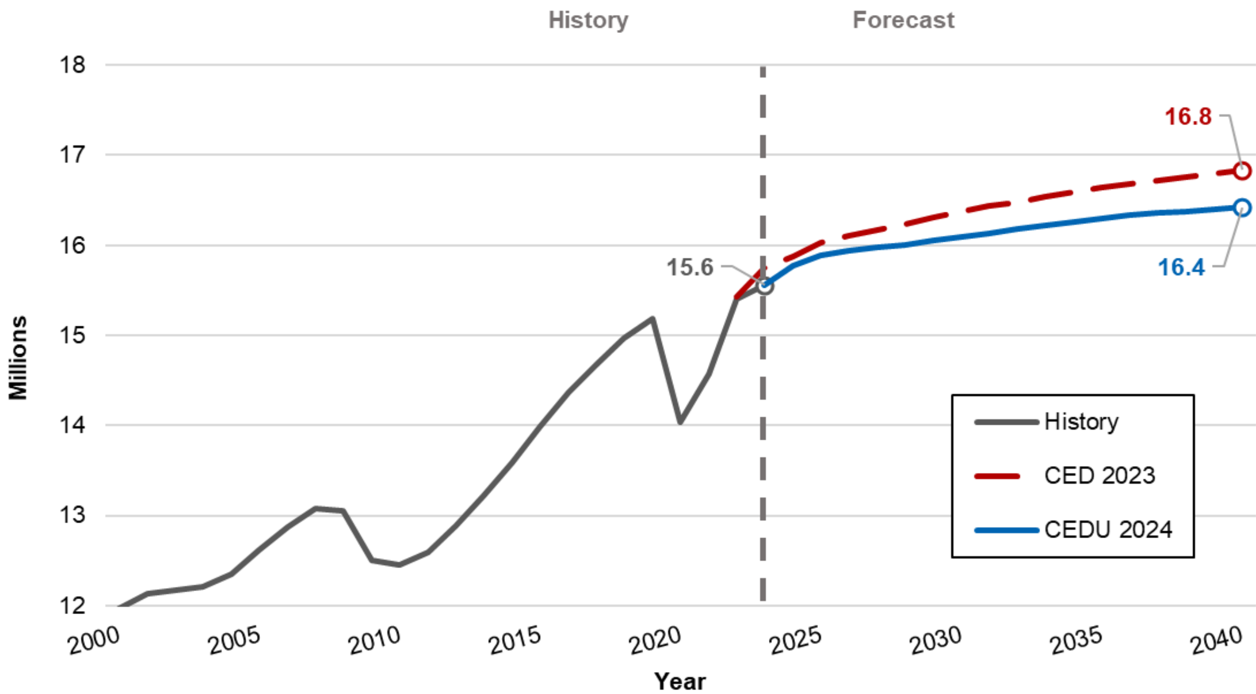
Source: CEC using data from Moody's Analytics

Commercial Employment

Figure 12 compares commercial employment[17] 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.

17 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

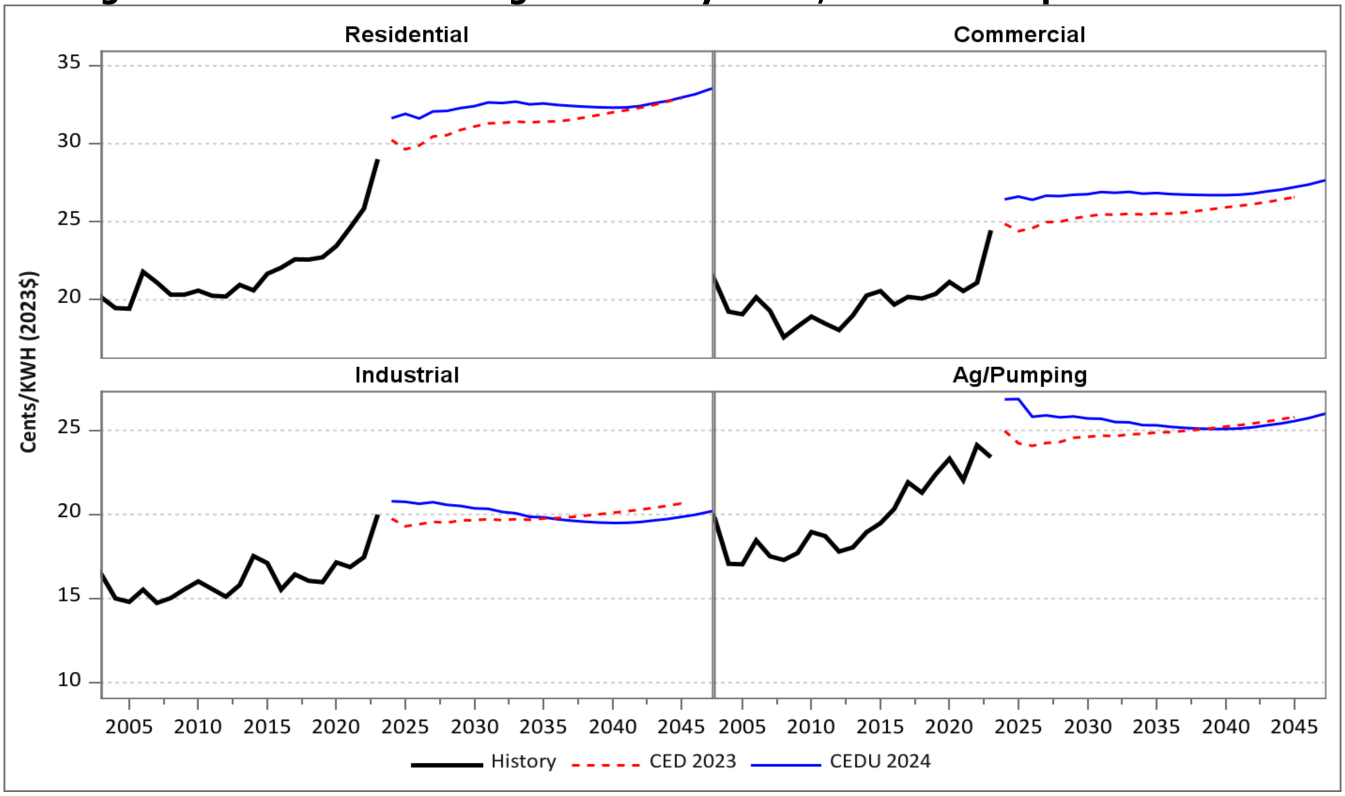
Electricity Rates

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 wildfire-related costs, which includes spending to reduce the risk of utility-caused wildfires, vegetation management, wildfire liability insurance, and the costs of recovering from past wildfire events. 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 IOU territories compared to 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.

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



Source: CEC

Transportation Trends

California remains fully committed to zero-emission transportation by implementing its innovative climate policies and allocating an unprecedented amount of funding to support the transition. The state has surpassed its zero-emission truck sales and vehicle sales targets two years ahead of schedule, as well as exceeding its goal of 10,000 fast EV chargers more than a year early. The success of the state's initiatives has made ZEVs a leading export and driven significant advancements in manufacturing and job creation.

CEC analysis of California Department of Motor Vehicles (DMV) data shows more than 2.1 million light-duty (LD) ZEVs sold in the state as of 2024 Q3.[18] LD ZEV sales continued to increase market share in 2024. As of the third quarter of 2024, ZEVs represent more than 26 percent of all new LD vehicles sold. With continued growth in light-, medium-, and heavy-duty

18 For more information on ZEV sales and other light-duty passenger vehicle sales, see the CEC's Zero-Emission Vehicle Dashboard web page, https://www.energy.ca.gov/data-reports/energy-almanac/zero-emission-vehicle-and-infrastructure-statistics.

ZEVs,[19] the state will continue to focus on supporting the surge in ZEV demand by bolstering the expanding network of accessible, reliable, and convenient ZEV refueling facilities throughout California.

As ZEVs become mainstream, the state is focused on swiftly deploying resources to meet rising demand for these vehicles and establishing an accessible, reliable, and convenient charging network.[20] As of August 2024, California has surpassed 150,000 public and shared-private chargers for passenger vehicles installed statewide, including 137,648 Level 2 chargers and 14,708 fast chargers.[21] This updated charger total is the result of improved data collection by the CEC using additional data sources to track operational chargers and includes chargers previously installed but not captured in prior updates. Of the 48,000 chargers added to the data set since the end of last year, 24,000 new chargers were installed in the first half of 2024.

The state is leveraging $364 million of federal funding from the National Electric Vehicle Infrastructure (NEVI) Program to build out fast charging along transportation corridors. The federal funding is supplementing over $650M in projected state funding for building out charging stations for light duty vehicles between FY 2024-2025 through FY 2027-2028.

The CEC is also tracking infrastructure development for medium and heavy-duty (MDHD) ZEVs, which can be viewed via an interactive dashboard on the CEC's website*, MDHD ZEV Infrastructure Development in California*. California has an estimated 10,768 charging ports and hydrogen refueling nozzles that are in varying stages of development or have been completed. Most of the charging ports are private charging depots used by individual fleets or private charging plazas that require a subscription. MDHD hydrogen infrastructure is a more nascent, developing sector, but there are an estimated 24 public hydrogen refueling stations under development, and four that have been completed. Additionally, seven transit agencies have hydrogen refueling infrastructure to refuel their fuel cell electric bus fleets, and 10 transit agencies are planning to install hydrogen infrastructure in the future. California, Washington, and Oregon were awarded $102M from the federal Charging and Fueling Infrastructure Program to build out ZEV infrastructure for MDHD. This new federal funding supplements the

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19 For more information on MDHD ZEVs registered for on-road travel, see CEC's dashboard web page, https://www.energy.ca.gov/data-reports/energy-almanac/zero-emission-vehicle-and-infrastructure-statistics/medium-and-heavy.

20 For more information on ZEV funding and support opportunities, see CEC's Clean Transportation Program web page, https://www.energy.ca.gov/programs-and-topics/programs/clean-transportation-program.

21 For more information on EV chargers, see CEC Electric Vehicle Charger web page, https://www.energy.ca.gov/data-reports/energy-almanac/zero-emission-vehicle-and-infrastructure-statistics-collection/electric.

state's planned investments of over $700 million between FY 2024-2025 through FY 2027-2028.

Transportation fuel prices, especially those for gasoline, have experienced some volatility. 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. 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 rapid ZEV adoption.[22] In September of 2024 no price spikes occurred, a contrast to the previous two years.

In a more consistent pattern than that seen with gasoline, retail hydrogen prices at the pump have more than doubled since 2021, averaging over $34/kg in October 2024. This sustained increase is due to increased costs of fuel production, fuel transportation, delivery, and retailing. As hydrogen fuel cell vehicles are a key part of California's ZEV goals, the CEC will continue to work toward ensuring fuel cell drivers can conveniently refuel their vehicles and supporting cost-reduction opportunities.

Building Electrification Trends

California continues to position itself in achieving 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.[23] Fulfilling these goals sets the pace for the state's residential and commercial sectors in achieving their 2030 and 2045 GHG emission mandates required by Senate Bill 32 (Pavley, Chapter 249, Statutes of 2016), Assembly Bill 3232 (Friedman, Chapter 373, Statutes of 2018), and Assembly Bill 1279 (Muratsuchi, Chapter 337, Statutes of 2022).[24]

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22 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

23 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.

24 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.

Officially launched in May 2024, the CEC joined a public-private partnership with the Building Decarbonization Coalition called the California Heat Pump Coalition.[25] The CEC awarded a three-year $9 million contract authorized by Assembly Bill 102 (Ting, Chapter 38, Budget Act of 2023) 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 market actors, working to accelerate California's achievement of the six million heat pump goal. The partnership builds on a previous memorandum of understanding 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, where more than 1.5 million heat pumps are estimated to have been installed as of 2023 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 both existing homes and for all-electric new construction in low-income communities.

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 (Ting, Chapter 38, Statutes of 2023), and an additional $40 million as part of AB 157 (Gabriel, Chapter 994, Statutes of 2024).[26] 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

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25 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.

26 CPUC. Decision 23-02-005. https://docs.cpuc.ca.gov/PublishedDocs/Published/G000/M501/K931/501931113.PDF.

program.[27] 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 the ongoing need for financial support for affordable and market-rate projects to ensure lasting heat pump adoption.

Furthermore, 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 Assembly Bill 179 (Ting, Chapter 796, Statutes of 2022).[28] 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 Department of Energy to augment state EBD funds with federal funds from the Home Energy Rebates Programs component of the Inflation Reduction Act. In total, $567.2 million in state and federal funding would be available for the Statewide Direct Install program if approved. 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 putting the state on a better trajectory to reduce greenhouse gas emissions from buildings in an equitable manner, sustained funding and private investment will be required to achieve the Governor's climate goal of installing 6 million heat pumps by 2030.

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27 CPUC. 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.

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

Lastly, the federally funded Inflation Reduction Act will support both the Home Efficiency Rebates Program and the High Efficiency Electric Home Rebate Act Program in the state. 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 will 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.[29]

Upcoming zero-nitrogen oxides (NOx) and zero-greenhouse gas (GHG) emission appliance standards for space and water heaters 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.[30] 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 (Btus) 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.[31] The district has an initial proposal to amend Rules 1111 and 1121, which will affect space and water heaters, and expects a board vote at the end of 2024.[32] The SCAQMD has

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29 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.

30 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.

31 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.

32 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 August 20, 2024.

stricter standards than the BAAQMD, where the appliance 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 appliance 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.[33] 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.[34] 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-emission appliance standards for space and water heater for the California Energy Demand Forecast and showed significant energy impacts. CARB staff have not finalized the regulatory proposal for zero-emission appliance standards and expect to bring them for a board vote in 2025.

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.[35] 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

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33 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.

34 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.

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

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 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. Staff members are considering when and how to account for these large loads in the forecast process.

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, creating deviations from previous energy consumption trends. 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 their service territory comes from data centers. SCE reported load growth from data centers over the next five years for their 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.

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 ZEV forklift regulation, beginning in 2026, mandates that most new forklifts sold be zero-emission and existing forklifts be replaced after 13 years. This regulation would increase the number of electric forklifts given the older age of the current forklift fleet. It can also create the challenge of building adequate charging stations for a new forklift fleet that needs to operate around the clock during processing season, especially when there remains little capacity to accommodate additional demand.

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 inform 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

There is uncertainty surrounding the role of hydrogen in the state's energy future. This is due to unknowns about the infrastructure build out to support grid-connected hydrogen production, unknowns on the potential for off-grid production, and uncertainty in use cases for hydrogen. For example, the light-duty fuel cell electric vehicle market has remained a very small portion of the total ZEV market, reaching a record low 0.12 percent of ZEV sales year-to-date as of Q3 2024.[36] As a result of the above factors, there is a similarly high level of uncertainty in forecasting electricity demand for hydrogen production, especially via grid-connected electrolysis.

At the May 16, 2024, IEPR Commissioner Workshop on Electricity Load Growth areas, presenters offered different forecasts (for grid and self-generation resources) that estimate that by 2030, demand and usage from electrolysis will be about 1.5 GW capacity and 5,000

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36 For example, CEC ZEV Statistics analysis shows that LD fuel cell electric vehicles represent less than 0.12% of all new ZEVs sold in 2024 as of Q3. This is the lowest proportion of ZEV sales since 2015, when fewer than 200 total LD fuel cell electric vehicles had been sold in the state. For more information, see the CEC's Zero-Emission Vehicle Statistics page. https://www.energy.ca.gov/data-reports/energy-almanac/zero-emission-vehicle-and-infrastructure-statistics-collection/new-zev.

GWh annually at 50-percent capacity factor.[37] However, estimates then diverge significantly in the later forecast period, depending on the extent of hydrogen across various economic activities. The estimates range from 9.5 GW to 79 GW in 2050. Past CEC estimates indicate about 3 GW capacity need in 2050.

In the Senate Bill 100 process, staff have put forward a new framework that will be useful for consideration of electricity system impacts associated with electrolysis. During the August 7, 2024, staff Webinar on Demand Scenarios for Senate Bill 100, staff presented a framework that would provide varying degrees of flexibility for electrolytic production of hydrogen.[38] Results are expected as part of the SB 100 report, and the framework will be useful for better assessment of hydrogen's role in the state's energy system, including future IEPR Forecasts.

Hydrogen vehicles are currently included in LD and MDHD transportation models, although the LD sector has seen a significant decline in hydrogen-powered ZEV sales for 2024. Sales of hydrogen-powered LD ZEVs were already a very small portion of total ZEV sales. The medium- and heavy-duty sector has seen the introduction of hydrogen-powered vehicles, and the forecast anticipates some adoption. For example, certain public transit and port operation entities have already begun increasing the share of hydrogen-powered ZEVs in their fleets. However, the forecast does not currently model electricity demand necessary to satisfy hydrogen demand.

Staff will continue to monitor the hydrogen market for trends, including developments in the state's Alliance for Renewable Clean Hydrogen Energy Systems, which received a $1.2 billion grant from the federal government to develop a hydrogen production framework for the western region.[39] 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 electric vehicles will be critical for the medium- and heavy-duty sector to switch to these ZEVs in place of battery-electric ZEVs. 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.

37 See Materials from the May 16, 2024, IEPR workshop on Electricity Load Growth Areas for discussions of hydrogen. https://www.energy.ca.gov/event/workshop/2024-05/iepr-commissioner-workshop-electricity-load-growth-areas.

38 For more information on the Senate Bill 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.

39 For more information on ARCHES, see the ARCHES website, https://archesh2.org/arches-officially-launches/.

The role of hydrogen in the industrial and agriculture sectors, especially via electrolysis, is similarly uncertain.

Industrial Manufacturing

At the May 16, 2024, IEPR 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 in developing in California need sufficient grid capacity to support operations. As described above, the forecast incorporates economic development projections which inform distribution 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.

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
    - Assessing fuel substitution in the industrial and agricultural sectors, including the potential for hydrogen to assist with state decarbonization goals
    - Developing a probabilistic hourly electricity dataset to support resource planning
    - 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
    - Updating the residential sector end-use model to account for changes in consumption after homes install PV
    - Incorporating of new data sources into EV load shape tools
    - Completing the California Vehicle Survey and integrating the information into the light-duty forecasting model
    - Improved geographic assignment of load for electric vehicles across existing forecast zones and other levels of geography
- *2026 IEPR Update* forecast and beyond
    - 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.[40] This chapter focuses on wave and tidal energy, as directed by Senate Bill 605, and summarizes the findings in the consultant report *Wave and Tidal Energy: Evaluation of Feasibility, Costs, and Benefits*.[41] 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 (SB) 605 (Padilla, Chapter 205, Statutes of 2023) 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.

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40 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.

41 Ibid.

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

Furthermore, the Senate Bill 605 statute requires the CEC, 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 to identify suitable sea space for offshore wave energy and tidal energy projects in state and federal waters considering 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,[42] 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 due to 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 has the potential to provide geographic diversity to complement land-based

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

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 currently procuring resources to meet the requirements of the Renewables Portfolio Standard and using integrated resource planning to meet greenhouse gas emission requirements and Senate Bill 100's policy that requires 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.[43] Wave and tidal energy may be able 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.[44]

Along California's coastline, the estimated wave energy resource potential is 37 gigawatts, generating 140 terawatt hours annually.[45] 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

43 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.* CEC-200-2021. https://efiling.energy.ca.gov/EFiling/GetFile.aspx?tn=237167&DocumentContentId=70349.

44 Ibid.

45 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.

depth. There are many wave energy converter (WEC) technologies, which can be categorized into six main device archetypes:[46]

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

Table 6 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.

Table 6: 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)

46 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.

Device Archetype	Example Technologies or Device Developers	Configuration	Optimal Conditions
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.[47]

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 are easier to maintain but typically generate less electricity than offshore WECs due to the decrease in wave energy as waves come to shore.[48]

Nearshore WECs are deployed 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.[49]

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

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47 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.

48 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.

49 Ibid.

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).[50]

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 from 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.[51]

NREL has estimated that tidal energy resource along California's coastline exceeds 1.8 terawatt-hours (TWh) annually.[52] Similar to wave energy, this resource estimate does not consider technological and environmental barriers which 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:[53]

- Axial-flow turbines
- Crossflow turbines
- Oscillating hydrofoil
- Tidal kite
- Archimedes screw
- Vortex-induced vibration

50 Ibid.

51 Ibid.

52 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, CO. https://www.nrel.gov/docs/fy21osti/78773.pdf.

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

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

Table 7 summarizes the device archetypes, example technologies and developers, device configuration, and optimal conditions for technology deployment.

Table 7: 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
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 2023, 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.[54] 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); marine aquaculture; seabed/seawater mining; desalination; coastal resilience and disaster recovery; maritime transport and logistics; and tourism and recreation

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54 Ibid.

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. 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.[55]

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 varies from technology type/design and location of deployment. These can

55 Ibid.

include habitat alteration, marine life mortality or harm due to collision, entanglement, noise disturbance, electromagnetic fields, and other impacts.

- **Cost competitiveness**: Due to the industry being in its 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 the Renewables Portfolio Standard and Senate Bill 350's required greenhouse gas emissions reduction requirements 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 technical 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.[56]

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56 Kilcher, L., M. Fogarty, and M. Lawson. 2021. *Marine Energy in the United States: An Overview of Opportunities.* https://www.nrel.gov/docs/fy21osti/78773.pdf.

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

- **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 efforts 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 base load 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 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.[57] However, direct engagement with coastal communities and an evaluation of site-specific marine uses is 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.[58] A similar, expanded planning tool for state permitting processes could provide additional information for project planning and development.

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

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

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 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.
- **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 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's surface that is fixed or floating, or one that is resting on the seafloor. There are also smart subsea hubs which 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.[59] 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 to rest on the seafloor with protective equipment to minimize 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 is discussed in the next section titled "Permitting Requirements for Wave and Tidal Energy Projects."

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
- 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 50kV) above the mean high tide line. Other state agencies may have CEQA requirements depending

59 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.

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.[60] The CPUC may run the processes concurrently and may 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 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 or other oversight permitted.[61] 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 is 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.[62] There could be instances where a transmission project does not cross federal land, but a federal permit is still required. For example, a federal

60 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 its 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.

61 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.

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

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, 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.[63] 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 energy resources to colocate 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:[64]

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63 Grantham, K. (2024, July). "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.

64 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

- 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 their 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.[65]
- **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

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.

65 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.[66]

- **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.[67]
- **BOEM**: BOEM 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[68]

66 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.

67 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.

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

- Coastal development permit[69]
- State tidelands lease
- California endangered species incidental take permit
- Land and streambed alteration agreement
- 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 pursuant to 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

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

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. Additionally, some areas of the coastal zone have certified Local Coastal Programs for which local governments have a role in coastal development permitting outside of 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.[70] 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 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 sea floor.
- Introduction of new structures and Fish Aggerating Devices (FAD).

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70 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.

- 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. Additionally, some of the monitoring results from existing wave and tidal energy installations may be applicable to assessing effects in California's marine environment.

The CEC recently published the *Assembly Bill 525 Offshore Wind Energy Strategic Plan*,[71] 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.

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.[72] 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

71 Jones, Melissa, Jim Bartridge, and Lorelei Walker. 2024. *Assembly Bill 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.

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

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 to 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 the IEPR chapter on wave and tidal energy. This report will include considerations that may inform 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, 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. California's future vision for marine energy includes meaningful engagement with coastal communities, indigenous peoples, and stakeholders 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 provide direction and guidance for 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 incentives to support investment in wave and tidal energy technology, such as the development and investments in technology research, demonstration, and deployment. This exploration may include incentives for colocating wave and tidal energy with offshore wind projects as they are developed in California.
- Develop, to the extent possible, clear regulatory processes for deployment of 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 to better assess, avoid, minimize, and mitigate 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

A priori bias correction describes a process for correcting bias exhibited by Global Climate Model projections before they are used as input to a Weather Research and Forecast model.

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. This includes many future updates of building standards, appliance regulations, and new or expanded energy efficiency programs.

Additional achievable fuel substitution (AAFS) refers to 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.

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

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.

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 for 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.

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

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

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.

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

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

A **load modifier** is an add-on to the baseline forecast which may have a different hourly profile. Load modifiers can be used to account for changes in technology, policy, or other trends which are not yet certain but are reasonably expected to occur.

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.

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 its 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 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
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