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DRAFT STAFF REPORT

Analysis of Flexible Demand Appliance Standards: HVAC Thermostats

2026 Flexible Demand Appliance
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California Energy Commission

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PREFACE

On October 14, 2020, the California Energy Commission (CEC) adopted an order instituting rulemaking (OIR) for flexible demand technologies for appliances to consider standards, test procedures, labeling requirements, and other flexible demand measures. The OIR also authorizes the CEC to investigate and adopt, if appropriate, additional priority measures as determined by the lead commissioner.

On November 19, 2020, the CEC released a notice for a lead commissioner workshop to receive public input on the approach to develop "Flexible Demand Appliance Standards."

On December 9, 2020, the CEC released a staff paper on flexible demand standards for public comment.

On December 14, 2020, the CEC held a lead commissioner workshop to provide interested parties the opportunity to inform the CEC about the product, market, and industry characteristics of the appliances identified in the OIR, as well as additional appliances.

On September 1, 2021, the CEC released a request for information to seek proposals for standards, test procedures, labeling requirements, and other measures to improve the flexible demand of electricity for specified appliances.

On October 18, 2023, the CEC adopted regulations at its business meeting for flexible demand appliance standards, including specific standards for pool controls.

This staff report proposes standards for HVAC thermostats, a subset of thermostats controlling electric space-conditioning appliances, and describes the basis for such standards. The report includes an analysis of cost-effectiveness, feasibility, and statewide benefits of the proposed standards per the requirements of Section 25402(e) of the Public Resources Code.

ABSTRACT

Senate Bill 49 (Skinner, Chapter 697, Statutes of 2019) authorizes the CEC to adopt and periodically update standards for appliances to facilitate the deployment of flexible demand technologies that enable appliance operations to be scheduled, shifted, or curtailed to improve grid reliability and/or to reduce emissions of greenhouse gases (GHG) associated with electricity generation (Public Resources Code, Section 25402(e)). This report contains staff's proposed flexible demand appliance standards for thermostats controlling electric space-conditioning systems. The report contains staff analysis of the cost-effectiveness and feasibility of the proposed standards, as well as discussion of their projected statewide load-shift potential, avoided GHG emissions, related environmental impacts, and benefits.

The proposed additions to Title 20 of the California Code of Regulations set the following proposed standards for HVAC thermostats, a subset of thermostats controlling electric space-conditioning systems:

- Automatic scheduling capabilities for heating and cooling loads based on the cost of electricity and grid conditions
- Connectivity requirements that enable access to localized grid condition data and keep the on-device clocks accurate
- Memory requirements that ensure thermostat access to grid condition data
- Minimum consumer preferences and opt-in/opt-out settings that flexible demand schedules must follow
- User interface requirements that keep consumers informed and in control of flexible demand capabilities
- Open communication standards for participation in demand response programs
- Cybersecurity standards to protect consumers using flexible demand appliances
- Requirements to make sure updates do not degrade flexible demand capabilities
- Marking requirements
- Test procedures for devices to demonstrate compliance.

The proposed standards are cost-effective and feasible. The incremental retail cost of compliant HVAC thermostats would increase the cost to the consumer by around $12. This is a one-time expense with no annual ongoing costs. Staff analysis demonstrates that by 2037, assuming complete stock turnover, compliant HVAC thermostats would:

- Avoid GHG emissions associated with electricity production by 50,496 metric tons annually,
- Avoid 780 MWh of electricity consumption during summer peak period, and
- Provide consumers with estimated electricity bill savings of $97 over a 10-year lifetime by allowing the device to automatically shift the time of electricity use.

Keywords: Senate Bill 49, flexible demand technologies, flexible demand appliances, thermostats for electric space-conditioning appliances, greenhouse gas emissions, cybersecurity, consumer consent, equity

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EXECUTIVE SUMMARY

Overview

This report supports the California Energy Commission's (CEC) rulemaking authority under Senate Bill (SB) 49. The report, which contains proposed regulatory language, details feasible performance standards for heating, ventilation, and air conditioning (HVAC) thermostats, a subset of thermostats that control electric heating, cooling, or both systems. The standards reduce greenhouse gas emissions and increase California's electric grid reliability. HVAC thermostats under the scope of these standards currently exist in many buildings and can shift energy use by using schedules and internet connections. Since electric heating and cooling use a lot of grid energy, enabling flexible control of HVAC thermostats can help lower pollution and make the power grid more reliable. The proposed standards require in-scope HVAC thermostats to be certified by the CEC as compliant with the standard. The proposed effective date for this flexible demand appliance standard is January 1, 2028, one year after adoption by the CEC.

Scope

Table ES-1 shows examples of the thermostats for electric space-conditioning appliances that are in-scope or out-of-scope of the proposed regulation.

Table ES-1: In-Scope and Out-of-Scope Thermostats for Electric Space-Conditioning Appliances

In-Scope Devices ("HVAC thermostats")	Out-of-Scope Devices
Low-voltage thermostats	Millivolt thermostats
Proprietary thermostats for packaged systems and split systems	Building management system temperature controls
	Standalone temperature sensors
	Line voltage thermostats that serve devices other than portable corded electric resistance heaters
	Proprietary thermostat controllers that serve devices other than packaged system, split single-zone, and multizones system
	Portable corded electric resistance heaters

Source: California Energy Commission

Requirements for Compliance

Staff proposes minimum load-shift standards for HVAC thermostats (**Table ES-1**). These standards require the following capabilities:

1. Network connectivity ensures HVAC thermostats have the capability of receiving greenhouse gas (GHG) and electricity price data from the CEC's Market Informed Demand Automation Server (MIDAS) system. MIDAS is an online system that provides electricity prices, electricity-related GHG emissions, Flex Alerts, and other CEC-approved signals that thermostats can use to adjust operation based on grid conditions.
2. Integral memory enables HVAC thermostats to store energy price and emissions information, operating schedules, and the software needed to manage load shifting directly on the device.
3. Autoflex operating mode ensures HVAC thermostats can automatically plan how and when cooling and heating occur based on GHG levels and electricity prices.
4. User interface and transparency requirements ensure HVAC thermostats clearly display autoflex operating mode, GHG levels, electricity prices, and demand response events to help consumers make decisions about when to use energy.
5. Clock and persistence of settings requirements ensure HVAC thermostats keep the correct local time, even during a power outage.
6. Ability to opt-in/out ensures that consumers stay in control of their comfort.
7. Cybersecurity requirements ensure that HVAC thermostats meet consumer protection, consent, and California Code of Regulations, Title 20, Section 1692(c) requirements.
8. The Compliance Test Procedure provides the performance testing to verify required functionality.
9. Firmware and Ongoing Compliance ensures future software changes do not remove flexible demand capabilities.
10. Marking Requirements ensure clear product identification for enforcement and provide consumers with information on how to use load flexibility to reduce costs and emissions.

These requirements work together to give as many Californians as possible the ability to optimize their electric heating and cooling usage. Autoflex works by using consumer-input preferences, like set point ranges, and combines them with data on the state of the grid to create a set point schedule for the thermostat. Depending on the consumer's goals of saving and settings, autoflex can use data from their exact electricity bill and regional greenhouse gas emissions. The proposed standards leave the method of creating autoflex operating schedules from the signals up to manufacturers and other innovators, such as aggregators, utilities, and automation service providers

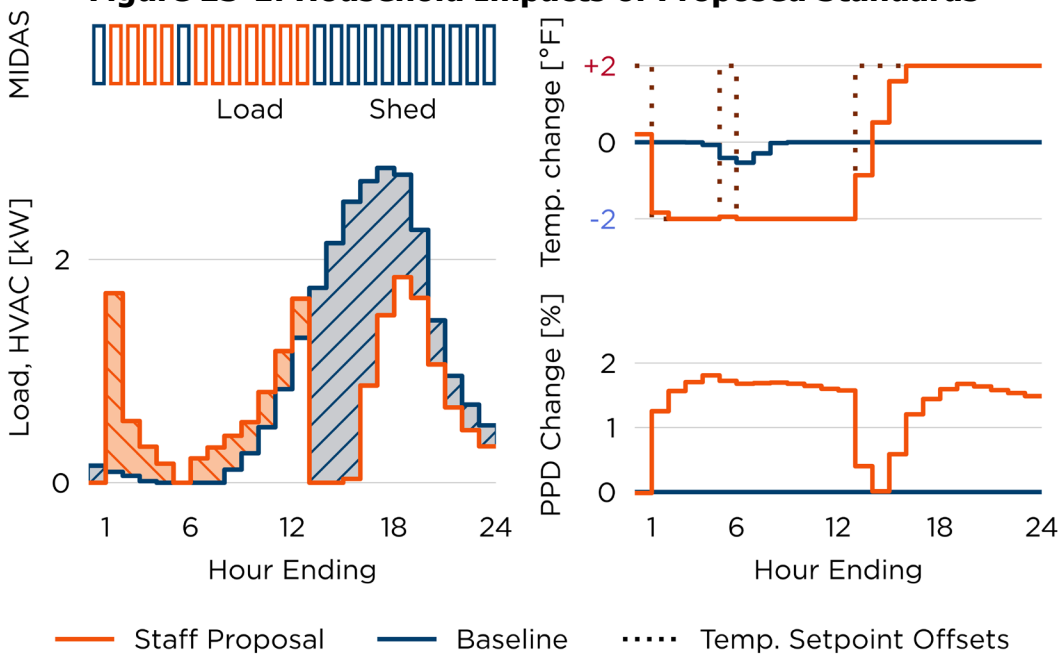
The proposed standards add load flexibility functions to thermostats without keeping people from managing their homes to their liking. The consumer may opt out of the schedule for the day or turn off autoflex completely. At all times the consumer remains in full control of their thermostat and can change the schedule or opt out at any time.

Heating and cooling usage depends heavily on individual preferences, behavior, and home insulation. The proposed standards add load flexibility functions to thermostats without

keeping people from managing their homes' comfort. **Figure ES-1** shows staff's analysis of a simple load-shift strategy of increasing or decreasing set points by 2°F based on grid conditions. Staff's analysis found that this simple approach to complying with the proposed standards enables load shifting without compromising occupant comfort. Staff expect manufacturers and aggregators to innovate further to shift load with nearly indiscernible changes to comfort.

The proposed standards provide a way to increase comfort in older homes while reducing electricity bills. Justice communities have more homes with less efficient space-conditioning appliances. These homes use more power to reach the same comfort as homes with higher efficiency equipment and better insulation. The proposed standards require grid condition data to be preloaded into the thermostat, which can be used without an internet connection. Residents of justice communities are more likely to live near polluting energy plants that operate when the grid is strained. By shifting space-conditioning usage away from peak periods, the proposed standards reduce the operation of these plants, improving air quality.

Figure ES-1: Household Impacts of Proposed Standards



Modeled impacts of a load shift based on price and GHG signals on an average summer day (July 28th) in Fresno (CZ13) to a prototype home's HVAC load, indoor air temperature, and predicted percentage dissatisfied (PPD). Additional details are provided in Appendix D.

Source: California Energy Commission.

Economic and Energy Impact

CEC staff evaluated three autoflex operating schedule modes that favor different elements: low electricity price, GHG avoidance, and a balance of these two.

- Staff Proposal: created autoflex operating schedules using both price and GHG data

- Alternative 1: created autoflex operating schedules using only electricity prices
- Alternative 2: created autoflex operating schedules using only GHG emissions data

While each mode demonstrated technical feasibility, none met the legislative goals as comprehensively as mode 3, which is the staff proposal. Modes 1 and 2 are Alternatives 1 and 2 respectively.

Table ES-2 summarizes the impact of the proposed standard against the two alternatives, comparing life-cycle benefits, one-hour load shifting potential, and annual avoided greenhouse gas emissions in 2037.

Table ES-2: Benefits of HVAC Thermostat Staff Proposal and Alternatives

Proposal	Per Unit Total Life-Cycle Benefit (In $2026)[a]	Statewide Energy Shifted During 8 p.m. Hour Daily, 2037 (MWh)[b]	Statewide Avoided GHG Emissions in 2037 (Thousand metric tons CO_2e) and Monetary Benefit (In $2026)[c]
Staff Proposal: Autoflex Using Combined Highly Dynamic Electricity Prices and Marginal GHG Emissions Rates	$97	780	50 / $16M
Alternative 1: Autoflex Using Highly Dynamic Electricity Prices	$86	780	39 / $12M
Alternative 2: Autoflex Using GHG Marginal Emission Rates	$65	780	44 / $14M

Source: California Energy Commission

Notes:

a. See Appendix A, Table A-30, "Costs and Benefits Considered for Cost-Effectiveness per HVAC Controller," Staff Proposal, Alternative 1, and Alternative 2 rows, "Total Life-Cycle Benefit" column.
b. See Appendix A, Table A-22, "Estimated HVAC Thermostats Statewide Load Shift from Peak Hour," Staff Proposal, Alternative 1, and Alternative 2 rows, "Load Shifted During 8 p.m. Hour for a Single Summer Weekday 8/7/2037" column.
c. See Appendix A, Table A-21, "HVAC Thermostat Staff Proposal and Alternatives," "Annual GHG Avoided" row and "Year 10 (2037)" columns for the Staff Proposal, Alternative 1, and Alternative 2

CHAPTER 1: INTRODUCTION

Prologue to Flexible Demand Appliance Standards

In August 2020, as firefighters battled wildfires burning more than a million acres across the state, Governor Gavin Newsom tweeted, "If you don't believe in climate change, come to California."[1] Climate change is an active threat impacting California's 40 million residents and its unique and varied environment. The severity of the impacts — more regular and severe wildfires, heat waves, ocean acidification, reduced or shifting habitats, and worsening air quality — will continue to grow unless global GHG emissions are dramatically reduced and the state's economy is decarbonized.

Flexible demand technologies enable appliances to schedule, shift, or curtail associated electrical demand. Senate Bill 49 (Skinner, Chapter 697, Statutes of 2019) authorizes the California Energy Commission (CEC) to adopt flexible demand appliance standards to improve grid reliability and minimize greenhouse gas emissions while maintaining cost-effectiveness for California consumers.[2] SB 49 requires the development and implementation of state standards that promote the use of flexible demand technologies in appliances and encourage consumer participation in load flexibility programs. Flexible demand technologies enable appliances to schedule, shift, or curtail electrical demand.

Figure 1-1 shows an advertisement for California's Flex Your Power Program that illustrates demand flexibility by asking California electricity consumers to reduce the use of electrical appliances during peak demand hours between 4 and 9 p.m. Shifting the use of electricity away from peak demand hours lowers GHG emissions caused by fossil fuel energy production. A Flex Your Power Alert ("Flex Alert") is usually issued in the summer when extremely hot weather drives up electricity use, making the power supply limited or scarce. It occurs during the evening peak periods when renewable energy resources such as solar power generation are offline, and electricity consumers are returning home from work and switching on their electric appliances. Flex Alerts depend on consumers to change their electricity usage and do not necessarily provide direct benefits to the consumers beyond reducing the chance of an outage.

These standards assist Californians by ensuring that HVAC thermostats sold in the state include features that enable appliance operations to be scheduled, shifted, or curtailed directly by either the end user or through a third party with the customer's consent. The standards also enhance the cybersecurity of internet-connected appliances that are subject to the proposed standards.

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1 Governor Gavin Newsom. 2020. Remarks August 22, 2020, https://twitter.com/gavinnewsom/status/1297364484940431360.

2 Skinner. 2019. Senate Bill 49, https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201920200SB49.

Figure 1-1: Flex Your Power Advertisement



Source: Energy Upgrade California[3]

Flexible Demand Within an Electrical Grid in Transition

California has set ambitious but attainable goals to transition to 100 percent renewable and zero-carbon electricity by 2045. The proliferation of clean energy resources in California has led to new electricity grid operating conditions. Many renewable energy sources, such as wind and solar, are intermittent, meaning that they are affected by seasonal variations and may be available only at certain, easily predictable times of the day.

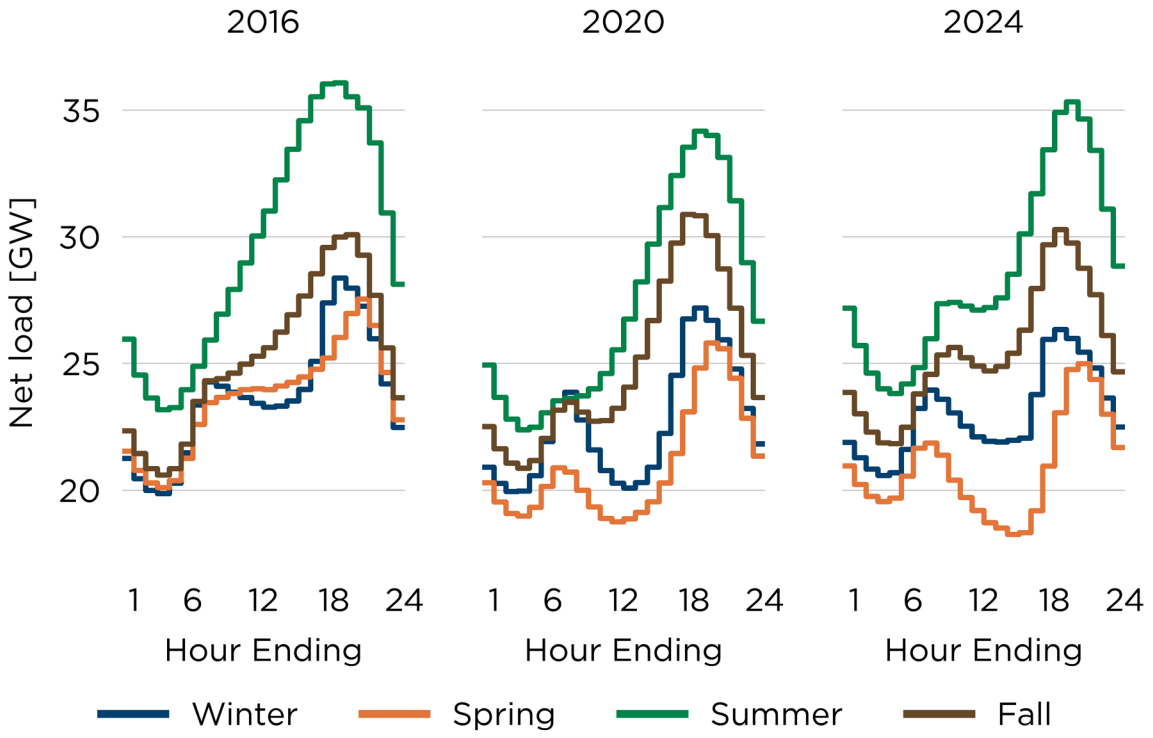
Consumers benefit from the transition to a decarbonized economy when they can make informed choices and align their use of energy to the availability of low- and zero-carbon resources. Consumers adjusting when and how they use thermostats for electric space-conditioning appliances can save money on their utility bills and maximize clean energy use while avoiding high emissions generation from fossil fuels and costs associated with electrical grid upgrades. Shifting load away from peak periods also prevents the usage of peaker plants, which are traditionally fossil-fueled power generators often built in or around justice communities.

Figure 1-2 illustrates how electricity Net Load has evolved as California has introduced more renewable generation. The lowest daily net loads (gross demand minus solar and wind) have shifted from morning to midday in recent years because of the growth of behind-the-meter

3 Energy Upgrade California. "What Is a Flex Alert?" https://energyupgradeca.org/flex-alert-v4.

photovoltaics (PV) that can supply power directly to end users and avoid using grid-supplied power, though other factors are contributors.[4] You can most easily see this lower midday net load in the 2020 and 2024 figures. This lower net load contributes to the curtailment of renewable generation typically during the spring when electrical demand is low and solar or wind production is high. In fact, curtailment of clean energy sources is becoming increasingly common, with six equivalent days of 100 percent clean electricity in 2022 rising to fifty-one equivalent days in 2024.[5] Grid-scale batteries are absorbing some of electricity that would be curtailed, but there is enough supply that California is still curtailing substantial amounts of electricity. Nonsolar resources, increasingly batteries, serve the sharp increases in electricity demand during the morning and evening periods. The most challenging operating hours occur in late summer between 7 and 8 p.m. when the sun has set and the load from cooling remains high.

Figure 1-2: Changes in Seasonal Net Load in California From 2016 to 2024



Source: California Energy Commission, data from California Independent System Operator Open Access Same-Time Information System (OASIS)

Figure 1-3 displays forecasted GHG emissions attributable to California's electricity generation as they vary by time of day and season for 2030. Green shaded areas represent times with

4 Rothleder, Mark. March 16, 2022. "Our Evolving Grid." California ISO, https://www.caiso.com/about/Pages/Blog/Posts/Our-Evolving-Grid.aspx.

5 California Energy Commission. "Tracking Progress Toward 100% Clean Energy," https://www.energy.ca.gov/data-reports/clean-energy-serving-california/estimated-california-iso-clean-energy-days. Accessed September 26, 2025.

low GHG emissions. Low GHG emissions occur when renewable energy generation is abundant relative to electricity demand. Red shaded areas represent times when GHG emission intensities are relatively higher. The arrows indicate how load may be shifted from early morning into the day and from evening into the afternoon to better align appliance load with times of low-carbon electricity generation.

For managing appliance load, CEC staff examined intentional scheduling, delaying, and curtailing. An appliance can be scheduled to operate during low-carbon periods, thereby relieving anticipated grid demand and avoiding periods of intense GHG emissions. Appliances can also shift load through use of a delay timer, which provides less flexibility than scheduling but can be incorporated into electromechanical equipment. Further, an appliance can curtail usage altogether in response to a request during a Flex Alert or unexpected generation shortfall. Other approaches suggested by interested parties, with supporting analysis, may be considered for inclusion in regulations under the authority provided in SB 49.

Figure 1-3: Electricity GHG Emission Intensity by Season in 2030 ($MTCO_2e/MWh$)

Hour	Winter			Spring			Summer			Fall		
0	0.37	0.35	0.34	0.26	0.14	0.12	0.15	0.32	0.35	0.36	0.37	0.35
1	0.37	0.36	0.34	0.25	0.16	0.13	0.17	0.32	0.37	0.37	0.37	0.36
2	0.38	0.36	0.34	0.26	0.16	0.15	0.19	0.33	0.38	0.38	0.38	0.36
3	0.38	0.36	0.34	0.26	0.17	0.16	0.21	0.33	0.38	0.38	0.38	0.36
4	0.37	0.36	0.34	0.25	0.17	0.16	0.21	0.33	0.37	0.37	0.37	0.36
5	0.37	0.35	0.34	0.24	0.14	0.14	0.20	0.33	0.37	0.36	0.36	0.35
6	0.35	0.33	0.32	0.24	0.16	0.12	0.13	0.30	0.35	0.36	0.35	0.34
7	0.34	0.32	0.28	0.12	0.05	0.04	0.04	0.12	0.15	0.27	0.28	0.31
8	0.22	0.20	0.10	0.04	0.03	0.03	0.03	0.05	0.06	0.07	0.07	0.10
9	0.08	0.08	0.05	0.03	0.03	0.03	0.03	0.05	0.05	0.05	0.05	0.05
10	0.07	0.06	0.04	0.03	0.03	0.03	0.03	0.05	0.05	0.05	0.04	0.05
11	0.07	0.06	0.04	0.03	0.03	0.03	0.03	0.05	0.05	0.05	0.04	0.05
12	0.07	0.06	0.04	0.03	0.03	0.03	0.03	0.05	0.05	0.05	0.04	0.05
13	0.07	0.06	0.04	0.03	0.03	0.03	0.03	0.05	0.05	0.06	0.05	0.05
14	0.08	0.07	0.04	0.03	0.03	0.03	0.04	0.06	0.07	0.08	0.06	0.06
15	0.29	0.23	0.06	0.04	0.04	0.04	0.04	0.09	0.12	0.21	0.20	0.23
16	0.34	0.33	0.28	0.14	0.05	0.05	0.05	0.11	0.18	0.27	0.30	0.32
17	0.32	0.31	0.30	0.20	0.09	0.08	0.08	0.16	0.23	0.28	0.30	0.31
18	0.31	0.30	0.28	0.19	0.13	0.09	0.13	0.24	0.30	0.31	0.29	0.30
19	0.31	0.29	0.26	0.18	0.13	0.13	0.18	0.28	0.31	0.31	0.29	0.30
20	0.32	0.30	0.27	0.17	0.13	0.12	0.18	0.29	0.31	0.32	0.31	0.31
21	0.33	0.31	0.29	0.18	0.11	0.09	0.15	0.28	0.32	0.33	0.33	0.32
22	0.34	0.33	0.31	0.21	0.11	0.09	0.14	0.30	0.33	0.35	0.35	0.34
23	0.36	0.34	0.32	0.23	0.13	0.12	0.14	0.32	0.34	0.36	0.36	0.35

Source: California Energy Commission

Time-of-Use Pricing and Automation Provide Benefits to Consumers

"Time-of-use (TOU) rates," as used in this report, broadly refers to rates consumers pay for electricity that are fixed months ahead of time but are different by time of day, day of the week, and season. TOU rates change price two or more times throughout the day to encourage consumers to use electricity when demand is lower. This technology helps prevent outages, reduce strain on the electric grid, and support electric grid reliability. Newer, more granular approaches to time-varying electricity prices, including the day-ahead hourly rates set to take effect under California's Load Management Standards,[6] provide greater opportunities for cost savings than fixed schedule shifting.

Advanced metering infrastructure (AMI) allows utilities to collect consumer energy usage in real time. AMI records the quantity and time of electrical use at the electric meter and communicates wirelessly to the utility. Both TOU rates and AMI are widely available to consumers in California.[7]

Consumers can shift electricity load to maximize bill savings and health benefits resulting from reduced pollution, provided these price signals are received.[8] **Figure 1-4** shows the alignment of a typical daily TOU rate schedule and marginal GHG emission rate. The TOU rate signals to the consumer when to use and when not to use energy.[9] The GHG marginal emission rate can similarly inform the consumer when it is best to use energy, typically in the middle of the day.

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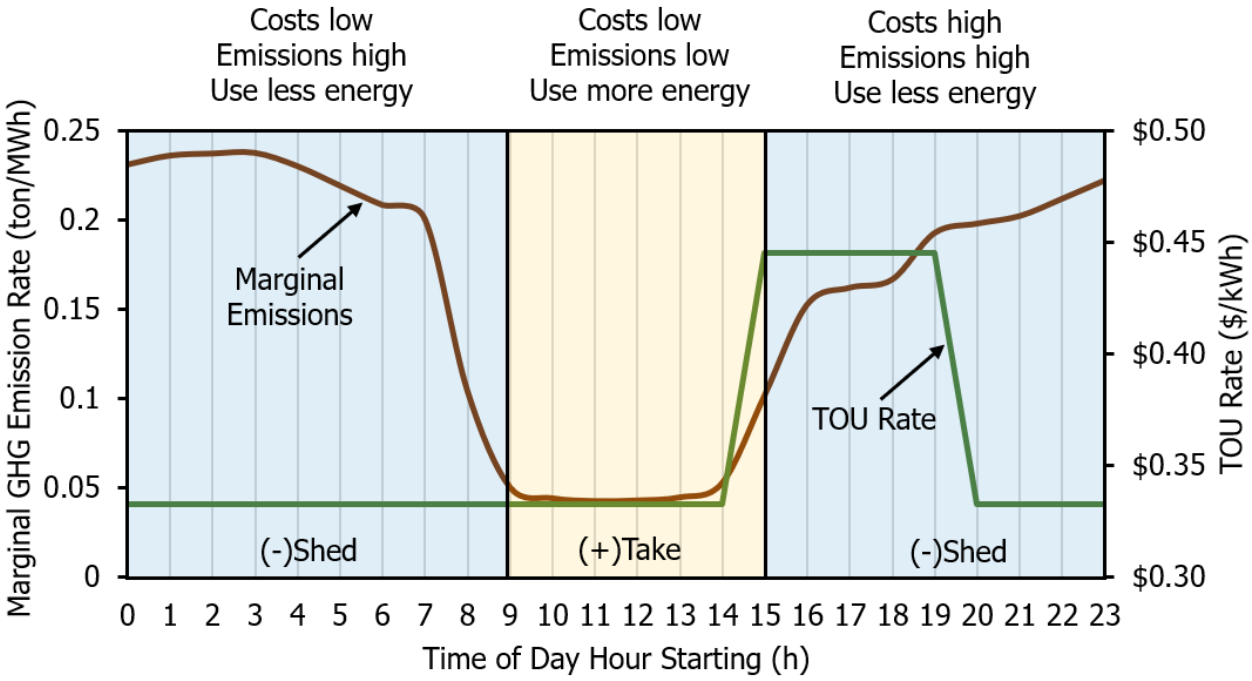
6 Load Management Standards. California Code or Regulations, Title 20, Division 2, Chapter 4, Article 5, https://govt.westlaw.com/calregs/Browse/Home/California/CaliforniaCodeofRegulations?guid=ID6B950105CCE11EC9220000D3A7C4BC3&originationContext=documenttoc&transitionType=Default&contextData=(sc.Default).

7 Herter, Karen and Gavin Situ, P.E. 2021. *Analysis of Potential Amendments to the Load Management Standards: Load Management Rulemaking*. Docket Number 21-OIR-03. California Energy Commission. Publication Number CEC-400-2021-003-SF, https://efiling.energy.ca.gov/GetDocument.aspx?tn=241067&DocumentContentId=74898.

8 Neenan, Bernard and Jiyong Eom (Electric Power Research Institute). 2008. *Price Elasticity of Demand for Electricity: A Primer and Synthesis*. Electric Power Research Institute. Available at https://www.epri.com/research/products/1016264.

9 SMUD. 2023. "Sacramento Municipal Utility District SmartPricing Options Pilot Program." Available at http://smartenergycc.org/wp-content/uploads/2016/03/SMUD-2016-SGCC-Customer-Engagement-Case-Study-3-16-16.pdf.

Figure 1-4: Daily GHG and Bill Savings Through Load Scheduling



Source: California Energy Commission

Automation

In recent years, manufacturers have introduced automation to a range of appliances in response to customer preferences and to provide greater usefulness.[10] Automation of HVAC thermostats provides consumers with a way to save money and reduce GHG emissions by automatically responding to electricity prices, GHG emission signals, or both. For flexible demand applications, automation enables an HVAC thermostat to use these signals to adjust the timing or operation while maintaining the consumer's desired comfort settings. The use of this automated flexible demand functionality results from consumer action and is subject to the consumer's consent, including the consumer's ability to enable, disable, or otherwise control the applicable flexible demand functionality. This automated response is the basis for autoflex, in which the HVAC thermostat automatically shifts or modulates its operation in response to applicable grid, price, or GHG conditions without requiring the consumer to manually adjust the HVAC thermostat set points.

The CEC's Market Informed Demand Automation Server (MIDAS) contains Flex Alerts in addition to electric utility rates and rates of marginal GHG emissions for the state's large

10 Association of Home Appliance Manufacturers (AHAM). 2016. "Connectivity: New Levels of Convenience," https://www.aham.org/AHAM/Innovation/Connectivity/AHAM/Innovation/Connectivity.aspx?hkey=12ff39f3-ebad-4594-959b-3812ffdfff93.

utilities in a machine-readable format.[11] MIDAS provides a platform for customers and third-party service providers to obtain information to achieve price-based or GHG-based shifts of electric load. The MIDAS database provides hourly, location-based predictions of grid conditions through these signals, allowing HVAC thermostats to optimize their operation schedules on a day-ahead basis. The specific communications and pathways between MIDAS, utilities, automation service providers, consumers, and appliances will vary as technologies and policies evolve. Refer to Figure 2.1: Schematic of the MIDAS Ecosystem for more information.

Senate Bill 49 Legislative Criteria

SB 49 (Skinner, Chapter 697, Statutes of 2019) authorizes the CEC to adopt flexible demand appliance standards to improve grid reliability and minimize greenhouse gas emissions. SB 49 expands upon existing law that authorizes the CEC to adopt energy efficiency standards for reducing "the wasteful, uneconomic, inefficient, or unnecessary consumption of energy."[12] SB 49 requires the development of state standards that promote the use of flexible demand technologies and encourage consumer participation in load flexibility programs. The flexible demand standards are required to "enable appliance operations to be scheduled, shifted, or curtailed to enhance grid reliability, reduce emissions of greenhouse gases associated with energy generation, or both enhancement and reduction."

SB 49 also directs the CEC to proactively consult with the California Public Utilities Commission (CPUC) and load-serving entities to "better align the flexible demand standards with demand response programs administered by the state and load-serving entities and to incentivize the deployment of flexible demand appliances."

In determining cost-effectiveness, SB 49 specifies that the CEC may consider factors such as the value of the energy shifted, the effect on the efficacy of the appliance for the consumer, and the life-cycle cost to the consumer to comply with the standards. The CEC may consider GHG emissions when determining the cost-effectiveness of an appliance with flexible demand capability. The CEC considers other relevant factors, including the effect of proposed standards on justice communities, housing costs, the statewide costs and benefits over the lifetime of the standard, the economic impact on California businesses, and the costs and benefits associated with alternative approaches considered.

The analyses in **Chapter 6,** covering economic, energy, and environmental impacts, fulfill these statutory requirements by quantifying the costs, benefits, and performance implications of the proposed thermostat standards in accordance with SB 49 criteria. **Chapter 6** is organized into three major sections:

- The Economic Impacts section evaluates incremental costs, bill savings, statewide economic effects, and cost-effectiveness;

11 California Energy Commission (CEC). 2023. "Market Informed Demand Automation Server (MIDAS)," https://www.energy.ca.gov/proceedings/energy-commission-proceedings/load-management-rulemaking/market-informed-demand.

12 Skinner. 2019. Senate Bill 49.

- The Energy Impacts section assesses load-shifting potential, contributions to grid reliability, and renewable integration; and
- The Environmental Impacts section analyzes avoided greenhouse gas emissions, air quality improvements, and public health benefits.

SB 49 provides the CEC with the authority to establish regulations to enforce violations of flexible demand appliance standards (FDAS). This authority includes a penalty not to exceed $2,500 for each violation.

California Energy Policy

The Warren-Alquist Act establishes the CEC as California's primary energy policy and planning agency.[13] The act mandates that the CEC reduce the wasteful and inefficient consumption of energy and water in the state. California has enacted numerous pieces of legislation to guide local and state policy toward a clean energy future. This section summarizes the major pieces of legislation and executive direction to reduce GHG emissions across the economy with a particular focus on buildings.

Decarbonization of electricity used by appliances is the central focus of the CEC's implementation of the FDAS as conceived under SB 49. The CEC's *2023 Integrated Energy Policy Report* (*IEPR*) addressed the importance of load flexibility in the state's decarbonization efforts, stating:

> "Rapid and sustained deployment of millions of distributed energy resources (DERs), including flexible loads like EV chargers and heat pumps, will be needed to meet the state's goals for decarbonizing transportation and buildings."[14]

The *2023 IEPR* also emphasizes load flexibility as a critical strategy for reducing the need for new energy infrastructure and supporting electrical grid reliability. Load flexibility is the practice of adjusting load (or energy usage) to match the supply of electricity. Electricity customers with smart devices can automatically shift their energy usage to when electricity is cheaper and clean, and use less energy when the grid is under stress or running polluting power plants

These specific policy drivers also exist in the broader context of legislative and executive support for aggressive and effective climate legislation. Assembly Bill 1279, described below, is one of 40 bills signed during the 2021–2022 legislative session that work toward achieving California's climate goals.[15]

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13 CEC 2025. California Public Resources Code Section 25000 et seq, https://leginfo.legislature.ca.gov/faces/codes_displayexpandedbranch.xhtml?tocCode=PRC&division=15.&title=&part=&chapter=&article=&nodetreepath=35.

14 Bailey, Stephanie, Jennifer Campagna, Mathew Cooper, Quentin Gee, Heidi Javanbakht, and Ben Wender. February 2024. *2023 Integrated Energy Policy Report*, page 1. CEC, https://www.energy.ca.gov/data-reports/reports/integrated-energy-policy-report-iepr/2023-integrated-energy-policy-report.

15 Governor Gavin Newsom. September 16, 2022. "Governor Newsom Signs Sweeping Climate Measures, Ushering in New Era of World-Leading Climate Action," https://www.gov.ca.gov/2022/09/16/governor-newsom-signs-sweeping-climate-measures-ushering-in-new-era-of-world-leading-climate-action/.

Load Management Standards

The Warren-Alquist Act defines load management as "any utility program or activity that is intended to reshape deliberately a utility's load duration curve" (Public Resources Code Section 25132). Load management strategies, including those established by the CEC's first load management standards, have been used to help balance the supply and demand of energy in California since the 1970s.

The 2022 Load Management Rulemaking culminated at the October 12, 2022, business meeting of the CEC in the adoption of amended Load Management Standards that increase statewide demand flexibility through regulation (California Code of Regulations [CCR] Title 20, Sections 1621–1625).[16] The regulations require large investor-owned utilities (IOUs), large publicly owned utilities (POUs), and large community choice aggregators (CCAs) to begin uploading time-dependent rates into the Market Informed Demand Automation Server (MIDAS) starting in July 2023. This requirement allows customers and automation service providers to link flexible loads to this statewide real-time signaling system and enables the automation of customer end uses in real time.

Further, the Load Management Standards require that regulated parties provide optional rates that are based on locational marginal cost and change at least hourly. Once implemented, these rates will offer the opportunity for customers to receive compensation for shifting electricity use to low-cost hours of the day.

Executive Order S-3-05 (2005)

Then-Governor Arnold Schwarzenegger signed this executive order in 2005 to move the state to combat GHG emissions.[17] It set targets for California to reduce GHG emissions to 2000 levels by 2010, 1990 levels by 2020, and 80 percent below 1990 levels by 2050.

Assembly Bill 32 (Núñez, Chapter 488, Statutes of 2006)

AB 32, known as the Global Warming Solutions Act of 2006, established a goal to reduce statewide greenhouse gas emissions to 1990 levels by 2020.[18]

Executive Order B-18-12 (2012)

In 2012, then-Governor Edmund G. Brown Jr. directed all State of California agencies, departments, and other entities to reduce GHG emissions.[19] The Governor specifically directed state entities to exceed Energy Code requirements for new buildings, reduce grid-based

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16 CEC. 2022. "California Code of Regulations [CCR] Title 20, Sections 1621–1625," https://govt.westlaw.com/calregs/Browse/Home/California/CaliforniaCodeofRegulations?guid=ID6B950105CCE11EC9220000D3A7C4BC3&transitionType=Default&contextData=%28sc.Default%29&bhcp=1.

17 Governor Arnold Schwarzenegger. June 2, 2005. Executive Order S-3-05, https://www.library.ca.gov/wp-content/uploads/GovernmentPublications/executive-order-proclamation/5129-5130.pdf.

18 Núñez. 2006. Assembly Bill 32, https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=200520060AB32.

19 Governor Edmund G. Brown Jr. 2012. Executive Order B-18-12, https://www.ca.gov/archive/gov39/2012/04/25/news17508/index.html.

energy purchases, participate in demand-response programs, reduce water use, develop on-site renewable resources, and prioritize many other sustainable and green building measures.

Executive Order B-30-15 (2015)

Governor Brown signed this executive order in 2015 to establish an interim GHG emission reduction target.[20] The interim goal is to achieve 40 percent below 1990 GHG emissions by 2030 to keep the state on track for an 80 percent below 1990 levels by 2050 goal.

Senate Bill 350 (De León, Chapter 547, Statutes of 2015)

SB 350 codified California's goals of reaching 50 percent procured renewable energy generation, doubling energy efficiency savings in electricity and gas end uses by 2030, and studying barriers to energy efficiency and clean energy for justice communities.[21]

Senate Bill 32 (Pavley, Chapter 249, Statutes of 2016)

SB 32 amended the Global Warming Solutions Act of 2006.[22] It called for a statewide reduction of greenhouse gas emissions of 40 percent below 1990 levels by 2030. The bill codified the goal initially set in Governor Brown's Executive Order B-30-15.

Assembly Bill 197 (E. Garcia, Chapter 250, Statutes of 2016)

AB 197 was a companion bill to Senate Bill 32 (2016).[23] The bill emphasized the need to implement all climate change policies equitably so that benefits reach all Californians, including those in justice communities.

Executive Order B-55-18 (2018)

Governor Brown's 2018 executive order took the additional step of positioning California for a carbon-neutral future.[24] The order set a new statewide goal to achieve carbon neutrality as soon as possible and no later than 2045, as well as maintain net negative emissions thereafter.

Senate Bill 100 (De León, Chapter 312, Statutes of 2018)

SB 100 increased the Renewables Portfolio Standard (RPS) to 50 percent by 2025 and 60 percent by 2030.[25] Moreover, the bill set a policy that eligible renewable resources and zero-

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20 Governor Edmund G. Brown Jr. 2015. Executive Order B-30-15, https://www.ca.gov/archive/gov39/2015/04/29/news18938/.

21 De León. 2015. Senate Bill 350, https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB350.

22 Pavley. 2016. Senate Bill 32, https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160SB32.

23 Garcia. 2016. Assembly Bill 197, https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201520160AB197.

24 Governor Edmund G. Brown Jr. 2018. Executive Order B-55-18, https://www.ca.gov/archive/gov39/wp-content/uploads/2018/09/9.10.18-Executive-Order.pdf.

25 De León. 2018. Senate Bill 100, https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=201720180SB100.

carbon resources supply 100 percent of retail sales of electricity to end-use customers and 100 percent of electricity procured to serve all state agencies by December 31, 2045. Also, the CEC, CPUC, and the California Air Resources Board (CARB) are required to prepare a joint report to the Legislature addressing the implementation of the policy focused on technologies, forecasts, existing transmission, maintaining safety, environmental protection, affordability, and system and local reliability in 2021 and every four years thereafter.

Senate Bill 1477 (Stern, Chapter 378, Statutes of 2018)

SB 1477 required the CPUC to develop two new incentive programs.[26] These programs, BUILD and TECH, provide incentives for low-emission space- and water-heating equipment for new homes and for near-zero-emission building technologies in new and existing homes to reduce GHG emissions.

Assembly Bill 3232 (Friedman, Chapter 373, Statutes of 2018)

AB 3232 required the CEC to prepare a building decarbonization assessment in consultation with the CPUC, CARB, and the California Independent System Operator (California ISO).[27] This report assessed the potential for California to reduce greenhouse gases from buildings by 40 percent below 1990 levels by 2030. The assessment illustrated the state's pathway to decarbonizing single-family, multifamily, and commercial buildings; identified challenges to and opportunities from decarbonizing; estimated the impact of decarbonization activities on the electricity grid; and illustrated topics and data gaps needing additional analysis in future proceedings.

Senate Bill 68 (Becker, Chapter 720, Statutes of 2021)

SB 68 requires the CEC to develop and publish guidance on best practices to help reduce barriers for building owners to transition to electric equipment and appliances and install electric vehicle (EV) charging equipment. It also authorizes awarding of money from an existing grant program, funded by surcharges on energy ratepayer utility bills, for technological advancements that reduce the costs of electrifying building-related applications.[28]

Assembly Bill 205 (Committee on Budget, Chapter 61, Statutes of 2022) and Assembly Bill 209 (Committee on Budget, Chapter 251, Statutes of 2022)

AB 205, among other provisions, authorizes the Demand Side Grid Support Program (DSGS) and appropriates $200 million to the CEC to offer incentives to electric customers that provide load reduction and backup generation to support the state's electrical grid during extreme

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26 Stern. 2018. Senate Bill 1477, https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180SB1477.

27 Friedman. 2018. Assembly Bill 3232, https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180AB3232.

28 Becker. 2021. Senate Bill 68, https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=202120220SB68.

events, reducing the risk of blackouts.[29] AB 209 expands the program beyond just publicly owned utility customers. AB 209 also established the Equitable Building Decarbonization Program (EBD) with the goals to reduce GHGs related to the building sector.[30] The program has two components: a direct install program and a statewide incentive program for low-carbon building technologies.

The Direct Install Program provides decarbonization retrofits to low-income households. The Statewide Incentive Program incentivizes the increased adoption of low-carbon building technologies. The appropriation for the EBD Program is $922 million. SB 306 (Chapter 387, Statutes of 2023) directs the CEC to submit an annual report to the Legislature on the status of the EBD Direct Install Program beginning on or before September 1, 2024, and until the funds are expended. Two later budget appropriations (SB 101, 2023 and AB 102, 2023) directed an additional $114 million to the DSGS program, though neither made significant changes to the DSGS program.

Assembly Bill 1279 (Muratsuchi, Chapter 337, Statutes of 2022)

AB 1279 codifies the statewide carbon-neutrality goal to dramatically reduce climate pollution.[31] It establishes a clear, legally binding, and achievable goal for California to achieve statewide carbon neutrality as soon as possible, no later than 2045, and establishes an 85 percent emissions reduction target as part of that goal.

Senate Bill 846 (Dodd, Chapter 239, Statutes of 2022)

SB 846 requires the CEC, in consultation with the CPUC and the California ISO, to adopt a goal for load shifting to reduce net peak electrical demand and adjust this target in each biennial Integrated Energy Policy Report thereafter.[32] The CEC published a *Senate Bill 846 Load Shift Goal Report* that sets a goal of 3,000 MW of the 2030 total target of 7,000 MW to load modifying interventions, such as those attributed to flexible demand appliance standards.[33]

Senate Bill 1020 (Laird, Chapter 361, Statutes of 2022)

SB 1020 established interim targets to reach SB 100 clean energy goals and requires state agencies to purchase 100 percent zero carbon electricity by 2035 to serve their load.[34] This bill requires the CPUC, CEC, and CARB, on or before December 31, 2023, and annually thereafter,

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29 Committee on Budget. 2022. Assembly Bill 205, https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=202120220AB205.

30 Committee on Budget. 2022. Assembly Bill 209, https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=202120220AB209.

31 Muratsuchi. 2022. "The California Climate Crisis Act," https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=202120220AB1279.

32 Dodd. 2022. "Senate Bill 846," https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=202120220SB846.

33 Neumann, Ingrid, Ph.D., and Erik Lyon. May 2023. *Senate Bill 846 Load Shift Goal Report*. CEC. Publication Number: CEC-200-2023-008, https://www.energy.ca.gov/publications/2023/senate-bill-846-load-shift-goal-report.

34 Laird. 2022. "Senate Bill 1020," https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=202120220SB1020.

to jointly issue an energy reliability report.[35] This bill seeks to provide greater specificity toward the SB 100 targets in addition to establishing greater clean energy leadership within state agencies.

Assembly Bill 1373 (E. Garcia, Chapter 367, Statutes of 2023)

AB 1373 directs the CEC to incorporate specified electricity demand forecasts and related information into its energy planning and expands state energy and water planning provisions. The bill also requires the CPUC to consider specified electricity procurement and resource planning issues in furtherance of the state's clean energy and greenhouse gas reduction goals. AB 1373 further supports California's transition to a clean electricity system by strengthening coordination among energy planning, electricity procurement, and water-related infrastructure planning.[36]

Assembly Bill 2462 (Calderon, Chapter 569, Statutes of 2024)

AB 2462 requires the CPUC to continue preparing annual recommendations regarding actions to limit utility cost and rate increases consistent with California's energy and environmental goals, including GHG reduction goals. The bill also requires specified electrical and gas corporations to study and report on measures to limit costs and rate increases. This legislation reflects the state's continued focus on balancing energy affordability with implementation of California's clean energy and climate policies.[37]

Assembly Bill 2779 (Petrie-Norris, Chapter 741, Statutes of 2024)

AB 2779 requires the California Independent System Operator (CAISO), as part of its transmission planning process, to report on the use of grid-enhancing technologies identified in approved transmission plans and the associated costs and efficiency savings. The legislation supports the use of technologies that can improve transmission system efficiency and help accommodate California's evolving electricity resource portfolio.[38]

Senate Bill 254 (Becker, Chapter 119, Statutes of 2025)

SB 254 establishes the California Transmission Accelerator and related financing mechanisms to accelerate the development of eligible transmission projects and coordinate state transmission planning. The legislation is intended to improve the efficiency of transmission

35 Kootstra, Mark (CEC) and Nathan Barcic (CPUC). May 2023. *Joint Agency Reliability Planning Assessment Report*. California Energy Commission. Publication Number: CEC-200-2023-007, https://efiling.energy.ca.gov/GetDocument.aspx?tn=250176&DocumentContentId=84899.

36 Garcia2023. "Assembly Bill 1373," https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=202320240AB1373.

37 Calderon 2024. "Assembly Bill 2462," https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=202320240AB2462.

38 Petrie-Norris 2024. "Assembly Bill 2779," https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=202320240AB2779.

development, support California's clean energy and reliability objectives, and reduce or offset ratepayer costs associated with transmission infrastructure.[39]

Assembly Bill 825 (Petrie-Norris, Chapter 116, Statutes of 2025)

AB 825 establishes a framework to ease California's participation in an independent regional organization for electricity market governance. The legislation is intended to support broader regional electricity market coordination while maintaining California's renewable energy and clean electricity policies. Increased regional coordination may improve the integration of renewable resources and support electric system reliability.[40]

Assembly Bill 1207 (Irwin, Chapter 117, Statutes of 2025)

AB 1207 extends and modifies California's market-based GHG compliance mechanism, historically known as the Cap-and-Trade Program and referred to in the legislation as Cap-and-Invest. The legislation aligns the program with California's longer-term GHG reduction goals and extends the program through 2045, while modifying program design, reporting, and oversight requirements. The legislation provides continued policy support for statewide GHG reduction efforts affecting the energy and other major economic sectors.[41]

Senate Bill 840 (Limón, Chapter 121, Statutes of 2025)

SB 840 modifies the allocation and oversight of revenues deposited into the Greenhouse Gas Reduction Fund and establishes additional reporting and evaluation requirements for GHG reduction programs. Together with AB 1207, SB 840 supports the continuation and implementation of California's statewide market-based GHG reduction strategy through 2045.[42]

Equity in Flexible Demand Appliance Standards

Senate Bill 350 (De León, Chapter 547, Statutes of 2015) required the formation of the Disadvantaged Communities Advisory Group (DACAG). The DACAG advises the CEC and CPUC on how to design and implement policies and programs to be more effective on behalf of justice communities and in the achievement of California's clean energy and pollution reduction goals. The DACAG adopted an equity framework as a guide as it discusses and comments on proceedings at the CPUC and CEC, which includes the areas discussed below.[43] The CEC is committed to reducing barriers preventing justice and tribal communities from accessing clean energy opportunities. Many of the effects of climate change are expected to

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39 CEC 2025. "Transmission Legislation and Implementation Status." Available at https://www.energy.ca.gov/programs-and-topics/topics/california-transmission-system/transmission-legislation-and.

40 Petrie-Norris 2025. "Assembly Bill 825," https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=202520260AB825.

41 Irwin 2025. "Assembly Bill 1207," https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=202520260AB1207.

42 Limón 2025. "Senate Bill 840," https://leginfo.legislature.ca.gov/faces/billNavClient.xhtml?bill_id=202520260SB840.

43 CEC. 2018. *Equity Framework*, https://efiling.energy.ca.gov/GetDocument.aspx?tn=224742.

hit these communities the hardest.[44] CEC staff working on the flexible demand appliance standards has a focus on the equity framework goals discussed below, as the CEC proposes flexible demand standards for a range of appliances in the coming years.

Health and Safety

While enabling the electrification of appliances is the primary goal of SB 49, electricity generation from combustion sources emits GHGs and criteria air pollutants such as particulate matter, sulfur oxides, carbon monoxide, nitrogen oxides, and volatile organic compounds — the latter two of which are also precursors of ground-level ozone.[45] People of color are more than three times more likely to be breathing the most polluted air than white people.[46] People living in poverty are most likely to live near sources of pollution and are more likely to be vulnerable to the health impacts of air pollution, including asthma, diabetes, and heart disease.[47] Requiring the deployment of flexible demand technologies will reduce the deployment of electricity generation methods associated with emissions of criteria air pollutants and GHGs, either directly or indirectly, and, in doing so, bring health benefits to residents living within justice communities.

Access and Education

Access and education are key to ensuring that justice communities benefit from clean energy technologies, energy efficiency, and other environmental investments. SB 49 requires the CEC to consult with the CPUC to better align the staff proposal with demand-response programs administered by state and load-serving entities. Many programs administered by the CPUC and CEC provide incentives for customers in justice communities to upgrade their appliances with efficient and flexible demand technologies.[48] CEC staff continues to work with the CPUC and DACAG to create outreach efforts for these programs.[49]

Internet access is commonly a prerequisite for current demand response and load flexibility programs. However, people in justice communities are much more likely to have limited or no internet access. For example, 40 percent of low-income (annual income below $20,000)

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44 CEC. 2022. "Commitment to Diversity," https://www.energy.ca.gov/programs-and-topics/topics/research-and-development/commitment-diversity.

45 CARB. 2026. "Criteria Pollutant Emission Inventory Data." Available at https://ww2.arb.ca.gov/capp/cst/emission-inventories.

46 American Lung Association. 2021. *State of the Air 2021 Report*, page 11 https://www.lung.org/getmedia/17c6cb6c-8a38-42a7-a3b0-6744011da370/sota-2021.pdf.

47 PSE Healthy Energy. 2020. *California Peaker Power Plants Energy Storage Replacement Opportunities*, pages 2–3, https://www.psehealthyenergy.org/wp-content/uploads/2020/03/California.pdf.

48 Ammon, Scott J. November 2019. *CPUC Program Options to Promote Clean Energy and Reduce Air Pollution in AB 617 Environmental and Social Justice Communities*, pages 40-41. CPUC, https://www.cpuc.ca.gov/-/media/cpuc-website/industries-and-topics/reports/ab617-report-final-11252019.pdf.

49 Chac, Erica, Geoffrey Dodson, and Tiffany Mateo-Wilson. September 2020. *Building Initiative for Low Emissions Development Program Implementation Plan*. CEC. Publication Number CEC-300-2020-010-REV, https://efiling.energy.ca.gov/getdocument.aspx?tn=234936.

households do not have internet access.[50] Although connectivity helps make operations more specific to individual electricity bills and emissions, the proposed standards do not limit flexible demand capabilities to those who have internet access.

Financial Benefits

Minimum standards for inclusion of flexible demand functions and features address a key barrier that prevents residents of justice communities from receiving benefits from demand-based incentive programs. Manufacturers often bundle advanced features such as connectivity and programmability with premium features that enhance the look of the appliance. Advanced features also tend to appear on larger appliances. This practice by manufacturers means advanced features are more common on more expensive models and rarely on entry-level models.[51] The proposed standards are a method of addressing these barriers by requiring the connectivity and programmability features to be included in every model offered for sale in California.

Building owners often require renters to pay the energy costs of the home or apartment. Building owners may also decide to furnish or replace appliances with no-frills base models that are most often less energy-efficient to save on the purchase price. This split incentive, or instance where the motivations of the renter responsible for paying the utility bills and the building owner do not align, is a significant barrier, affecting 45 percent of renter households in California.[52] Because 60 percent of low-income households are renters, split incentives disproportionally affect justice communities.[53] Flexible demand standards can overcome the split incentive by requiring that all buildings that are sold, leased, or rented in California include flexible demand technologies.

Consumer Protection

The Legislature prioritized customer privacy and protection in SB 49 in part by emphasizing customer consent and cybersecurity. Staff's goal in proposing these regulations is to provide protection to all customers, including those in justice communities.

The proposed standards include requirements that manufacturers and third parties inform and receive consent from customers to enable flexible demand services. Consent allows the customer to choose their level of participation in flexible demand and balance their needs and preferences for use of the appliance with financial and environmental benefits. A key

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50 Lusson, Karen. *Smart Thermostats: Assessing Their Value in Low-Income Weatherization Programs*. National Consumer Law Center, 2020, https://www.nclc.org/wp-content/uploads/2022/09/rpt-smart-thermostats-jan2020.pdf.

51 Peters, Jane S., Marti J. Frank, and Caroline Chen. 2012. "Home Appliance Programs Hit the Wall." 2012 International Energy Program Evaluation Conference, Rome, Italy, https://energy-evaluation.org/wp-content/uploads/2019/06/2012-iepec-session21-home-appliance-programs-hit-the-wall-peters-and-frank.pdf.

52 Greenlining. 2019. *Equitable Building Electrification*, page 18, https://greenlining.org/wp-content/uploads/2019/10/Greenlining_EquitableElectrification_Report_2019_WEB.pdf.

53 Evergreen Economics. December 2016. *Needs Assessment for the Energy Savings Assistance and the California Alternate Rates for Energy Programs*, page 43, https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/energy-efficiency/iqap/2016-linafrvol1.pdf.

component of consent is providing customers with information on the flexible capabilities of the appliances, which can be accomplished through product literature as well as labeling and marking of products and packaging. Another key component of consent is the ability of the customer to override flexible demand settings or requests at their discretion.

Lastly, staff proposes cybersecurity regulations to require appliances to meet minimum standards to protect consumers. The standards include requirements for security, so the appliance is better secured as the consumer begins their use. Further discussion of consumer protection is in Chapter 2, "Implementation."

CHAPTER 2: IMPLEMENTATION

Flexible Demand Appliance Standards Framework

The CEC proposes to leverage an existing regulatory framework in the California Code of Regulations (CCR), Title 20, Section 1690 et seq. for implementing the FDAS for a subset of thermostats controlling electric space-conditioning appliances and meeting the statutory requirements of SB 49. Previous flexible demand appliance standards for pool controls were chaptered into law in 2023. The proposed regulations are organized into ten parts, shown in **Table 2-1**. This chapter describes these parts as they apply within the scope of the proposed regulations. **Chapter 5** describes the specific standards that apply to in-scope HVAC thermostats.

Table 2-1: Implementation Framework

Scope and Definitions
Test Methods
Flexible Demand Standards
Labeling and Marking Standards
Connectivity Standards
Cybersecurity Standards
Consumer Consent Standards
Appliance Certification Procedures
Enforcement Procedures
Administration of Civil Penalties

Source: California Energy Commission

Scope and Definitions

The scope describes HVAC thermostats that are subject to the regulations. Staff chose existing United States Department of Energy (U.S. DOE) and CEC definitions to provide clarity to the scope of the new regulation. The term "HVAC thermostat" refers to the select types of thermostats controlling electric space-conditioning appliances that are within the scope of the proposed standards.

The scope applies to HVAC thermostats manufactured on or after the effective date of the regulation that are sold or offered for sale, rented, imported, distributed, or leased for use in California. There are no requirements placed on existing thermostats in California nor HVAC

thermostats that were manufactured before the effective date of this regulation. Sell-through of existing stock manufactured prior to implementation of this regulation is permitted.

Test Methods

Test methods enable uniform assessment of appliance performance and verification of compliance with minimum standards before entering the stream of commerce. Staff proposes a specific required performance test method for HVAC thermostats.

The proposed standards will be verified by the CEC's enforcement unit by inspecting and testing HVAC thermostats available for purchase in California.

The testing requirements of CCR Section 1698(ab) in the demand flexibility standards establish a framework and set of criteria for test laboratories that would be responsible for testing the specific flexible demand appliances.

Flexible Demand Standards

The proposed standards are effective for purposes of compliance no sooner than one year after the date of adoption. Staff assumes an effective date of January 1, 2028, as the basis for analyses provided in this staff report.[54] The standards apply to appliances manufactured on or after the effective date that are sold or offered for sale, rented, imported, distributed, or leased for use in California.

While statute requires at least one year between its adoption by the CEC and the effective date of the standards, staff recognizes that interested parties have sometimes requested later effective dates or alignment with U.S. DOE appliance efficiency updates.[55] CEC staff considers the proposed effective date feasible after reviewing available in-scope HVAC thermostats on the market. Staff notes that specification of a later effective date does not significantly change the underlying staff analysis or findings. However, a later effective date could significantly impact the state's 2030 load-shift goal of 3 gigawatts (GW) of load-modifying shifts.[56]

Market Informed Demand Automation Server (MIDAS)

Shifting appliance operations to times with lower GHG emissions associated with electricity generation requires access to signals on near real-time grid conditions. The CEC's MIDAS contains two of these signals, hourly GHG signals and hourly price signals. **Figure 2-1** shows a visual flowchart of the signals maintained in MIDAS and various pathways for appliances around the state to access MIDAS.

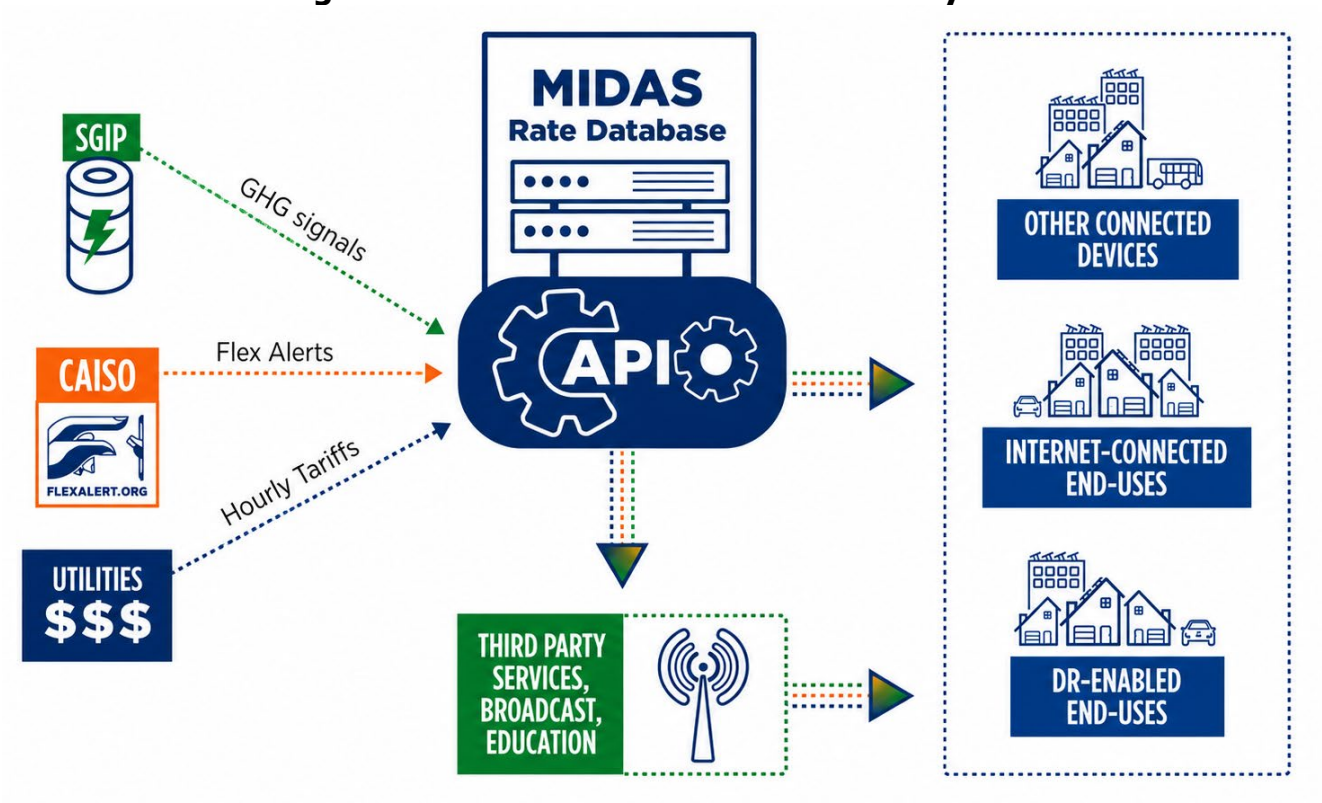
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54 The requirement for soonest effective date of adopted FDAS is codified in the Public Resources Code, Section 25402(c)(1)(A). https://leginfo.legislature.ca.gov/faces/codes_displaySection.xhtml?lawCode=PRC&sectionNum=25402

55 Air-Conditioning, Heating, & Refrigeration Institute. 2021. Comments to Docket 20-FDAS-01, Feb. 3, 2021, TN 236601, page 10. Available at https://efiling.energy.ca.gov/GetDocument.aspx?tn=236601&DocumentContentId=69607.

56 Neumann, Ingrid and Erik Lyon. May 2023. *Senate Bill 846 Load-Shift Goal Report*.

Figure 2-1: Schematic of the MIDAS Ecosystem



Source: California Energy Commission

Proposal: Static and Dynamic MIDAS Signals

Staff proposes HVAC thermostats contain statewide price and GHG signals in the integral memory at the point of sale. These statewide signals can be updated from MIDAS and represent averages of local signals weighted by the electricity usage of each region. Because the statewide signals are loaded into the integral memory of the thermostats and can be used to shift load without continually being updated, these MIDAS signals are referred to as "static." Manufacturers must upload the most recent static signals to the appliances by the time of final factory software image. This step is commonly at the end of the manufacturing process where settings and applications are installed onto the devices. The static MIDAS signal will be updated regularly by the CEC and available to manufacturers at a constant URL. Over-the-air updates to the static signal can also be performed through the MIDAS API.

With the consumer's consent, HVAC thermostats connected to the internet will also be capable of pulling day-ahead MIDAS signals. Because these signals are updated every day, they are referred to as "dynamic." Dynamic MIDAS signals can be linked to a consumer's precise rate structure and local GHG emissions through their rate identification number (RIN). The dynamic price signal can be any of the rate structures available to the consumer, including hourly rates that utilities will regularly maintain on MIDAS starting January 1, 2027.[57]

57 Load Management Tariff Standard, California Code of Regulations, Title 20, Section 1623, https://govt.westlaw.com/calregs/Document/I3DD8C7209D4311EDA65FDF2B31A571F6.

Self-Generation Incentive Program GHG Signals

MIDAS provides the same hourly GHG signals as the CPUC's Self-Generation Incentive Program (SGIP) provided by WattTime. These location-based, hourly GHG signals are based on the implied marginal heat rate (IMHR) method used in the CPUC Avoided Cost Calculator (ACC). IMHR uses locational marginal prices (LMPs) as measures of how much pollution fossil gas power plants are emitting in a given region at a given time. As LMPs increase, electricity is supplied by increasingly less efficient and higher GHG-emitting power plants. When LMPs are low, electricity is supplied by more efficient, less emission-intensive sources, with solar generation among the most efficient and cleanest resources. While additional details are provided by the CPUC,[58] staff provides an overview of the method and data sources here.

$$CO_2^{h,r} = IMHR_{h,r} * EF_{FG}$$

The equation above shows the relationship between the SGIP GHG Signal (CO_2), IMHR, and emissions factor for fossil gas ($EF_{FG} = 0.053$ MTCO$_2$e/MMBtu HHV from 2021 ACC), for hour h and distribution region r. IMHR is related to LMP, variable operations and maintenance costs for a fossil gas power plant (VOM), commodity price of gas ($GasP$), transportation price of gas ($GasTransP$), and the costs associated with Cap and Invest compliance ($CapTradeP$):

$$IMHR_{h,r} = \frac{LMP_{h,r} - VOM}{GasP_d + GasTransP + EF_{FG} * CapTradeP_d} \quad ,$$

where values with the subscript d vary daily. CAISO's Open Access Same-Time Information System (OASIS) provides LMP for each distribution region (for example, DLAP_PGAE-APND, DLAP_SCE-APND, DLAP_SDGE-APND) and $CapTradeP$ (Greenhouse Gas Allowance Index). Values for VOM are given by the CPUC (0.90 $/MWh in 2024 ACC). Values for $GasTransP$ are given by the CPUC and CEC IEPRs for Northern and Southern California (0.1006 $/therm to 0.0468 $/therm in 2021 ACC). Daily gas prices are not publicly available but can be accessed from sources such as Natural Gas Intelligence (NGI).[59]

Marking Requirements

Staff proposes that appliances must display key identification information in a permanent, legible, and clearly visible location on each unit. This information includes the manufacturer's name or brand, model number, and date of manufacture, showing at least the year and month. If the date is provided in a coded format, manufacturers must provide the code to the CEC upon request.

Staff proposes that appliances must also include user information on load flexibility. This information shall be marked on the retail packaging or front page of the printed or digital user manual in the same font size, and format as the key identification information provided on the unit. The following statement must be included:

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58 Verdant Associates. March 7, 2025. *2023 Impact Evaluation Report*. Appendix A – Greenhouse Gas Impacts Estimation Methodology. California Public Utilities Commission, https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/self-generation-incentive-program/2023_sgip_impact_evaluation.pdf

59 Natural Gas Intelligence, https://naturalgasintel.com/.

"This device can shift operation to periods that avoid greenhouse gas emissions from electric power generation plants, which most often align with reduced electric rates. Please consider taking advantage of this load flexibility functionality. More information is available on the FDAS program page on the CEC's website."

Connectivity Standards

Introduction to Connectivity for Appliances

Connectivity is the ability to connect systems or application programs so that they can exchange control signals or information. Modern networks have many different devices that operate with different programming languages, processors, and operating systems. Connectivity standards establish common rules to enable communication between devices and, in so doing, ensure that communication signals can be understood and appropriately used by the receiving appliance.[60]

Proposal: Basic Connectivity

Staff proposes requiring HVAC thermostats to be connected devices as described in CCR, Title 20, Section 1691(a). Under the "connected device" definition in Section 1691(a), HVAC thermostats must be capable of wirelessly communicating via open standards with entities outside the device by means of integrated or separate communications hardware or software. Under the definition, connected devices must also be able to connect to the internet. This proposal would ensure that HVAC thermostats can receive data originating from the internet.

Occasional service disruptions or power outages will cause thermostats to disconnect from the internet. Staff proposes requiring thermostats that suddenly lose internet connection (and were not purposely disconnected by the consumer) to continue current operating schedules until either completion or 24 hours have passed from the disconnecting event, whichever happens first. If internet connection fails again, staff proposes requiring thermostats to create their next operating schedule from data loaded in the integral memories of the thermostats. All compliant thermostats will have statewide static data for emissions and prices for this purpose, as discussed in the section above.

Staff proposed requiring thermostats to be able to receive, store, and use data from outside authorized entities — such as aggregators and utilities — that would be used instead of the statewide static data. This capability allows third parties to offer more customized and optimized operations for their customers and consumers.

Furthermore, staff proposes requiring thermostats to comply, at minimum, with OpenADR 3.1. Manufacturers can implement additional communication protocols, including proprietary ones, provided all requirements to OpenADR 3.1 are still met. Open automated demand response (OpenADR) is a connectivity protocol used to send price and event messages to many types of residential and commercial appliances and systems. OpenADR has wide acceptance in the energy market. OpenADR is one of several connectivity protocols used by the ENERGY STAR®

60 IBM. Updated April 24, 2026. "What is Connectivity?" https://www.ibm.com/docs/en/zvm/7.4?topic=connectivity-what-is.

Connected Criteria.[61] Revision 3.1.0 of the OpenADR protocol uses RESTful web service best practices (instead of the SOAP-like services used in OpenADR 2.0b) and supports both webhooks via HTTP and MQTT for Virtual Top Nodes (VTNs) to push notifications to clients. Staff proposes not requiring thermostats to be registered directly with OpenADR so manufacturers can avoid the additional costs. Staff included additional manufacturer and third-party-related expenses required to create a certified OpenADR product in the cost-benefit analysis shown in **Appendix A**.

Other potential applications of connectivity include receiving CAISO Flex Alerts to curtail use during a grid emergency according to the thermostat owner's preference. The thermostat could also automatically retrieve publicly available information such as electricity price data and GHG data, available from MIDAS, and use it to optimize appliance operations. Compliance with OpenADR 3.1 provides aggregators and utilities access to setting operating schedules in consumer-owned thermostats after receiving their consent. Connectivity also enables on-device clock synchronization, a service that keeps the system clock at the correct time, ensuring that scheduled behaviors occur when expected. **Table 2-2** lists connectivity standards reviewed by staff for the proposed connectivity requirements.[62]

61 ENERGY STAR. 2022. "Connected Criteria for Partners," https://www.energystar.gov/products/smart_home_tips/about_products_connected_functionality/connected_criteria_partners.

62 Cerf, Vint. 2021. "A Brief History of the Internet & Related Networks." Internet Society, https://www.internetsociety.org/internet/history-internet/brief-history-internet-related-networks/; OpenADR Alliance. 2022. "OpenADR Resources," https://www.openadr.org/general-resources; Institute of Electrical and Electronics Engineers. 2022. "IEEE 802 Standards," https://ieeexplore.ieee.org/browse/standards/get-program/page/series?id=68; Z-Wave Alliance. 2022. "Learn About Z-Wave," https://z-wavealliance.org/technology-overview/; LoRa Alliance. 2022. "What Is LoRaWAN Specification," https://lora-alliance.org/about-lorawan/. Connectivity Standards Alliance. 2022. "Build With Matter," https://csa-iot.org/all-solutions/matter/; National Radio Systems Committee. 2022. *United States RBDS Standard*, https://www.nrscstandards.org/standards-and-guidelines/documents/standards/nrsc-5-d/nrsc-5-d.pdf.

Table 2-2: Communication and Connectivity Standards

Connectivity Standard	Organization	Description	Network / Application layer
TCP/IP	Defense Advanced Research Projects Agency (DARPA)	Internet protocol suites	Network layer
OpenADR	Open Automated Demand Response (OpenADR) Alliance	Smart grid standard	Application layer
CTA-2045[a]	Consumer Technology Association (CTA)	Modular communications interface standard	Application layer
IEEE 802 standards	Institute of Electrical and Electronics Engineers (IEEE)	Common data link and physical layer protocols	Network layer
Z-Wave	Z-Wave Alliance	908.42 MHz wireless communications protocol	Application / Network layer
LoRaWAN	LoRa Alliance	US915 ISM wireless communications protocol	Application / Network layer
Matter	Connectivity Standards Alliance	Home automation connectivity standard	Application layer
Radio Broadcast Data System	National Radio Systems Committee	Standard protocol for radio stations to broadcast digital data NRSC-5-D	Application layer

Source: California Energy Commission

Note:

a. CTA-2045 is also a Hardware standard

Alternative: No Connectivity

Many HVAC thermostats may be programmed to follow schedules per the consumer's preferences, similar to a setback thermostat required by Title 24. The HVAC thermostat programming configuration does not require an internet connection for setup. Manual scheduling offers a simple way for a consumer to schedule, delay, or change the electrical demand of an appliance. However, connectivity improves benefits, including consumer bill savings, avoided GHG emissions, and enhanced grid reliability because it allows thermostats to

access day-ahead grid, price, and emissions data and apply dynamic scheduling that responds to grid conditions. Without connectivity and access to relevant data, thermostats cannot optimize operation in response to grid conditions, limiting both user savings and environmental benefits.[63]

Discussion of Interested Parties Proposals for a Connectivity Standard

Many interested parties that participated in proceedings introducing the statutory requirements for flexible demand appliance standards commented that the CEC should use OpenADR for communications. Interested parties who responded to a 2024 request for information (RFI) on low-voltage thermostats broadly agreed on the importance of two-way communication between the utility or grid operator and the end node receiving the signal.[64] Interested parties also provided support for test methods and standards based upon the U.S. EPA ENERGY STAR Connected Criteria specifications.[65] Some interested parties supported, while other interested parties opposed, standards based upon the CTA-2045 communication protocol.[66]

The staff proposal does not prescribe the use of a specific physical layer that could support more market development. The staff proposal requires compliance with the OpenADR protocol as a minimum to provide a reliable way for aggregators and utilities to communicate with the thermostats while allowing other additional protocols, including proprietary ones.

Some interested parties commented that machine-readable signals exist to provide current and forecasted marginal GHG emission rates for California and have been used to optimize charge/discharge cycles for energy storage systems.[67] Marginal GHG emission signals can also be combined with TOU rates to optimize load while the electricity rate remains constant. Staff analyzed the benefits of shifting based on a GHG signal and a combined GHG/TOU rate signal. While there are significant benefits, staff found a less burdensome approach for manufacturers by prescribing flexible capabilities with connectivity to achieve significant GHG emission reductions, allowing the manufacturer many possibilities for advanced control algorithms that balance consumer preferences to input signals while ensuring space-conditioning is available for the consumer.

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63 Vivint. July 11, 2023. "10 Advantages of Home Automation," https://www.vivint.com/resources/article/advantages-of-home-automation.

64 California Energy Commission. 2024. "Docket 24-FDAS-03," https://efiling.energy.ca.gov/Lists/DocketLog.aspx?docketnumber=24-FDAS-03.

65 California Investor-Owned Utilities. 2021. Comments to Docket 20-FDAS-01, Feb. 3, 2021, TN 236618, page 3.
AHRI, Comments to Docket 20-FDAS-01, TN 236601, page 3,
OpenADR, Comments to Docket 20-FDAS-01, TN 236599, pages 2–3,
https://efiling.energy.ca.gov/Lists/DocketLog.aspx?docketnumber=20-FDAS-01.

66 Bradford White Corporation. 2021. Comments to Docket 20-FDAS-01, Feb. 3, 2021, TN 236580, page 4,
https://efiling.energy.ca.gov/GetDocument.aspx?tn=236580&DocumentContentId=69585.
AHAM, Comments to Docket 20-FDAS-01, TN 236600, page 3,
https://efiling.energy.ca.gov/GetDocument.aspx?tn=236600&DocumentContentId=69604.

67 WattTime. 2021. Comments to Docket 20-FDAS-01, Feb. 3, 2021, TN 236594, page 3,
https://efiling.energy.ca.gov/GetDocument.aspx?tn=236594&DocumentContentId=69594.

California ISO launched a new Flex Alert system to communicate with appliances through text messaging. The system relies on a secured blockchain to protect user data and response history.[68] The new Flex Alert will provide California ISO with the ability to view aggregated or collected data about how many subscribers in a county responded to a recent Flex Alert. The staff proposal enables products that comply with the flexible demand standard to participate in the new California ISO Flex Alert system through the support of connectivity using an open standard.

Cybersecurity Standards

Introduction to Cybersecurity for Appliances

SB 49 mandates that the CEC establish cybersecurity standards to protect customers using flexible demand appliances. These cybersecurity standards were adopted during the first FDAS rulemaking.[69] In adopting flexible demand appliance standards for HVAC thermostats, they will be subject to these general cybersecurity requirements. Many cybersecurity attacks begin by exploiting the device with the weakest security practices, then extending the attack to other devices on the same network. Therefore, HVAC thermostats with network capabilities must implement minimum cybersecurity features to protect the consumer and the integrity of the network.[70]

Staff reviewed cybersecurity frameworks implemented by OpenADR, as well as national standards and methods referenced in the National Institute of Standards and Technology (NIST) Special Publication 8259A and NIST Interagency Report (IR) 7628 Revision 1.[71] SB 49

68 Energy Web. September 20, 2021. "California Grid Operator Launches New Demand Flexibility Platform Enhancements to Flex Alert System, Leveraging Energy Web Technology," https://medium.com/energy-web-insights/california-grid-operator-launches-new-demand-flexibility-platform-enhancements-to-flex-alert-system-e01ae8030da0.

69 CEC. 2023. "Pool Control Rulemaking," https://www.energy.ca.gov/proceeding/pool-controls.

70 Cybersecurity and Infrastructure Security Agency. 2023. "Cybersecurity Best Practices," https://www.cisa.gov/topics/cybersecurity-best-practices.

71 OpenADR Alliance. 2022. "OpenADR and Cyber Security," https://www.openadr.org/cybersecurity.
NIST. 2014. "Guidelines for Smart Grid Cybersecurity," https://nvlpubs.nist.gov/nistpubs/ir/2014/NIST.IR.7628r1.pdf.

requires CEC to consider NIST's reliability and cybersecurity protocols. **Table 2-3** lists cybersecurity standards that staff reviewed for applicability for HVAC thermostats.[72]

72 NERC. 2022. "CIP Standards," https://www.nerc.com/pa/Stand/Pages/Project-2014-XX-Critical-Infrastructure-Protection-Version-5-Revisions.aspx;
NIST. 2022. "IoT Device Cybersecurity Capability Core Baseline," https://nvlpubs.nist.gov/nistpubs/ir/2020/NIST.IR.8259A.pdf;
British Standards Institution. 2021. "PAS 1878:2021 Energy Smart Appliances – System Functionality and Architecture — Specification," https://www.bsigroup.com/globalassets/localfiles/en-gb/energy-smart-appliances-programme/pas1878.pdf;
British Standards Institution. 2021. "PAS 1879:2021 Energy Smart Appliances – Demand Side Response Operation – Code of Practice," https://www.bsigroup.com/globalassets/localfiles/en-gb/energy-smart-appliances-programme/pas1879.pdf;
Jackson. 2018. Senate Bill 327, https://leginfo.legislature.ca.gov/faces/billTextClient.xhtml?bill_id=201720180SB327;
UL. 2020. "ANSI/CAN/UL Standard for Software Cybersecurity for Network-Connectable Products, Part 1: General Requirements," https://standardscatalog.ul.com/ProductDetail.aspx?productId=UL2900-1;
ETSI. 2020. "Cyber Security for Consumer Internet of Things: Baseline Requirements," https://www.etsi.org/deliver/etsi_ts/103600_103699/103645/02.01.02_60/ts_103645v020102p.pdf;
NIST. 2022. "Profile of the IoT Core Baseline for Consumer IoT Products," https://csrc.nist.gov/pubs/ir/8425/final;
NISTIR 8425. 2023. "NISTIR 8425 Standards," https://csrc.nist.gov/pubs/ir/8425/final.

Table 2-3: National and Industry Cybersecurity Standards

Cybersecurity Standard	Organization	Description
NERC Critical Infrastructure Standards	North American Electric Reliability Corporation (NERC)	Minimum cybersecurity standards for critical grid infrastructure
NIST 1108r4, Appendix J	National Institute of Standards and Technology (NIST)	List of reviewed smart grid interoperability standards
NIST 8259A	National Institute of Standards and Technology (NIST)	Cybersecurity for internet of things (IoT) device manufacturers
PAS 1878:2021 and 1879:2021	British Standards Institute	British standards for smart appliances
SB 327, Jackson, 2018	California State Government	CA statute on connected devices and information privacy
UL 2900-1 Standards	Underwriters Laboratories	Minimum standards for network-connectable products
ETSI TS 103 645	Cyber Security for Consumer Internet of Things	Good practices for IoT devices
NISTIR 8425	National Institute of Standards and Technology (NIST)	Core cybersecurity features for general consumer IoT devices

Source: California Energy Commission

Staff reviewed cybersecurity features listed in **Table 2-4** for applicability when proposing standards for HVAC thermostats. In March 2024, the Federal Communications Commission (FCC) adopted rules for the voluntary Internet of Things Cybersecurity Labeling Program, where entities can choose to comply with the requirements and receive authority to utilize the FCC IoT label bearing the U.S. Cyber Trust Mark. Fundamental to ensuring compliance with the program are the standards NISTIR 8425 and NISTIR 8259, both found in the above table.[73]

73 Federal Communications Commission. March 15, 2024. "FCC Adopts Rules for IoT Cybersecurity Labeling Program," https://www.fcc.gov/document/fcc-adopts-rules-iot-cybersecurity-labeling-program.

Table 2-4: Flexible Demand Appliance Cybersecurity Standards

Topic	Description	Threat/Benefit/Necessity
NERC CIP–007-1 R5.3.	Critical Infrastructure Protection standards	Password minimum complexity requirements
Device Identification	The manufacturer shall assign a unique logical identifier to the connected device	Asset management
Device Configuration	The configuration of the connected device's software shall be changed by authorized entities only	Reduces risk of compromised software
Data Protection	The connected device shall provide consumer data protection for personal information	Reduces risk of compromised consumer data
Authentication	The connected device shall contain a security feature that requires a user to generate a new means of authentication	Default passwords are a major contributing factor to large-scale security compromises
Software Update	The manufacturer shall have an update policy that informs how the manufacturer will support software updates, informing that the device is capable of being updated whenever new vulnerabilities are discovered	Software updates reduce the risk of compromised software
Restart Settings	Upon device restart, the device shall automatically restore the most recently programmed settings, including reconnection to a network	Maintains installation settings after power interruptions of up to 72 hours for the lifetime of the appliance
Automatic Rejoin	When physical or logical communication is lost, the device shall automatically attempt to rejoin communications	Ease of use to the consumer for network or power interruptions
Override Function	The connected device shall allow the change of event responses and event response settings at any time	Ensures consumer-centric features are incorporated into designs

Source: California Energy Commission

The following are examples of cybersecurity requirements included in the existing Flexible Demand Appliance Standards:

Identification

Appliance device identification allows a consumer or network entity to identify an appliance uniquely. The device identification must be logical, meaning readable by other devices. Device identification supports asset management, which in turn supports vulnerability management, access management, data protection, and incident detection.[74]

Security Measures

Appliances must have security measures implemented when the appliance is configured and installed for the end user or consumer. Security misconfigurations are common gaps that can be exploited: many vulnerabilities have been traced to software flaws and misconfigurations of system components.[75] Manufacturers often set default software configurations for devices to be as open and multifunctional as possible. The current general cybersecurity requirements address these issues by requiring the authentication of users and system configurators.

Connectivity

Connected appliances shall provide consumer data protection for personal information. As a simple example, displaying personal data or credentials in plaintext on the user interface is a common security risk for unauthorized users to gain credentials and personal data. For this example, the manufacturer could simply not allow plaintext displays of personal credentials on the user interface, providing an additional level of security in the event an unauthorized user accesses the device. Manufacturers can choose from a range of options to implement the most appropriate solution to protect consumer data for their device application.

Data Update

The device must be able to update to the latest available software version. Consumers shall be informed of all software updates by the appropriate entity, and all updates must be easy to implement, understandable, and timely for the consumer. Updates must be delivered over a secure channel and must not reduce the functionality of the device from the initially installed functionality.

Operation Restore

Upon appliance restart, the appliance shall automatically restore the most recently programmed settings, including reconnecting to the network. Should the appliance lose physical or logical communication from the network, the appliance shall automatically attempt to rejoin the physical or logical communication. The appliance shall also have an override function for consumer use. The override function shall allow consumers to opt out of a flexible demand program and change the event responses and event response settings anytime.

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74 NIST. 2020. "IoT Device Cybersecurity Capability Core Baseline."

75 NIST. 2011. "Guide for Security-Focused Configuration Management of Information Systems." *Special Publication (NIST SP) - 800-128,* NIST National Institute of Standards and Technology, https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.800-128.pdf.

Consumer Consent

Flexible demand features included in HVAC thermostats are subject to consumer consent requirements. "Consent" means permission or agreement to use the capabilities of an appliance to automatically schedule, shift, or curtail its use, and to collect and use the information needed for doing so. Consent may be expressed or implied. In addition, consent may be incorporated into opt-in programs or opt-out default settings.

Requirements for consumer consent help ensure that end users of regulated appliances are aware of the networking capabilities of the device and provide methods for consumers to decline participation in data sharing and the flexible demand program. The manufacturer must thoroughly explain the capabilities of the appliance and offer opt-in or opt-out choices to the end user, depending on the product-specific requirements.

Appliance Certification Procedures

Manufacturers are required to certify each model of HVAC thermostat within the scope of the regulation to the CEC's flexible demand program database as described in Section 1695 of the proposed regulatory language. Certifying a model as compliant with the flexible demand standards allows effective enforcement by providing regulators with a list of products that could be sold or offered for sale, rented, imported, distributed, or leased for use in California. Certifying compliance to the CEC also allows distributors and retailers to verify that products can be sold legally.

Procedure for Manufacturer to Access the CEC Database

To submit an appliance for certification, manufacturers or manufacturers' third-party certifiers would first need to set up a company account in the CEC's flexible demand program database and request access. Company accounts include basic information about the company. The request for a company account is then reviewed and approved by CEC staff. If the CEC rejects the account request, a notification explaining the rejection will be sent to the person who submitted the request.

Data Submittal Requirements

Data submission regulations specify the certification information to be submitted to the CEC's database. There are a few parameters that are required for all appliances: model number, manufacturer name, and brand name. Additional data submittal requirements are in Title 20, Section 1696, Table A-1 and Table A-2 and Appendix B, Table C-1. The required information is necessary to determine whether the appliance meets the applicable regulatory standards and helps describe the characteristics and design of the product.

Procedure for the Manufacturer to Submit Data

The manufacturer or manufacturer's third-party certifier would have the option to submit the data using an online template or manually through the database. In either case, as part of the submission, the manufacturer would be required to sign electronically a declaration certifying that the appliance meets all applicable regulations and that the submitted information is accurate. These certification procedures ensure that, while manufacturers may choose how to

submit data, the format, content, and verification requirements remain consistent across all submissions.

Procedure for CEC to Review Data

Staff will validate all submitted data to verify that the appliance complies with all applicable standards. Once validated, the submitted model(s) would immediately be listed in the CEC's database and can legally be sold or offered for sale, rented, imported, distributed, or leased for use in California. If a model fails validation, the model will not be listed in the CEC's database, and the reason for the rejection will be sent to the submitter. If needed, the submitter may resubmit the information if there was a mistake in their original submission.

Procedure for a Manufacturer to Amend or Correct Data

For models that have been successfully added to the CEC's database, the manufacturer will have the ability to remove or amend the models by a data submission to the CEC. Once the new submission is reviewed and approved by the CEC, the change or deletion will immediately be made to the database.

Procedure for Displaying and Handling Submitted Data

Anyone from the public would be able to view, search, and download information for models listed in the CEC's database. This access is necessary for retailers, installers, distributors, consumers, and others to confirm if a specific model complies with the regulations. All the information submitted for each model would be available to the public. Models compliant with the most current requirements would be listed as "Active." If a model is listed as approved but then a new standard or testing requirement for that appliance goes into effect, the CEC will archive the models in these instances and notify the affected manufacturers. The CEC will then list the model as "Archived."

Procedure for Test Laboratories

Test laboratories approved by and listed in the CEC's database must be used to conduct the performance test procedure for HVAC thermostats. The manufacturer may work with any third-party lab to conduct the test, or they may conduct the test themselves. In either case, to be included in the CEC's list of approved labs, the lab must be capable of following the specific testing requirements outlined in the regulations. When submitting data to the CEC's database, the manufacturer would need to identify the test lab that was used from a list of approved test labs.

To become an approved test lab and be selectable in the CEC's database, the lab will first need to create a company account and submit a test laboratory application through the CEC's database. Once the application is approved by the CEC, the test lab will then be listed as an approved test lab in the CEC's database and the manufacturer will be able to select that test lab when submitting data for an appliance.

The general testing requirements proposed in the regulation set the standards for test laboratories that will be conducting testing in the future when test procedures are adopted for particular appliances. It is necessary to adopt these generalized testing requirements now so that testing laboratories are given advance notice of the procedural requirements. Laboratories

may make informed decisions on allocating resources to develop testing capability if testing is required in the future.

Procedure for Third-Party Submittal

The manufacturers would be responsible for ensuring their regulated appliances are listed in the CEC's database. However, they may delegate the authority to submit the data on their behalf to a third party, for example, to a third-party test laboratory.

For this process to occur, the third party must first create a company account in the CEC's database. Next, the third party would submit a "third-party certifier application" through the CEC's database to become approved to submit data for other companies. The application would include signing a declaration stating that they understand the certification requirements, they are capable of certifying data, and that the information submitted is accurate. Once the application is approved by the CEC, the third party will then be listed as an approved third-party certifier in the CEC's database. On the manufacturer's side, they would need to submit a "delegation of authority" through the CEC's database for the third party to submit data on their behalf.

Enforcement Procedures

Requirements for Compliance

An appliance complies with the regulations if it meets all the applicable flexible demand standards and other requirements, including testing and marking for that specific appliance type, and has been properly certified to the CEC's database. Compliant products can then be sold or offered for sale, rented, imported, distributed, or leased for use in California. When manufacturers certify their products to the CEC's database, the products will not be listed unless the submitted information demonstrates compliance with the applicable requirements in the regulations. The manufacturers would be required to declare that the submitted information is accurate when certifying products. A third party may file a statement regarding certification on behalf of a manufacturer, but in such cases the manufacturer remains responsible for the truth, accuracy, completeness, and timeliness of all required filings.

Authority to Enforce

The CEC has the authority to enforce the regulations under Public Resources Code Section 25402.11.

Inspection Procedures

The CEC intends to periodically inspect regulated appliances being sold or offered for sale, rented, imported, distributed, or leased for use in California to determine if the products comply with the regulations. If the unit does not comply with the applicable flexible demand standards or marking requirements, or if the unit is not properly certified to the CEC's database, the CEC may pursue enforcement actions, including the assessment of civil penalties (see subsection below) against the responsible person.

Submittal of Test Report Procedures

A manufacturer may be asked at any time to send copies of test reports supporting their appliance listings to the CEC. Information sourced from the test report is submitted to the CEC's database by the manufacturer as part of the proposed appliance certification. Therefore, staff may need to review the source documentation in some cases. The test report should demonstrate that the applicable testing requirements were met and that the product information and test data align with the information that was submitted to the CEC's database for that appliance.

If test report copies are requested, the CEC would send the request via email to the manufacturer's contact information listed in the CEC's database and include the reason for the request. If the manufacturer is unresponsive, or if the test report shows that the appliance does not comply with the regulations, the appliance may be removed from the CEC's database. The proposed regulations contain time periods for responding to such requests.

Testing Procedures

Section 1698 of the proposed regulatory language designates an Energy Commission-adopted test procedure with details such as laboratory conditions, test setups, baseline configuration verification, autoflex operating schedule verification, connected functionality verification, demand response event handling verification, and others.

A proposed test method with the test procedures is developed by UC Davis. The document will be docketed and available in CEC's Docket 24-FDAS-03.[76] After completion of the regulatory proceeding of the HVAC thermostats, the adopted test method document will be posted at the CEC's Flexible Demand Appliances Documents and Reports page.[77] .

Administrative Civil Penalties

The flexible demand appliance standards for HVAC thermostats will be subject to regulatory enforcement. The proposed administrative civil penalties are necessary to improve rates of compliance with the proposed regulations. Any person, including a manufacturer, retailer, contractor, importer, distributor, or lessor, who sells or offers for sale, rents, imports, distributes, or leases for use in California flexible demand appliances that do not comply with the regulations may be subject to civil penalties from the CEC under the proposed regulations. Noncompliance with the regulations falls into four categories:

- The appliance does not meet the applicable testing, marking, cybersecurity, consumer consent, or flexible demand requirements in the regulations for that specific appliance.
- The appliance is not certified to the CEC's database.
- The information submitted to the CEC's database for a specific model is revealed to be incomplete, inaccurate, or otherwise noncompliant with the regulation.

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76 California Energy Commission. "Docket 24-FDAS-03." Available at https://efiling.energy.ca.gov/Lists/DocketLog.aspx?docketnumber=24-FDAS-03

77 California Energy Commission. "Flexible Demand Appliances." Available at https://www.energy.ca.gov/proceedings/active-proceedings/flexible-demand-appliances

- A firmware update that impacts how the appliance automatically shifts load is not recertified to the CEC's database.

Enforcement Penalties and Judicial Review

Violations are proposed to be subject to administrative civil penalties of up to $2,500 for each unit that does not comply with the regulations and is sold or offered for sale, rented, imported, distributed, or leased for use in California. The penalty amount may vary depending on the severity of the violation, number of noncompliant units, cooperation of the responsible person, and additional factors contained in Public Resources Code Section 25402.11.

Notices of Violation

If an appliance is found noncompliant with the regulations, the CEC will notify the responsible person and provide steps to correct the situation and resolve the matter. Failure to adequately respond to this notification may lead to the issuance of a formal "notice of violation" followed by the commencement of adjudicative proceedings to impose civil penalties under CCR, Title 20, Section 1697. The notice of violation would be sent by certified mail or other means to the responsible person. The notice will contain the name and address of the responsible person, the regulation that the notice of violation is based upon, facts describing the violation, and other information.

Administrative Proceedings

An adjudicative proceeding may be held if the CEC determines that the responsible person has not made sufficient progress in addressing the violations noted in the notice of violation. The proceeding may be initiated no earlier than 30 calendar days after the notice of violation has been issued, allowing time for the responsible person to respond or take corrective action before formal proceedings begin.

Settlement

The CEC may at any time enter a settlement with a responsible person. The settlement agreement may include appropriate sanctions and remedies to address violations and promote compliance.

CHAPTER 3:
Regulatory Approaches

Overview

This chapter describes types of regulatory approaches that have been applied to thermostats. CEC staff considered and studied regulatory pathways to achieve flexible demand in thermostats for electric space-conditioning appliances. Staff evaluated the CEC Load Management Standards (LMS), state, federal, and international regulations, and the U.S. EPA ENERGY STAR Thermostats Specification. Staff concludes that the proposed standards are consistent with the existing regulations.

Historical Approach

CEC staff found no existing flexible demand standards for thermostats for electric space-conditioning appliances.

In 1979, the CEC adopted four load management standards for the five largest electric utilities in the state: Pacific Gas and Electric (PG&E), Southern California Edison (SCE), San Diego Gas and Electric (SDG&E), Los Angeles Department of Water and Power (LADWP), and Sacramento Municipal Utility District (SMUD). The four standards addressed rate structures, residential load control, swimming pool pump time control, and commercial building audits.[78]

California Regulations

The 2025 California Building Code establishes energy budgets based on efficient heat pumps for space or water heating to encourage builders to install heat pumps.[79]

The 2022 California Building Code, Joint Appendix JA5 provides the technical specifications for an Occupant Controlled Smart Thermostat (OCST). An OCST can be an independent device or part of a control system composed of multiple devices. An OCST is compliant with CCR, Title 24, Part 6, only if it has been certified to the CEC, as specified in Section 110.0.[80]

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78 CEC. 1979. § 1621. General Provisions, https://govt.westlaw.com/calregs/Document/I2B64F6409D4311ED835FC98C8E723B73?viewType=FullText&originationContext=documenttoc&transitionType=CategoryPageItem&contextData=(sc.Default).
CEC. 1979. § 1622. Residential Load Management Standard, https://govt.westlaw.com/calregs/Document/ID6D3DCF35CCE11EC9220000D3A7C4BC3?viewType=FullText&originationContext=documenttoc&transitionType=CategoryPageItem&contextData=(sc.Default).
CEC. 1979. § 1623. Load Management Tariff Standard, https://govt.westlaw.com/calregs/Document/I3DD8C7209D4311EDA65FDF2B31A571F6?viewType=FullText&originationContext=documenttoc&transitionType=CategoryPageItem&contextData=(sc.Default).

79 California Building Code. 2025. "Building Energy Efficiency Standards Summary," https://www.energy.ca.gov/sites/default/files/2024-12/2025_Energy_Code_Summary_ADA.pdf.

80 California Building Code. 2022. "Joint Appendix JA5," https://www.energy.ca.gov/sites/default/files/2022-08/CEC-400-2022-010-AP.pdf.

Federal Regulations

Existing Federal Standards

There are no existing federal standards for the flexible demand capabilities of HVAC thermostats.

Voluntary Federal Standards

The U.S. EPA ENERGY STAR program established a specification for smart thermostats.[81] The specification for smart thermostats encourages the use of open standards for communication protocols to facilitate demand response in HVAC thermostats.

International Regulations

In October 2023, the United Kingdom enacted the Energy Act 2023, which gives the government the power to mandate certain standards for certain energy smart appliances, including appliances used in connection with heating, air conditioning, or ventilation.[82]

The British Standards Institution published *PAS 1878: 2021 Energy Smart Appliances — System Functionality and Architecture — Specification* and *PAS 1879: 2021 Energy Smart Appliances — Demand Side Response Operation — Code of Practice*. These standards propose a technical specification for energy-smart appliances and demand-side response service providers to document a method to enable standardized control, subject to explicit consumer consent, of an energy-smart appliance in an electricity network. The standards have four principles for consumer demand-side response:[83] interoperability, data privacy, grid stability, and cybersecurity.

Australian and New Zealand Standards AS/NZS 4755 provide a demand-response framework for demand-response-enabling devices. The standards specify minimum physical requirements, minimum levels of functionality, various means for communications and connections, and labeling and marking requirements. The standards include air conditioners.[84] The AU/NZS 4755 demand response standard has a similar scope to the current FDAS staff proposal for

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81 U.S. EPA ENERGY STAR Program. 2022. "ENERGY STAR Program Requirements Product Specification for Smart Thermostat Products Draft 1 Version 2.0," https://www.energystar.gov/sites/default/files/asset/document/ENERGY%20STAR%20Version%202.0%20%20Smart%20Thermostat%20Draft%201%20Program%20Requirements.pdf.

82 United Kingdom Parliament. 2022. Energy Act 2023, https://www.legislation.gov.uk/ukpga/2023/52/section/239/enacted.

83 British Standards Institute. 2021. "PAS 1878:2021 Energy Smart Appliances. System Functionality and Architecture — Specification," https://www.bsigroup.com/en-GB/about-bsi/uk-national-standards-body/about-standards/Innovation/energy-smart-appliances-programme/pas-1878/.

British Standards Institute. 2021. "PAS 1879:2021 Energy Smart Appliances. Demand side response operation – Code of Practice," https://www.bsigroup.com/en-GB/about-bsi/uk-national-standards-body/about-standards/Innovation/energy-smart-appliances-programme/pas-1879/.

84 Australian Energy Market Operator. 2020. "AS 4755 Demand Response Standard," https://aemo.com.au/en/initiatives/major-programs/nem-distributed-energy-resources-der-program/standards-and-connections/as-4755-demand-response-standard.

thermostats. The CEC proposal allows consumer override, scheduling, and a connected capability allowing the consumer to select the appropriate actions to meet their needs.

Industry Standards

The fourth edition of CSA C828:19 Canadian Standards Association contains performance requirements for line voltage thermostats used with individual room electric space heating devices. The CEC staff proposal does not impose any requirements inconsistent with this standard.[85]

85 Canadian Standards Association (CSA Group). 2019. "Performance Requirements For Line Voltage Thermostats Used With Individual Room Electric Space Heating Devices," https://www.techstreet.com/standards/csa-c828-19?product_id=2089271.

CHAPTER 4: Thermostats

Overview

This chapter describes the types of thermostats in the market. A thermostat for electric space-conditioning appliances schedules the start and stop of basic HVAC operations and may control an electric heat pump, electric resistance heater, air conditioner, or a combination of such equipment.

Thermostat and Space Conditioning

The first thermostats to control room temperatures were invented in the 1880s. Residential thermostats were introduced in the 1900s. In recent decades, electronic programmable capabilities have been introduced. The most recent innovation is adding the ability of the thermostat to communicate with outside devices and respond to weather and utility grid conditions.[86]

Many thermostats directly monitor the temperature of the indoor space, while some take inputs from separate temperature sensors. When the temperature rises or falls outside the limits set by the user, the thermostat will adjust the supply of power or directly command the heating or cooling system to return the room temperature to the user-defined set point. The thermostat typically displays the current temperature of the indoor space and the set point. Some thermostats also display the operational status of the equipment.

While thermostats are also used to control the temperature in industrial and refrigeration applications, these applications are outside the scope of the proposed regulation. The type of thermostat is determined by the equipment that is being controlled and distinguishing characteristics such as the operating voltage used to command the equipment and thermostat power source, as shown in **Table 4-1**. **Figure 4-1** shows how low-voltage thermostats for electric space-conditioning appliances issue commands to turn on or off the ventilation, heating, and cooling systems.

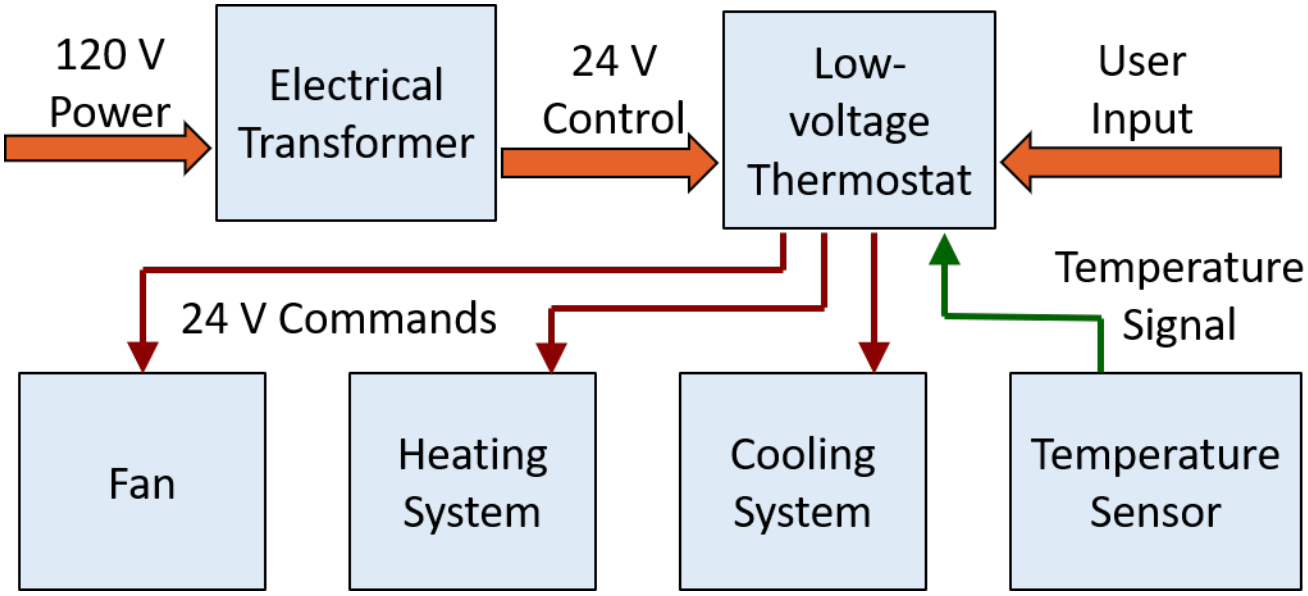
86 Walker, Ian and Alan Meier (Lawrence Berkeley National Laboratory). 2008. *Residential Thermostats: Comfort Controls in California Homes*. California Energy Commission. Publication Number: CEC-500-03-026, https://www.osti.gov/servlets/purl/937569.

Table 4-1: Thermostat and Equipment Controlled

Thermostat	Operating Voltage	Power Source	Equipment Type Controlled
Low-voltage System	6-30 V	120 V circuit through step-down transformer	Gas and electric forced-air furnaces
Proprietary thermostats	Low Voltage DC	Battery powered	Mini-split AC (handheld proprietary thermostats)
Line Voltage	>30 V	120 V circuit	Portable corded electric resistance heaters
Millivolt	0.75 V	Thermocouple or thermopile generator	- Gravity wall room furnaces - Direct-vent or top-vent wall furnaces for small areas - Mobile home direct-vent wall furnaces

Source: California Energy Commission

Figure 4-1: Low-Voltage Thermostat Schematic



Source: California Energy Commission

Low-Voltage Thermostats

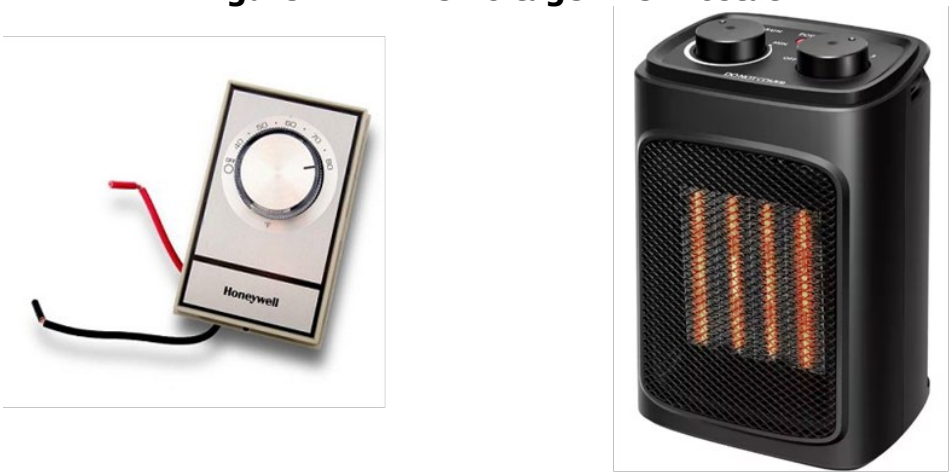
Low-voltage thermostats control a wide range of heating and cooling equipment, including fossil gas furnaces, central air conditioners, and heat pumps. Because of their ability to control this equipment, they are the most prevalent in California. All "smart" thermostats, those that can connect to the internet and often try to automatically optimize heating and cooling usage,

are included in this category. The devices can be distinguished from other thermostats by the low-voltage input power and command signals.

Line Voltage Thermostats

Line voltage thermostats control electric heating systems such as 120V portable corded electric resistance heaters, electric baseboard heaters, and radiant heaters. These devices control the supply of power directly rather than issuing commands to turn on heating equipment. Unlike low-voltage thermostats, line voltage thermostats do not control cooling equipment. Portable corded electric resistance heaters are self-contained, electrically powered space-heating devices that use electric resistance elements to generate heat by radiation or convention or both and are designed for indoor spaces. These devices are intended to be manually relocated by the user and are typically equipped with a flexible cord and plug for connection to a standard electrical outlet. **Figure 4-2** shows a line voltage wall-mounted heater and a portable corded electric resistance heater.

Figure 4-2: Line Voltage Thermostat



Wall Mounted Resistance Heater and Portable Corded Electric Resistance Heater

Source: Honeywell/Resideo/VIVOSUN

Millivolt Thermostats

Millivolt thermostats control gravity wall room furnaces and direct vent furnaces. They are powered by a thermopile that provides a small electrical current generated by the furnace pilot light. Millivolt thermostats do not control cooling equipment. **Figure 4-3** shows a millivolt thermostat.

Figure 4-3: Millivolt Thermostat



Source: Honeywell/Resideo

Proprietary Thermostats

A proprietary thermostat is an appliance, or combination of appliances, with a nonopen standard that controls electric, immobile heating, ventilation, and air-conditioning equipment. These thermostats typically use nonopen standards and may be designed to function with specific HVAC equipment models or brands. **Figure 4-4** shows proprietary thermostats for mini split and multi-stage HVAC systems.

Figure 4-4: Proprietary Thermostat



Minisplit and multistage HVAC system proprietary thermostats

Source: Daikin, Trane, and Senville

Dual-Fuel System Thermostat

A dual-fuel system thermostat controls a heating system that uses electricity and nonelectric fuel, such as fossil gas, and automatically selects the most appropriate heating source to maintain comfort and improve efficiency. For example, a heat pump with electric resistance auxiliary heat is not considered a dual-fuel system, but a heat pump paired with a gas or propane furnace as backup heat is considered dual-fuel. Also, an air conditioner with a gas furnace is not a dual-fuel system because only one heating source (gas) is used. Dual-fuel systems require two heating sources.

Thermostats can identify dual-fuel systems through system configuration, wiring signals, or communication with connected equipment. When a dual-fuel system is identified, thermostats can limit load shifting to electric operation and avoid shifting nonelectric heating cycles.

Building Management System Thermostats

Building management systems control the heating, ventilation, and air-conditioning systems of large office buildings. The approach differs from the wall-mounted thermostat found in homes because the user interface, control unit, and temperature sensor are separate devices. The system performance information is available for the building manager to use in decision-making relating to the overall building performance. The user interface device controls have set points that are restricted to prevent occupants from adjusting the temperature outside predetermined settings. A building management system can schedule components of the building to shut down during unoccupied times. **Figure 4-5** shows building temperature control components used in a building management system.

Figure 4-5: Building Temperature Controls Components



User Interface, Control Unit, and Temperature Sensor

Source: Honeywell/Resideo

Thermostat Capabilities and Technologies

Manual

Manual thermostats provide basic control functions to the user. The user can select heating, cooling, or ventilation and turn the equipment on and off. The user can set a temperature for the home. The manual thermostat relies on the user for inputs to alter the equipment operation. Manual thermostats represent about 22 percent for cooling systems and 33 percent for heating systems of the current installed thermostats within Californian homes.[87] **Figure 4-6** shows a manual thermostat.

87 RASS. 2019. "California Statewide Residential Appliance Saturation Study," https://www.energy.ca.gov/publications/2021/2019-california-residential-appliance-saturation-study-rass.

Figure 4-6: Manual Thermostat



Source: Honeywell/Resideo

Programmable

Programmable thermostats add the ability to store a schedule of heating and cooling temperatures and times. The schedule may be set to different temperatures at different times of day according to the preferences of the occupant while the home is occupied, vacant, or when the occupants are awake or asleep. Programmable thermostats offer ease of use to the occupant by automating the temperature adjustments. They represent about 57 percent for cooling systems and 51 percent for heating systems of the current installed thermostats in California homes.[88] **Figure 4-7** shows a programable thermostat.

Figure 4-7: Programable Thermostat



Source: Honeywell/Resideo

Connected and Smart

Connected and smart thermostats add occupant remote control and other capabilities. Manufacturers have introduced models that connect by Wi-Fi, by Bluetooth, or through an FM radio broadcast. Smart thermostats represent about 21 percent for cooling systems and 16 percent for heating systems of the current installed thermostats within Californian homes.[89]

88 Ibid.

89 Ibid.

Figure 4-8 shows a Wi-Fi connected smart thermostat and the phone app that allows remote control.

Figure 4-8: Connected and Smart Thermostat



Source: Honeywell/Resideo

Thermostat and Security System Combinations

Thermostats are sometimes combined with other systems to provide the consumer with additional benefits. Combined systems can integrate alarms with the operation of the home heating and cooling to suspend operation during an emergency such as a fire.

Temperature Control System Accessories

Some home heating and cooling systems have stand-alone temperature sensors and user interface displays in addition to thermostats. Temperature sensors and displays can be located within the conditioned space in positions that optimize functionality. The devices provide information to the thermostat for it to use to control the heating and cooling systems.

Figure 4-9 shows a thermostat user interface and a remote temperature sensor.

Figure 4-9: Thermostat User Interface — Thermostat User Interface *(left side)* and Temperature Sensor *(right side)*



Source: Honeywell

Home Energy Management System (HEMS) Integration

The user interface of a thermostat may be electronically integrated with a HEMS or smart home platform. This interface enables the exchange of data and control signals between the thermostat and other connected home devices or systems, either locally or via cloud-based services.

CHAPTER 5:
Proposed Standards

CEC staff intend for the proposed regulations to make energy in California more affordable, reliable, and better for the environment. By using energy wisely, people can lower their electricity bills and save money. Reducing energy use during high-cost times of the day helps keep the power grid strong and prevents blackouts. In addition, using cleaner energy at the right times helps cut greenhouse gas emissions and slows climate change. Together, these actions make California's energy system stronger, cleaner, and more affordable for everyone.

For these reasons, CEC staff proposes the following requirements for in-scope HVAC thermostats to meet the California Flexible Demand Appliance Standards. The proposed text is in **Appendix E:** Staff Proposed Regulation.

Based on analysis of in-scope HVAC thermostats, staff determined that the GHG emission reductions, electric grid reliability improvement, and utility bill savings under the proposed standard are substantial. The staff analysis estimates cumulative statewide benefits of $435 million (2028–2037), with each in-scope HVAC thermostat delivering about $97 in life-cycle benefits and an incremental retail cost of about $12 per unit. At full stock turnover, compliant thermostats would provide 780 MW of load shift during the 8 p.m. hour and avoid on average 50,500 metric tons of GHG emissions annually.

Using the social cost of greenhouse gases values from the U.S. Environmental Protection Agency's November 2023 report, the value of this annual GHG reduction is estimated at $15.9 million.[90] Staff also determined that the proposed standard is attainable by the proposed effective date, January 1, 2028. Further economic, energy, and environmental impacts are described in **Chapter 6**, and details on calculation methods and assumptions are in **Appendix A**.

The intent of this chapter is to provide clear explanation for why staff is making this specific proposal.

Scope and Definitions

This proposal requires in-scope thermostats (referred to here and in the proposed standards as "HVAC thermostats") to include flexible demand technology. CEC staff evaluated the flexible demand readiness of the types of thermostats used for controlling electric space-conditioning appliances. Staff reviewed the availability of products with scheduling and communication capabilities. Staff found that nearly 80 percent of in-scope HVAC thermostats available for

90 U.S. Environmental Protection Agency, Office of Policy, National Center for Environmental Economics and Office of Air and Radiation, Climate Change Division, November 2023. *Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances*, https://www.epa.gov/system/files/documents/2023-12/epa_scghg_2023_report_final.pdf.

purchase today (65 percent smart thermostats and 15 percent programmable thermostats [91]) already have basic features to incorporate the proposed capabilities with no major modifications, such as connectivity, integral memory, user interface, and so forth, as listed in the proposed standards section below. **Table 5-1** shows examples of thermostats controlling electric space-conditioning appliances that are in-scope or out-of-scope of the proposed regulation. Details on thermostat types are in **Chapter 4**.

Table 5-1: In and Out-of-Scope Thermostats for Electric Space-conditioning Appliances

In-Scope Devices ("HVAC thermostats")	Out-of-Scope Devices
Low-voltage thermostats	Millivolt thermostats
Proprietary thermostats for packaged systems, split systems	Building management system temperature controls
	Stand-alone temperature sensors
	Line voltage thermostats that serve devices other than portable corded electric resistance heaters
	Proprietary thermostat controllers that serve devices other than packaged system, split single-zone, and multi-zones system
	Portable corded electric resistance heaters
	Nonelectrical load within a dual-fuel system

Source: California Energy Commission

The proposed standards apply to low-voltage thermostats and proprietary thermostat controllers that serve one or more zones in the home using packaged or split HVAC systems. Low-voltage thermostats and proprietary thermostats serve a wide range of cooling and heating load systems. For HVAC thermostats controlling dual-fuel systems with electric cooling or heating with supplemental fossil gas heating or both, only the electric components are considered in-scope, while the fossil gas heating component is out-of-scope. Portable corded electric resistance heaters are out-of-scope. Staff proposes not to include line voltage wall-mounted thermostats because of the current and expected low installed stock count.[92] Proprietary thermostat controllers that serve portable AC units, through the wall AC, and

91 Grand View Research. *Thermostat Market Size, Share & Trends Analysis Report By Product (Smart Thermostat, Mechanical Thermostat), By End Use (Industrial, Commercial, Residential), By Region, And Segment Forecasts, 2025–2030*, https://www.grandviewresearch.com/industry-analysis/thermostat-market-report.

92 Canadian Standards Association (CSA Group). October 1, 2019. *Performance Requirements For Line Voltage Thermostats Used With Individual Room Electric Space Heating Devices*, https://www.techstreet.com/standards/csa-c828-19?product_id=2089271.

through the window AC units are out-of-scope because the proposed standards may disproportionately impact the equipment purchase price.

Millivolt thermostats are not in-scope because they do not control electric space-conditioning equipment. Building management systems are out-of-scope because the associated complexity requires a different approach for flexible demand. Stand-alone temperature sensors are out-of-scope because they do not directly control space-conditioning equipment. Staff did not consider a nonresidential application because the projected participation rate was low.

Proposed Standards Requirements

The proposed standards set minimum requirements for flexible demand capabilities in HVAC thermostats within the scope shown in **Table 5-1**. HVAC thermostats with flexible demand capability provide consumers with the option to shift when energy is used while still meeting their comfort and space-conditioning needs. A consumer could choose to reduce GHG emissions from electricity generation, lower their utility bill, or some combination of the two. A consumer could also select their preferred thermostat temperature and operation mode setting.

The proposed standards for HVAC thermostats include, but are not limited to:

- Network connectivity.
- Integral memory.
- Autoflex operating mode.
- User interface and transparency.
- Clock and persistence of settings.
- Ability to opt-in/out.
- Cybersecurity.
- Test procedure.
- Firmware and ongoing compliance.
- Marking.

How the Proposed Standards Work Together

Thermostats can shift electric heating and cooling through the operating schedules they send to HVAC equipment. The proposed standards facilitate this capability by ensuring that all in-scope HVAC thermostats can use data on the state of the electric grid to form these schedules.

The proposed standards establish an "autoflex operating mode." When this mode is turned on, thermostats use data on the state of the electric grid and consumer set point preferences to create operating schedules. For thermostats, operating schedules are commonly made up of hours of the day and indoor temperature set points. The proposed standards require that HVAC thermostats determine if an operating schedule could reduce electricity usage when the grid is stressed. If so, HVAC thermostats must create and implement an operating schedule that achieves this reduction. The proposed standards do not specify a way of achieving this

electricity reduction because different methods are available to different HVAC equipment types (single-stage, variable speed, and so forth).

Different manufacturers and automation service providers may also come up with different algorithms for converting electric grid signals and consumer settings into operating schedules. Consumers can disable autoflex at any time. These requirements are proposed in Section 1693(c)(2)(C) of **Appendix E**.

The primary source of data on the state of the grid comes from the Market Informed Demand Automation Server (MIDAS). Datasets from MIDAS contain information on hourly prices, greenhouse gas emissions, and other grid-related data. The proposed requirements provide three sources from which in-scope HVAC thermostats can access MIDAS data. The first two sources use the internet to query the MIDAS API every day. Because these datasets get updated daily, the proposed standards refer to them as "MIDAS dynamic datasets." If a consumer wants their thermostat to base the autoflex operating schedule on exactly how much they are paying for electricity, they can enter their Rate Identification Number, or "RIN." These numbers can be found in most electricity bills in the state; utilities also often provide QR codes.

If a consumer does not enter their RIN but still connects their HVAC thermostat to the internet, the proposed standards have a fallback option. The "default RIN" provides MIDAS dynamic datasets which are based on data from across the state. The requirements for how thermostats should access MIDAS data are proposed in Section 1693(c)(2)(D) of **Appendix E**.

The proposed standards place the third source of MIDAS data in the thermostat itself. Manufacturers load these "MIDAS static datasets" into the thermostats at the factory. Thus, the consumers who do not connect their thermostats to the internet can still access their flexible demand capabilities. Preloaded MIDAS datasets also give a fallback option for thermostats that get temporarily disconnected from the internet. Thermostats with some internet connectivity must be able to update the MIDAS static datasets in case the old dataset no longer reflects the overall state of the grid. The proposed requirements on what needs to be stored in the thermostat are provided in Section 1693(c)(2)(B) of **Appendix E**.

In-scope thermostats can continue to participate in demand response programs. The proposed standards require that they follow OpenADR 3.1 as Virtual End Nodes (VENs). With the consumer's consent, demand response events temporarily override the thermostat's operating schedule. After the event, or if the consumer overrides the event, the thermostat continues along the operating schedule from before the event. The proposed requirements for open standards communication and third-party demand response can be found in Section 1693(c)(2)(A), Section 1693(c)(2)(E), and Section 1693(c)(2)(F) of **Appendix E**.

The proposed standards provide other requirements to support the flexible demand capabilities of in-scope thermostats, such as those on user interface, cybersecurity, timekeeping, and persistence of settings. The following subsections detail each of the requirements in the proposed standards.

Network Connectivity

For HVAC thermostats to effectively shift load and participate in demand response programs, they should be able to connect to the internet. This section provides an overview of the requirements in the proposed standards to ensure these capabilities.

- Open standard communications:
  - HVAC thermostats must have the capability to connect to the internet.
  - They must communicate using open standards.
  - This ensures they can exchange data with the CEC's MIDAS system.
  - At a minimum, compliance with OpenADR 3.1 ensures a basic level of interoperability across all HVAC thermostats.
- MIDAS dataset retrieval and integrity
  - Internet-connected HVAC thermostats must be able to receive electricity price and GHG data from MIDAS.
  - Autoflex must be able to use two types of datasets:
    - MIDAS dynamic datasets
    - MIDAS static datasets
  - MIDAS dynamic datasets:
    - Used when the consumer connects their HVAC thermostat to the internet.
    - The consumer can enter their own RIN or use the default RIN
    - The HVAC thermostat must retrieve the dataset for that RIN at least once every 24 hours.
  - MIDAS static datasets:
    - The HVAC thermostat uses static datasets when not connected to the internet.
    - The OEM preloads the MIDAS static dataset into nonvolatile memory.
    - Static datasets can be updated from MIDAS if the HVAC thermostat connects to the internet.
  - If the HVAC thermostat loses its internet connection:
    - It keeps using the active MIDAS dataset.
    - If it cannot get an updated MIDAS dynamic dataset for 48 hours, it switches to the MIDAS static dataset.
  - HVAC thermostats must:
    - Assign version IDs and timestamps to each MIDAS dataset.
    - Keep a local history of at least seven past MIDAS datasets.
- Third-party demand response
  - HVAC thermostats must be able to participate in demand response if the consumer chooses.

    - Manufacturers must not rely on third-party services that may become discontinued.

The rationale for these requirements is as follows:

- These requirements are consistent with Senate Bill 49 by ensuring that thermostats can continually receive data on the state of the electric grid. Optimizing thermostat operation based on these data ensures that emissions associated with electricity generation are reduced and grid stability is enhanced. These functionalities are directly authorized by Public Resources Code Section 25402(e)(1).
- Consumers should have access to flexible demand technologies regardless of their access to the internet. To ensure that the greatest number of consumers can shift heating and cooling load, these requirements ensure that thermostats can optimize their usage whether they are temporarily disconnected from the internet or installed in homes without internet availability. These functionalities are directly authorized by Public Resources Code Section 25402(e)(1).
- Consumers should have access to flexible demand technologies without requiring specific information on their bill. Although RINs are not personally identifiable information, some consumers may not be comfortable disclosing them. These requirements ensure that all consumers who connect their thermostats to the internet can use day-ahead signals to optimize their heating and cooling load. Day-ahead signals provide more recent information compared to the preloaded signals. These functionalities are directly authorized by Public Resources Code Section 25402(e)(1).
- It is necessary to require interoperability because it facilitates thermostats to seamlessly exchange information with load-management program administrators. As discussed in **Chapter 2**, OpenADR 3.1 compliance ensures that demand response programs can use the same communication protocol for all thermostat events. The proposed standards do not require manufacturers to register with OpenADR and incur the registration fee. These functionalities are directly authorized by Public Resources Code Section 25402(e)(5).

Integral Memory (Non-volatile)

Thermostats need to be capable of accessing key autoflex elements at any time. Depending on internet connectivity, the thermostats may need to access data stored in their memory to continue to use autoflex. This section overviews the requirements from the proposed standards that ensure these capabilities.

Thermostats must have enough memory to store:

- MIDAS static datasets and MIDAS dynamic datasets.
- Rate Identification Numbers (RINs).
- Autoflex and demand response schedules.
- The software needed to create and use these schedules.

Manufacturers must preload the latest MIDAS static dataset by the time of final system image.

The memory must be nonvolatile, meaning:

- It must keep all data during a power outage.
- It must make the data available when power returns.

Thermostats must store MIDAS static datasets.

- When updated, the new datasets must replace the old one.

Thermostats must store consumer-entered RINs and the default RIN.

When the thermostat has an internet connection, it must:

- Get day-ahead MIDAS dynamic datasets from MIDAS.
- Store at least the seven most recent datasets.

These requirements enable the thermostats to shift load at preferred times.

- If the thermostat loses its connection, it uses the stored MIDAS static datasets and saved schedules.
- When a MIDAS dynamic dataset is available, the thermostat uses it to improve load shifting.

The rationale for these requirements is as follows:

- These requirements are consistent with Senate Bill 49 by ensuring HVAC thermostats have the necessary elements for autoflex even when they can't pull them from MIDAS through the internet. These functionalities are directly authorized by Public Resources Code Section 25402(e)(1).

Autoflex Operating Mode

Automatically generating and executing operating schedules based on data from MIDAS form the basis of the proposed standards. This section overviews the proposed requirements for "autoflex," the operating mode with these capabilities.

A thermostat must have autoflex turned on by default when shipped. Autoflex must include these features:

- Determine whether the HVAC thermostat can reduce greenhouse gas emissions or support grid reliability by changing the original operating schedule based on MIDAS data.
    - If there is such a schedule, called an "autoflex operating schedule," then the HVAC thermostat must create and implement it.
    - If not, then the HVAC thermostat does not need to create an autoflex operating schedule.
- The autoflex operating schedule must reduce electricity use during "autoflex peak hours." The method may involve varying set points, compressor speeds, or other aspects of HVAC equipment operation.
    - Autoflex peak hours are when signals within the active dataset are higher than or equal to the median value for that day. These signals can be prices, emissions, FlexAlerts, or other MIDAS data.

- The schedule may increase electricity use during nonpeak hours (also called "autoflex off-peak hours") to keep consumers comfortable.
    - This schedule can include actions like preconditioning.
- The schedule must follow consumer preferences.
    - It must follow the user's chosen temperature range (for example, 70°F to 78°F).
    - It must use the signal type the user selects (price, GHG, or another MIDAS signal).
- The schedule may not use nonelectric fuel to lower or raise electric use.
    - This prohibition stops dual-fuel systems from preconditioning with gas or other nonelectric fuels.
    - It also stops dual-fuel systems from switching to nonelectric fuels to reduce electric load.
- The consumer must be able to override any demand response event or autoflex operation. Autoflex operation shall resume midnight of the next day.
    - Turning off autoflex must not affect the normal function of the thermostat.

During setup, autoflex uses different datasets based on user choices:

- If the user connects to the internet and enters a RIN, autoflex uses the day-ahead MIDAS dynamic dataset linked to that RIN.
- If the user connects but does not enter a RIN, autoflex uses the day-ahead MIDAS dynamic dataset linked to the Default RIN which applies statewide.
- If the user does not enable connection, autoflex uses the preloaded MIDAS static dataset.

During operation, autoflex must switch datasets based on internet access:

- If the thermostat cannot connect to the internet, autoflex must use the MIDAS static dataset.
- This lets the thermostat keep shifting load even when the thermostat loses internet connection.

These features help HVAC thermostats reduce greenhouse gas emissions, support grid reliability, and lower consumer energy costs through load shifting.

The rationale for these requirements is as follows:

- These requirements are consistent with Senate Bill 49 by ensuring HVAC thermostats can schedule, shift, or curtail operations by generating load-shift schedules using GHG emission and electricity price data. Because there is a high correlation between the price signal and GHG signal, as shown in **Figure 5-1**, consumers who choose to prioritize bill savings still reduce GHG emissions associated with electricity generation. The price signal reflects marginal costs of energy generation and thus the reliability of the electricity grid. These functionalities are directly authorized by Public Resources Code Section 25402(e)(1).

- Maximum reduction of emissions and enhancement of grid reliability occurs when all Californians can use the flexible demand capabilities of their thermostats. These requirements maintain the load-shift capabilities of thermostats whether consumers choose to enter their RIN or not and whether consumers have reliable access to the internet or not. These functionalities are directly authorized by Public Resources Code Section 25402(e)(1).

User Interface and Transparency

The consumer should be able to see and change autoflex settings but remain in control of their comfort. An HVAC thermostat must have an integrated user interface capable of displaying key status and informational indicators and of allowing user control of core functions like:

- View whether autoflex is active.
- Whether to use the MIDAS static dataset, MIDAS dynamic dataset, or MIDAS dataset corresponding to a consumer-entered RIN for autoflex.
- When a demand response event is active (if enrolled in a demand response program).
- Enable or disable autoflex temporarily or permanently.
- Override autoflex operation or a demand response event for the day.
- View and adjust operating mode, schedule, and minimum and maximum allowable temperature set points.
- Adjust autoflex intensity and select price, GHG, or both as the basis for scheduling.
- Enter or modify a RIN (with affirmative user action).
- Request updates to the MIDAS static dataset.
- Price or GHG signals (with discretion on how to display the signals, such as with numbers, charts, icons, or changing colors, left to manufacturers).
- Current sensed and set point temperature.

When applicable, HVAC thermostat must indicate a notification on its user interface that a MIDAS dataset failed to update after trying for more than 24 hours. These requirements provide a user-friendly interface, promote transparency, increase consumer awareness of electrical grid behavior, and support informed participation in demand response and GHG avoidance.

The rationale for these requirements is as follows:

- The regulation promotes user awareness, transparency, and active participation in demand flexibility. Displaying clear system status information empowers consumers to make informed energy decisions that support grid reliability and emissions reduction.
- This requirement is consistent with Senate Bill 49 by ensuring an HVAC thermostat provides accessible, user-friendly on-device functionality. This allows consumers to respond effectively to price signals and GHG status. These functionalities are directly authorized by Public Resources Code Section 25402(e)(5).

- By providing visibility into autoflex status, GHG levels, electricity pricing events, and current demand response status, the thermostat interface allows consumers to choose how to align their energy use with cleaner or less expensive times, enhancing environmental and cost benefits.

Clock and Persistence of Settings

Scheduling load requires an accurate on-device clock and consistent settings. An HVAC thermostat must have the ability to maintain accurate local time to ensure that the consumer's preferred thermostat load flexibility schedules start and stop correctly and resume after a power outage correctly.

- The thermostat must accurately maintain local time for at least 72 hours during a power loss.
- The thermostat must also retain system settings and load flexibility schedules during the outage. Once power is restored, the thermostat can resume normal operation in alignment with consumer preferences.
- The thermostat must automatically synchronize the associated system clock to local time within 24 hours after connectivity is enabled.

The rationale for these requirements is as follows:

- This requirement ensures thermostats maintain accurate local time during power outages so that, when power is restored, load flexibility schedules operate as intended without manual resetting.
- Retaining local time, system settings, and load flexibility schedules during outages prevents misalignment in heating or cooling operations once service resumes, supporting demand flexibility program effectiveness.

Ability to Opt-In/Out

Consumers must remain in control of their comfort. HVAC thermostats must allow the consumer to opt-in to a demand response (DR) event or autoflex operating schedule and to create their own schedule.

An HVAC thermostat must have the capability for the consumer to:

- Opt-out of autoflex operation for the rest of the day (override) or permanently.
- Override any DR event.
- Opt-in to third-party programs such as DR programs that communicate using protocols provided in OpenADR 3.1 or the equivalent.

This requirement ensures that consumers retain full control over their thermostat preference settings.

The rationale for these requirements is as follows:

- This requirement is consistent with Senate Bill 49 by ensuring consumers can opt-out of load flexibility schedules or DR events at any time, giving them control over comfort,

operational preferences, and participation level. These functionalities are directly authorized by Public Resources Code Section 25402(e)(1).

- By combining flexibility with override controls, this requirement preserves consumer comfort while still encouraging participation in demand response and emissions-reduction programs.

Cybersecurity

An HVAC thermostat shall meet the cybersecurity, consumer consent, certification, and marking requirements specified in CCR, Title 20, Sections 1692(b), 1692(c), 1694, and 1695.

Test Procedure

An HVAC thermostat shall meet performance verification specified in CCR, Title 20, Section 1698. Data submittal requirements are specified in CCR, Title 20, Section 1696(c).

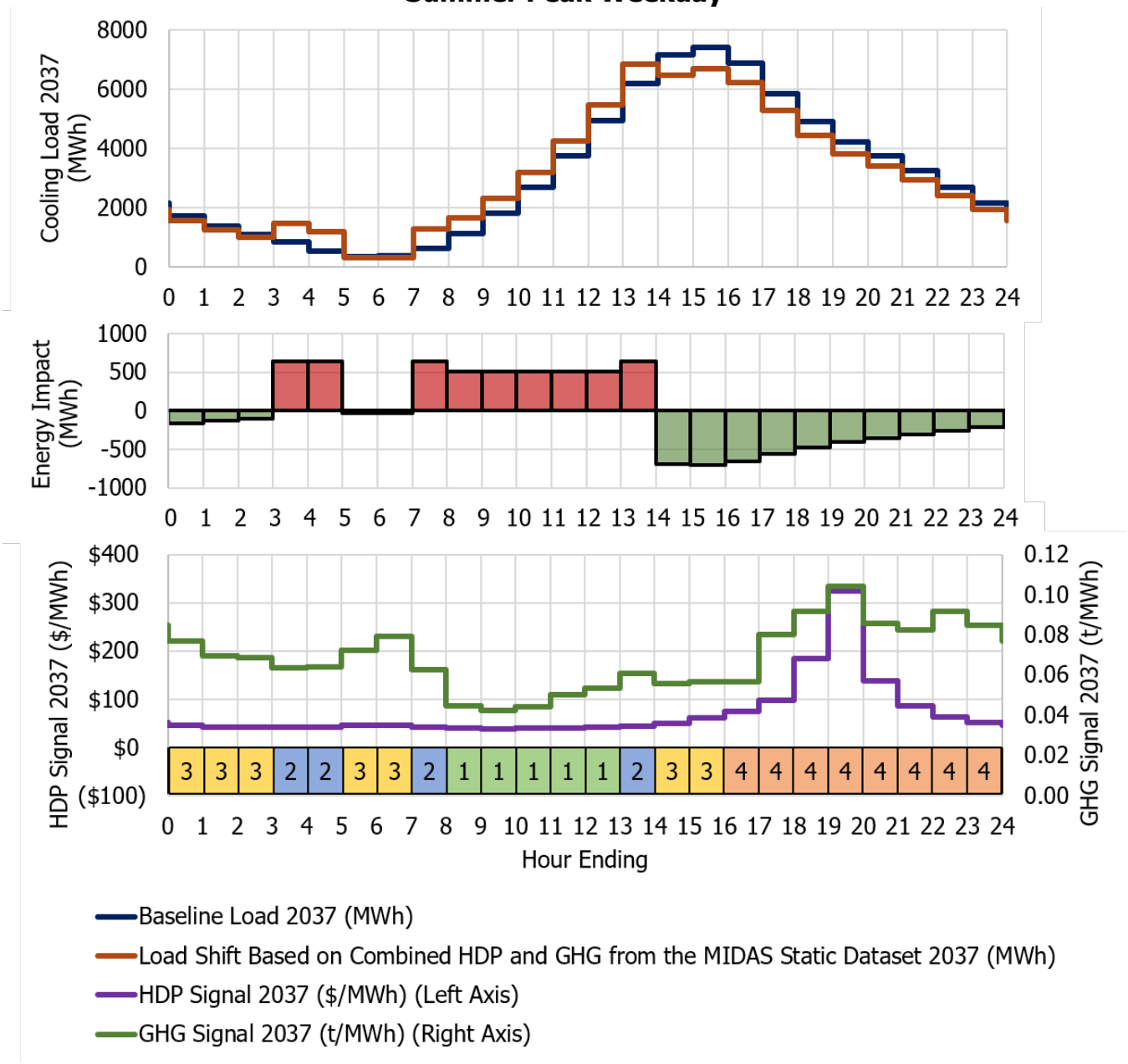
Firmware and Ongoing Compliance

Manufacturers shall submit updated certification for any firmware update that changes autoflex logic, dataset handling, fallback behavior, or update frequency. Manufacturers must also confirm that all updates do not reduce required flexible demand functionality.

Marking

No additional marking is required. See the section "Marking Requirements" in Chapter 2 for general marking requirements.

Figure 5-1: Load Shifting Based on Autoflex Combined Static and Highly Dynamic Electricity Prices and GHG Marginal Emission Rates for SCE on a Typical August Summer Peak Weekday



Source: California Energy Commission

Proposed Standards Incremental Cost

Staff estimated the incremental cost of complying with the proposed standards using a bottom-up engineering assessment of the additional hardware, software, cybersecurity, communications, testing, and certification functionality required by the PRL. The analysis estimated a manufacturer-level incremental cost ranging from about $2.00 to $12.30 per thermostat, with an average cost of approximately $7.15 per thermostat. Applying the U.S. Department of Energy (DOE) incremental retail markup factor of 1.68 results in an estimated

retail-level incremental cost of about $12 per thermostat.[93] Therefore, staff used an incremental retail cost of $12 per thermostat in the statewide cost-effectiveness analysis. Additional details regarding the individual cost components and assumptions used in the engineering assessment are provided in **Appendix A**, **Table A-15**.

Proposed Standards Impact on Consumer Comfort

Consumers use thermostats according to their own preferences. Staff found that the proposed standards keep occupants comfortable while shifting space-conditioning usage to times of lower emissions and rates. Staff used the California Building Energy Code Compliance for Residential Buildings software[94] (CBECC) to simulate the impact of load shifting. CBECC links thermostat set points to space-conditioning load and indoor home conditions. Staff used industry best practices to predict the impact on comfort. **Appendix D** provides details on CBECC and on staff methodology and assumptions.

Predicted percentage dissatisfied (PPD) is a metric commonly used to estimate consumer discomfort. It ranges from 5 percent (most comfortable) to 100 percent (least comfortable). Staff calculated PPD using ASHRAE Standard 55-2023 for both the baseline case without any load shifting and the case with an autoflex operating schedule. PPD has been criticized for overestimating the actual amount of dissatisfaction when compared to survey results, especially in homes.[95] Staff thus used the change in PPD as a conservative metric for predicting discomfort. Furthermore, staff considered load-shift strategies that increased PPD by more than 2.5 percent to be unacceptable. ASHRAE Standard 55-2023 considers an area to be in the "comfort zone" if the associated PPD is less than 10 percent, an increase of 5 percent from the most ideal conditions.

The proposed standards do not place requirements on how to create operating schedules from MIDAS data. Instead, in-scope HVAC thermostats should attempt to reduce load during peak hours. Thermostats can maintain consumer comfort by increasing heating and cooling during off-peak hours. Staff analyzed the impact of the proposed standards on consumer comfort by implementing a rudimentary load-shift algorithm: either increasing or decreasing set points by 2°F based on the MIDAS static dataset. **Appendix D** contains staff justification for considering a temperature offset of 2°F in the comfort analysis.

Figure 5-2 shows the effects of this rudimentary load-shift algorithm on modern single-family homes in some of the hottest climate zones around California. The thermostat set points

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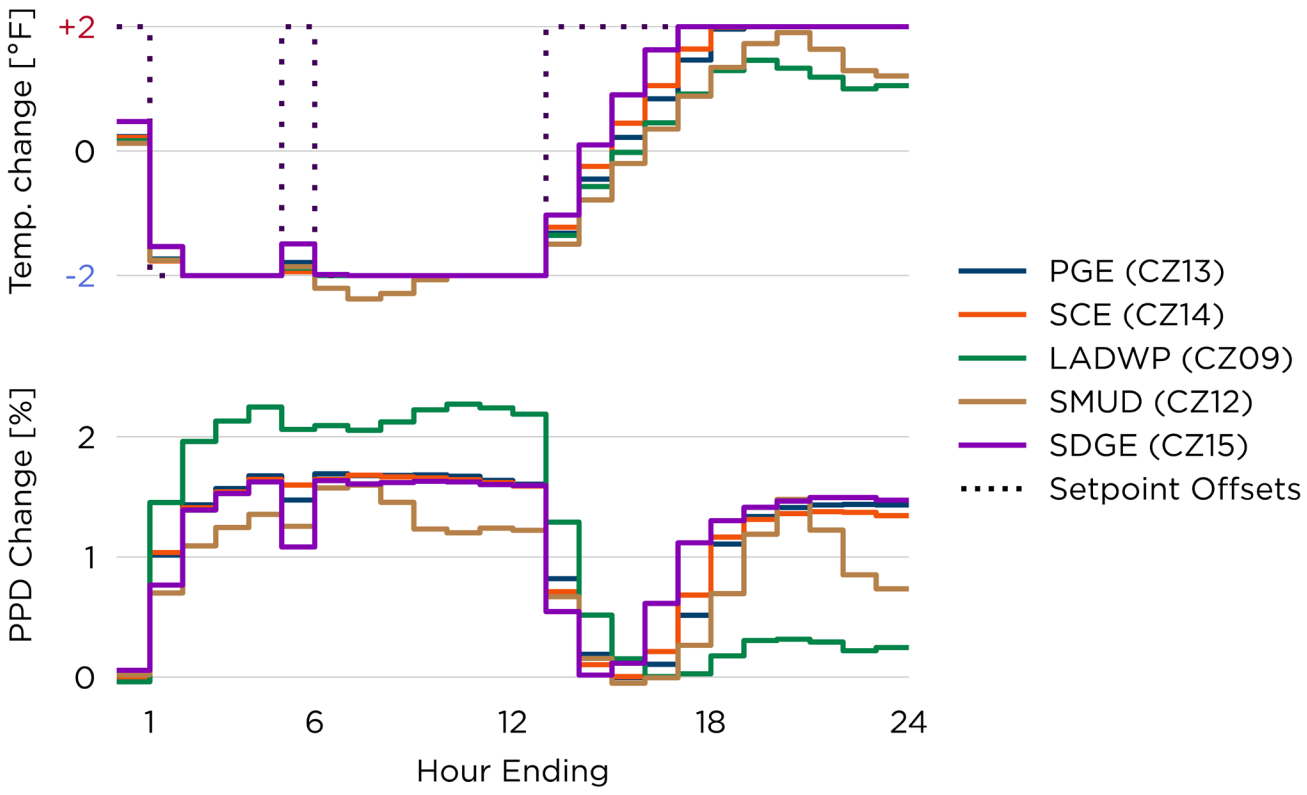
93 U.S. Department of Energy (DOE). March 2023. *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Room Air Conditioners*. Table 6.5.1, "Summary of Markups," p. 6-6, https://www.regulations.gov/document/EERE-2014-BT-STD-0059-0053.

94 CBECC 2025-2.1.1, https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2025-energy-code-compliance-software.

95 Cheung et al. April 15, 2019. "Analysis of the Accuracy on the PMV – PPD Model Using the ASHRAE Global Thermal Comfort Database II." *Building and Environment*. 153, pp. 205–217, https://www.sciencedirect.com/science/article/abs/pii/S0360132319300915. Li et al. October 1, 2020. "Improved Long-Term Thermal Comfort Indices for Continuous Monitoring." *Energy and Buildings* (2024). 224, 110270, https://www.sciencedirect.com/science/article/abs/pii/S0378778820303820.

(shown in dotted lines) were generated using the hourly price and greenhouse gas (GHG) signals from the MIDAS static dataset preloaded onto the appliances. Autoflex operating schedules precooled up to 2°F during off-peak hours and increased set points up to 2°F during peak hours. Homes in the summer usually precooled for several hours before peak periods. Then, the temperatures were allowed to increase up to 2°F above set point. Indoor temperatures stayed within +/- 2°F of the baseline set point, around 75°F depending on the climate zone. Hotter climate zones like Palm Springs (CZ15) reached the setback set point more quickly than slightly cooler climate zones like Burbank (CZ09). Compared to baseline conditions without any load shift, PPD increased at most by 2 percent, usually during the precooling periods.

Figure 5-2: Changes in Indoor Temperature and Consumer Comfort, Average Summer Day



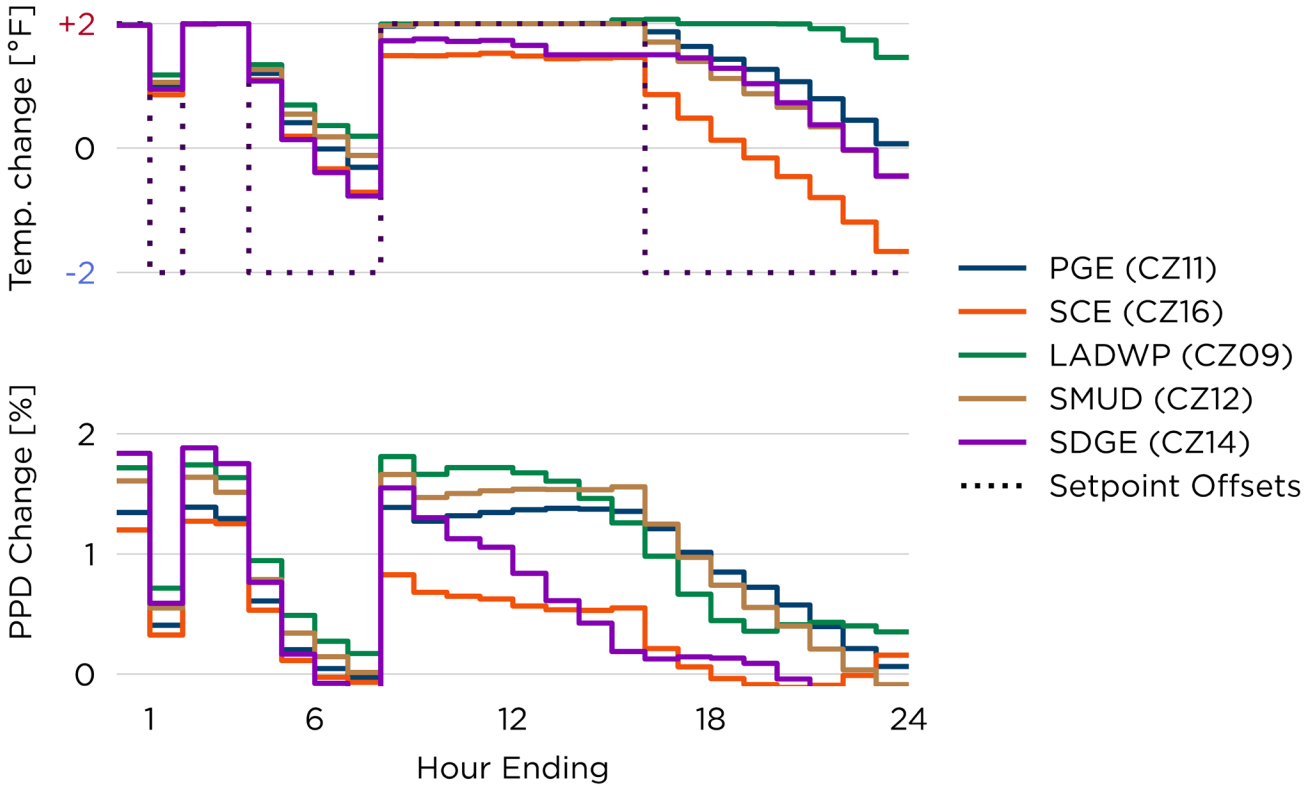
Modeled impacts of a rudimentary autoflex operating schedule for days with average summer temperatures in the hottest climate zones of each LSE service territory. The schedule shifts space-conditioning to off-peak times based on combining price and GHG signals from the MIDAS static dataset for 07/18/2024. The set point offsets (dotted lines) are +/- 2°F from the ideal set points of each climate zone (around 75 °F). The solid lines show changes in indoor temperatures. Simulations were conducted in CBECC-2025.2.0 and PPD was calculated using ASHRAE Standard 55-2023. Results are for newly constructed (2022), single-family, 1250 sq ft building prototypes from the California Prototypes Development Project.

Source: California Energy Commission

Similarly, **Figure 5-3** shows the effect of the rudimentary load-shift algorithm in some of the coldest climate zones in California. Instead of precooling, periods of loading corresponded to

preheating. During peak hours, homes gradually decreased in temperature. The baseline temperature without any load shifting was around 70°F depending on the climate zone. Changes in PPD stayed under 2 percent for all climate zones at all hours.

Figure 5-3: Changes in Indoor Temperature and Consumer Comfort, Average Winter Day



Modeled impacts of a rudimentary autoflex schedule for days with average winter temperatures in the coldest climate zones of each LSE service territory. The schedule shifts space-conditioning to off-peak times based on combining the price and GHG signals from the MIDAS static dataset for 02/03/2024. The set point offsets (dotted lines) are +/- 2°F from the ideal set points of each climate zone (around 70 °F). The solid lines show changes in indoor temperatures. Simulations were conducted in CBECC-2025.2.0 and PPD was calculated using ASHRAE Standard 55-2023. Results are for newly constructed (2022), single-family, 1250 sq ft building prototypes from the California Prototypes Development Project.

Source: California Energy Commission

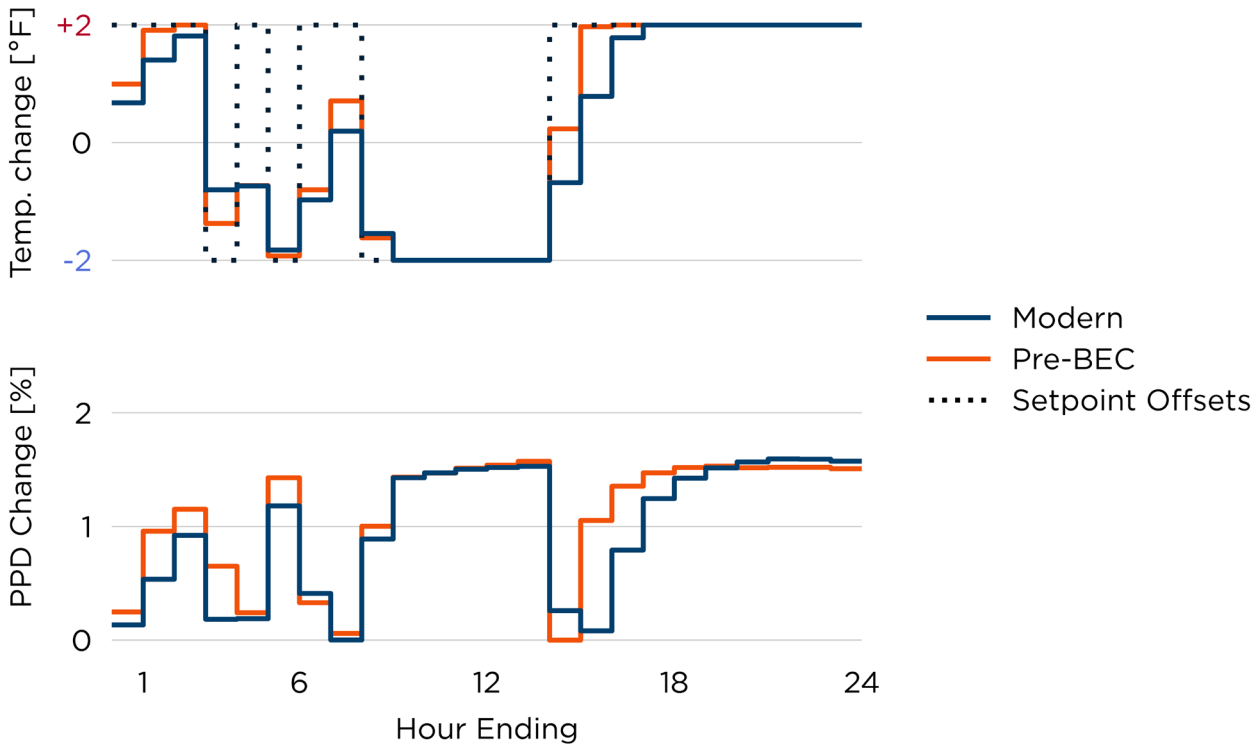
Changing set points has the least impact on comfort in well-insulated homes. CEC survey data shows that most residential buildings in California were built before 1978, when building energy codes were first established.[96] These homes have significantly worse thermal envelopes, exposing them more to changes in the weather compared to modern homes. Staff found that older homes held the precooled and preheated temperatures for shorter periods

96 According to RASS 2019, 51 percent of responses indicated their residences were built pre-1978, compared to 39 percent who indicated their homes were built afterward. Ten percent of responses did not indicate a build year.

than their more modern counterparts. **Figure 5-4** compares the performance of the proposed standards in prebuilding Energy Code (pre-BEC) and newly constructed homes on the hottest day of the year in the hottest climate zone, Palm Springs (CZ15). Staff simulated this worst-case scenario to estimate an upper limit to the impact the rudimentary load-shift algorithm could have on consumers. The precooling lasts for a shorter period in the old homes, reaching the setback temperature 1 hour later (4 p.m.) compared to 3 hours later (6 p.m.). However, in both homes, the change in PPD was less than 2 percent throughout the day.

Because cooling occurred for more hours, the percentage of load shifted for old homes was smaller compared that of new homes (28 percent vs. 45 percent). However, because older homes require more energy to cool, the staff proposal resulted in more TOU bill savings for the older home ($5.60) than for the newer home ($4.02). Staff analyzed the impact of other factors such as home size (single-story 1250 sq ft, single-story 1750 sq ft, two-story 2250 sq ft, and two-story 2750 sq ft) in **Appendix D** and found similar results.

Figure 5-4: Impact of Proposed Standards on Modern and Prebuilding Energy Code (pre-BEC) Homes in Palm Springs on the Hottest Day of the Year



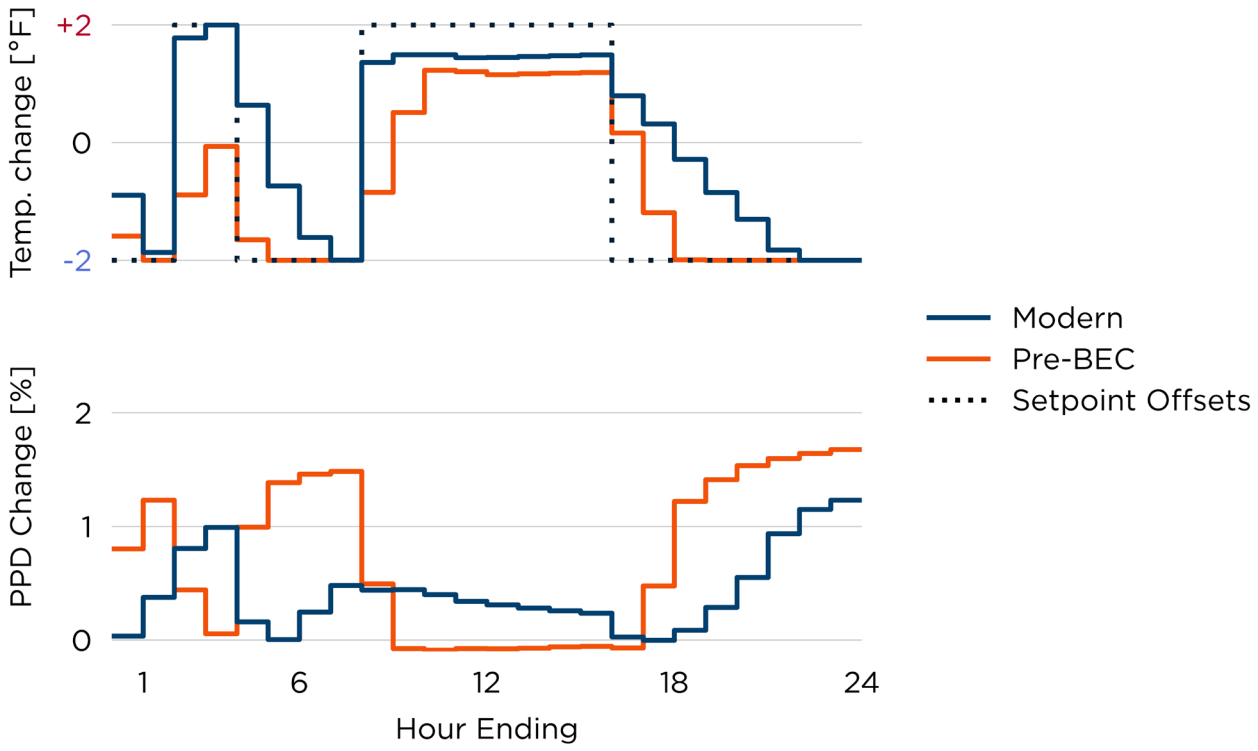
Modeled impacts of a rudimentary autoflex schedule generated by combining the price and GHG signals for Jun 20 in Palm Springs (Climate Zone 15) where the average temperature for the day is 106°F. The old home shifts 28% of its load ($5.60 in SDGE TOU bill savings) while the new home shifts 45 percent of load ($4.02 in SDGE TOU bill savings). The baseline temperature set point is 75.5°F. The dotted lines show the generated set points for the precooling and setback periods. Simulations were conducted in CBECC-2025.2.0 and PPD was calculated using ASHRAE Standard 55-2023. Pre-BEC and newly constructed modern (2022) building prototypes are the single-family 1250 sq ft homes from the California Prototypes Development Project.

Source: California Energy Commission

The rudimentary load-shift algorithm also maintains consumer comfort for the coldest days of the year. **Figure 5-5** shows the impact of the staff proposal on modern and prebuilding Energy Code homes in the coldest climate zone in California, Blue Canyon (CZ16). Like for cooling, older homes dissipate preheated energy more quickly than modern homes. The pre-BEC home reaches the setback temperature after 2 hours (7 p.m.), whereas the modern home takes 6 hours (11 p.m.). Because the indoor temperatures stay at the cooler setback temperature for longer in pre-BEC homes, the change in PPD is higher in pre-BEC homes. However, the changes in PPD stay under 2 percent.

The modeled effect of the staff proposal on electricity bills is more inconsistent for heating than for cooling. While the old home shifts 31 percent of load and saves $8.15 in TOU bills for this day, the modern home shifts 60 percent of load but gains $4.86 in TOU bills for this day. Because the modern home prototype uses a heat pump, the rudimentary load-shift algorithm causes an increase in backup electric resistance heating during the preheating periods. Staff modeled the effects of the staff proposal on homes for entire months of July and December in **Appendix D**. Staff found that on average, the staff proposal saved electricity bills. However, the rudimentary load-shift algorithm increased space-conditioning load more often in the winter.

Figure 5-5: Impact of Proposed Standards on Modern and Prebuilding Energy Code (pre-BEC) Homes in Blue Canyon on the Coldest Day of the Year



Modeled impacts of an autoflex schedule generated by combining price and GHG signals for February 4 in Blue Canyon (Climate Zone 16) where the average temperature for the day is 24.8°F. The old home shifts 31 percent of load ($8.15 in SCE bill savings), while the new home

shifts 60 percent of load (-$4.86 in SCE bill savings). The baseline temperature set point is 71°F. The dotted lines show the generated set points for the precooling and setback periods. Simulations were conducted in CBECC-2025.2.0, and PPD was calculated using ASHRAE Standard 55-2023. Pre-BEC and newly constructed modern (2022) building prototypes are the single-family 1250 sq ft homes from the California Prototypes Development Project.

Source: California Energy Commission

The differences in impacts depending on home location and build year show the need for the proposed standards to allow for customization of load-shift strategies. The same prescriptive set points will not provide the same levels of comfort throughout the state. Consumers also may have different priorities in what the load shift achieves. Residents of justice communities are more likely to live in older homes without the means to make capital-intensive upgrades on the building insulation or space-conditioning appliances. Load shifting potentially provides a way to decrease their electricity bills while making their homes more comfortable. Although the analysis using CBECC suggests that very large, daily load shifts could be possible in homes across California, staff does not prescribe its rudimentary load-shift algorithm in the proposed standards. Staff expects manufacturers and other innovators to be able to provide much better load-shift algorithms.

Any building energy simulation will use approximations in the model. For example, the California Simulation Engine (CSE) within CBECC assumes the air within a zone to be the same temperature throughout (well-mixed). Similarly, the thermostat measures the true temperature of the zone. In real buildings, the location of the thermostat in the zone can play a role in the temperature within the zone. Given the assumptions used in their modeling and the discourse on predictive discomfort metrics, staff opted to keep its analysis conservative. Underestimating negative consumer impacts would inadvertently lead to people permanently turning off all flexible demand functions.

Staff did not analyze potential long-term health effects associated with the impact on indoor temperature of the proposed standards. Space-conditioning is well-established as important for reducing mortality. Keeping indoor temperatures from reaching extremely cold or extremely hot temperatures has been found to help reduce cardiovascular and respiratory conditions, especially for older residents.[97] However, some studies suggest that constant indoor temperatures are linked to obesity and high risk of Type 2 diabetes, even suggesting that mildly cold or warm environments are actually healthy since they increase metabolism.[98] Thus, staff does not believe the proposed standards will adversely affect occupant health.

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97 Lima, F., Ferreira, P., and Leal, V. June 4, 2020. "A Review of the Relation Between Household Indoor Temperature and Health Outcomes." *Energies* 2020, 13, 2881, https://doi.org/10.3390/en13112881.

98 Van Marken Lichtenbelt, W., M. Hanssen, H. Pallubinsky, B. Kingma, and L. Schellen. April 25, 2017. "Healthy Excursions Outside the Thermal Comfort Zone." *Building Research & Information* 2017, 45:7, 819-827, https://doi.org/10.1080/09613218.2017.1307647.

Liu, G., H. Chen, Y. Yuan, and C. Song. "Indoor Thermal Environment and Human Health: A Systematic Review." *Renewable and Sustainable Energy Reviews* 2024, 191, 114164, https://doi.org/10.1016/j.rser.2023.114164.

Alternative Options for HVAC Thermostat Standards

In developing the proposed standard, CEC staff analyzed whether alternative approaches could meet the statutory goals for flexible demand appliance standards. These alternatives demonstrate the range of potential tradeoffs between consumer bill savings, GHG emissions reductions, and consumer comfort. Staff also reviewed additional alternatives suggested by interested parties or identified during the prerulemaking. These additional alternatives, along with the associated preliminary evaluation, are detailed in **Appendix D** for reference. Staff may identify more alternatives to the staff proposal with public engagement during the rulemaking.

Alternative One: Autoflex Based Only Using Highly Dynamic Electricity Prices

This alternative would require HVAC thermostats to create operating schedules based only on price signals from MIDAS. For the cost-benefit analysis, staff used the hourly electricity prices from the MIDAS static dataset to shift load, as shown in **Figure 5-6** for August 7, 2037, using HELM. Refer to **Appendix A** and **Appendix C** for more detailed information.

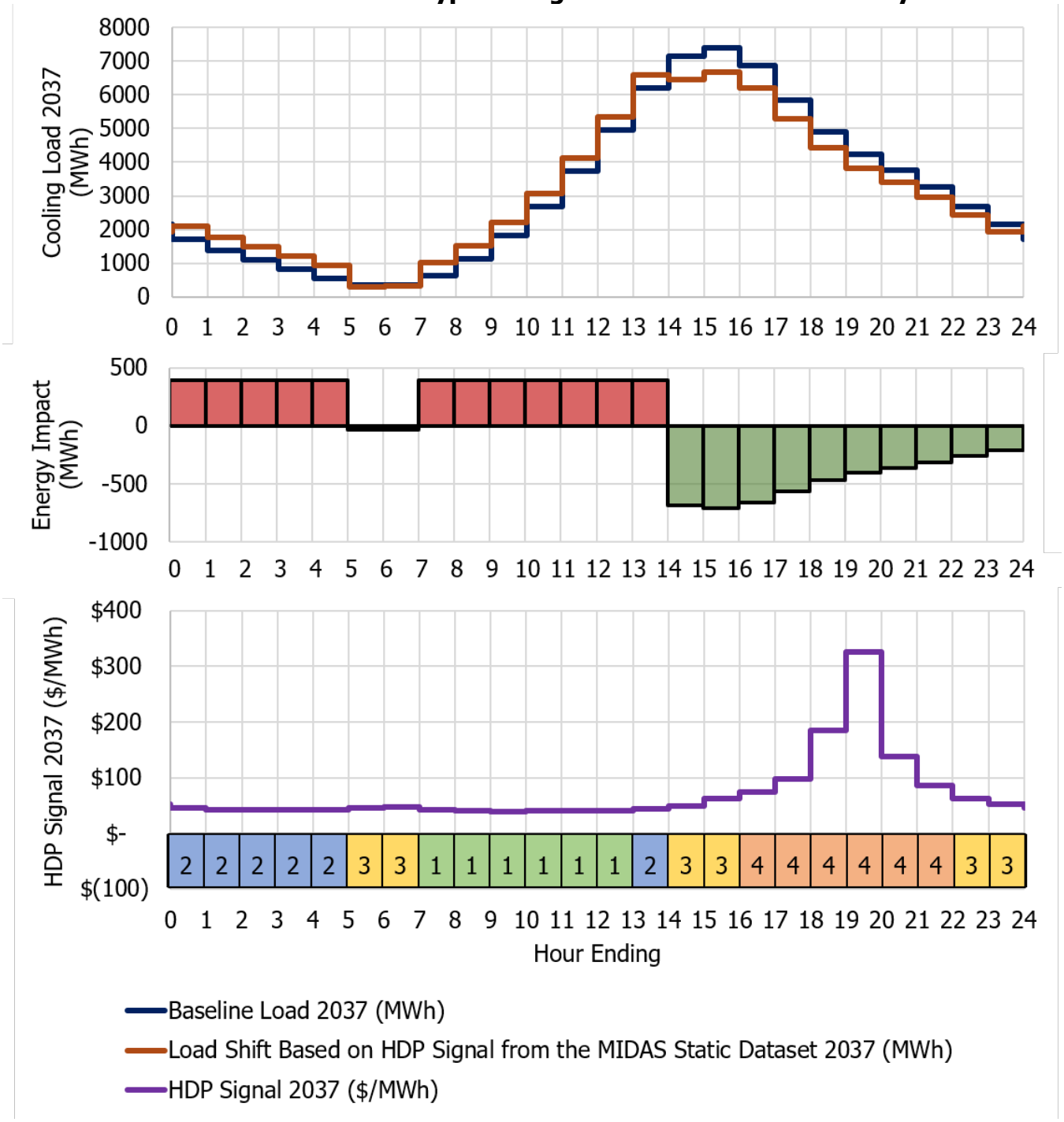
This alternative meets the legislative criteria in Public Resources Code Section 25402(e) by using the high correlation between highly dynamic electricity prices and GHG emissions associated with electricity generation. Optional highly dynamic rates, as required by the Load Management Standards (CCR, Title 20, Section 1623) for large IOUs, will be based on locational marginal cost, which is, in turn, linked to GHG emissions. However, even though this alternative reduces GHG emissions most of the year, there are a small number of hours in which the high prices do not coincide with high GHG emissions. Thus, staff's analysis shows that the staff proposal reduces more GHG emissions associated with electricity generation.

Table 5-2: Alternative One Benefits and Drawbacks

Benefits	Drawbacks
Potential for consumer bill savings by shifting one hour of load away from high-cost TOU periods	Does not achieve the same GHG emissions reductions when compared to the proposal and other alternative Misses an opportunity to align load shifting with periods of low-carbon generation, reducing overall environmental benefit Medium consumer comfort impact

Source: California Energy Commission

Figure 5-6: Load Shifting Based on Autoflex HDP Signals from the MIDAS Static Dataset for SCE on a Typical August Summer Peak Weekday



Source: California Energy Commission

Conclusion

While Alternative One could yield consumer cost savings and is technically feasible, it does not deliver the GHG reduction benefits achievable under the staff proposal. For this reason, staff does not recommend adopting Alternative One.

Alternative Two: Autoflex Based Only Using GHG Marginal Emission Rates

This alternative would require HVAC thermostats to create operating schedules based only on emission signals from MIDAS. For the cost-benefit analysis, staff used the hourly electricity prices from the MIDAS static dataset to shift load, as shown in **Figure 5-7** for August 7, 2037, using HELM. Refer to **Appendix A** and **Appendix C** for more detailed information.

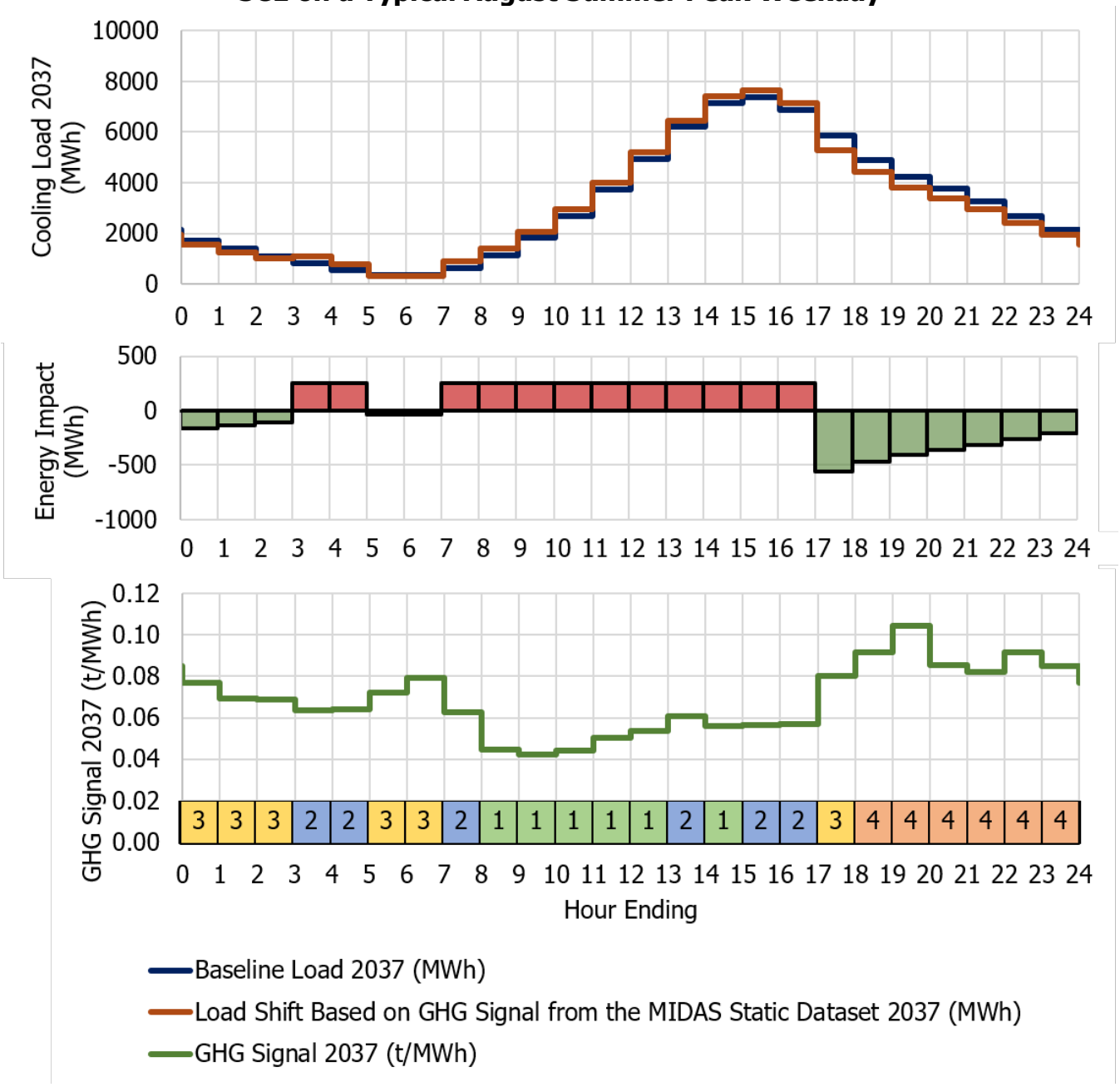
This alternative meets the legislative criteria in Public Resources Code Section 25402(e) by targeting reductions in greenhouse gas emissions. However, staff analysis shows the staff proposal is more cost-effective.

Table 5-3: Alternative Two Benefits and Drawbacks

Benefits	Drawbacks
Achieves the highest avoided GHG emissions of all alternatives	Produces the least total life-cycle consumer benefit ($77 in 2037 $ values) Could create a significant consumer comfort impact, as thermostats may preheat or precool at times that are unexpected, leading to confusion and lower acceptance Shifts load away from consumer TOU savings opportunities, making the option less cost-effective. High consumer comfort impact

Source: California Energy Commission

Figure 5-7: Load Shifting Based on Autoflex Static GHG Marginal Emission Rates for SCE on a Typical August Summer Peak Weekday



Source: California Energy Commission

Conclusion

Alternative Two offers the largest GHG emissions reduction but imposes significant consumer costs and comfort tradeoffs. Given the negative total life-cycle economic impact and reduced consumer acceptance, staff does not recommend this alternative as the adopted standard.

Comparison of Key Impacts of Proposed Standard vs. Alternatives

Table 5-4: HVAC Thermostat Staff Proposal and Alternatives

Proposal	Per Unit Total Life-Cycle Benefit (In $2026)	Statewide Load Shifted During 8 p.m. Hour Daily, 2037 (MWh)	Statewide Avoided GHG Emissions in 2037 (Thousand metric tons CO_2e) and Monetary Benefit (In $2026)
Staff Proposal: Autoflex Using the Combined HDP and GHG Signals from the MIDAS static dataset	$97	780	50 / $16M
Alternative 1: Autoflex Using the HDP Signal from the MIDAS static dataset	$86	780	39 / $12M
Alternative 2: Autoflex Using the GHG Signal from the MIDAS static dataset	$65	780	44 / $14M

Source: California Energy Commission

CHAPTER 6:
Economic, Energy, and Environmental Impacts

Overview and Findings

This chapter summarizes the economic, energy, and environmental impacts of the proposed flexible demand appliance standards for HVAC thermostats. **Appendix A** provides supporting assumptions, data sources, calculations, model inputs, and detailed results for the staff proposal and two regulatory alternatives. Results are shown for the first year of full implementation, 2028, and the complete stock-turnover year, 2037.

All technical figures, detailed calculation methods, and model graphics are presented in **Appendix A**. This chapter contains only summary tables, principal findings, and regulatory conclusions.

The proposed standards would require covered HVAC thermostats to include capabilities that allow electricity use to be scheduled, shifted, or curtailed in response to electricity prices, marginal greenhouse gas emission signals, demand-response events, and other authorized grid signals. The standards are intended to shift electricity use from higher-cost, higher-demand, or higher-emission hours to lower-cost, lower-demand, or lower-emission hours while preserving consumer control over thermostat operation.

Staff estimates that the standards would add an average of $12 to the retail price of a covered thermostat. The estimated statewide gross compliance cost is $8.38 million in 2028. These gross costs are below the $50 million major-regulation threshold. Staff therefore concludes that the proposed standards are not a major regulation. Staff assumes a January 2027 filing date, a January 2028 effective date, and a January 2029 full-implementation date. The major-regulation review period used in this DSR ends in January 2029.

The standards enable a shift in electricity load within the same day and do not reduce annual electricity consumption. Staff therefore assumes no annual utility revenue loss. Customer bill savings result from moving electricity use to lower-priced hours under time-varying rates.

The energy analysis shows that the standards would support the load-shifting purposes of Senate Bill 49. The environmental analysis shows net statewide reductions in greenhouse gas emissions and criteria air pollutants. The standards would not require construction, early replacement of existing thermostats, or substantial changes in product materials or waste. Staff therefore recommends a finding that the standards are exempt from the California Environmental Quality Act under the Class 7, Class 8, and common-sense exemptions.

Economic Impacts

Incremental Compliance Cost

Staff estimates that the proposed requirements would increase the retail price of a covered thermostat by an average of $12. This estimate is based on a manufacturer-level midpoint cost of $7.15 per unit and an incremental retail markup factor of 1.68 as shown in **Table 6-1**.

The estimate includes memory, clock and persistence, cybersecurity, OpenADR compliance, firmware and cloud functions, user-interface changes, certification, testing, and related retail-distribution effects.

The $12 cost is used once in the statewide gross-cost calculation. Staff does not add the individual cost components again as separate statewide costs because they are already included in the per-unit estimate.

Table 6-1: Incremental Cost Summary

Cost measure	Estimate ($2026/unit)	Use in analysis
Manufacturer-level low estimate	$2.00	Supporting range
Manufacturer-level high estimate	$12.30	Supporting range
Manufacturer-level midpoint	$7.15	Basis for retail estimate
Retail-level midpoint	$12.00	Base-case gross compliance cost

Source: California Energy Commission

Gross-Cost Major-Regulation Determination

Staff evaluates the major regulation threshold using gross regulatory costs before benefits. Utility-bill savings, avoided electricity-system costs, climate benefits, health benefits, reliability benefits, and broader economic benefits are reported separately and are not deducted from gross costs for this determination.

Staff assume that the proposed regulation will be filed with the Secretary of State in January 2027, become effective in January 2028, and be fully implemented in January 2029 as shown in **Table 6-2**. For this DSR analysis, the major-regulation review period begins in January 2027 and ends in January 2029. Staff estimates that gross regulatory costs remain below $50 million throughout this period.

The 2037 analysis year represents full stock turnover based on the assumed 10-year thermostat life. It is used to evaluate long-term energy, environmental, consumer, and economic effects and is not the full-implementation date or the end of the major-regulation review period.

Table 6-2: Regulatory Timeline

Regulatory milestone	Date
Estimated filing with the Secretary of State	January 2027
Effective date	January 2028
Full implementation	January 2029
End of major-regulation review period	January 2029

Source: California Energy Commission

Total annual gross economic cost equals the sum of incremental covered-product cost and separate costs outside the incremental cost estimate. Staff estimates the total gross economic cost to be $8.38 million in 2028. Details of the calculation are provided in the Gross Compliance-Cost Calculation subsection of **Appendix A**. As shown in **Table 6-3**, the estimated gross economic cost is well below the $50 million threshold.

Table 6-3: Gross-Cost Major-Regulation Threshold Comparison

Gross-cost category	2028 ($ millions)
Incremental covered-product cost	$8.33
Separate costs outside the incremental cost estimate	$0.05
Total gross economic cost	$8.38
Major-regulation threshold	$50.00
Amount below threshold	$41.62

Source: California Energy Commission

The flexible demand appliance standards for the HVAC thermostat proposed by the staff are not a major regulation. The proposed rule will not have an economic impact on California business enterprises and individuals in an amount exceeding $50 million in any 12-month period between the date the regulation is estimated to be filed with the Secretary of State through 12 months after the regulation is fully implemented. As noted in Chapter 2, compliance with the proposed requirements is January 1, 2028, or one year after the date of adoption, whichever is later.

Once compliance is required, the rule is fully implemented. Therefore, the proposed rule would be major if it had an economic impact of $50 million or more between the date of adoption and one year after compliance is required, that is, two years after adoption. As demonstrated by **Table A-32** in **Appendix A**, there is no 12-month period during the first year

implementation window where the proposed regulation has an economic impact exceeding $50 million. Therefore, the proposed rule is not a major regulation.

Consumer Bill Savings and Cost-Effectiveness

Consumers on time-varying electricity rates may reduce their bills by shifting thermostat-controlled electricity use to lower-priced hours. The standards do not assume a reduction in annual electricity use. Staff estimates annual consumer utility-bill savings of $7.4 million in 2028 and $79.5 million in 2037 for the staff proposal.

For an individual thermostat, staff estimates about $109 in undiscounted utility-bill savings over a 10-year useful life. The estimated present value of those savings is about $100 using a 2 percent annual discount rate. These benefits exceed the $12 incremental retail cost under the staff proposal as summarized in **Table 6-4**.

Table 6-4: Consumer Cost and Benefit Summary

Measure	2028 or Full Implementation	2037 or lifecycle
Annual statewide utility-bill savings	$7.4 million	$79.5 million
Annual gross thermostat cost	$8.33 million	$8.56 million
Undiscounted cumulative bill savings per thermostat	$10.7	$109.1
Present value of cumulative bill savings per thermostat	$10.7	$99.9
Incremental retail cost per thermostat	$12	$12

Source: California Energy Commission

Private-Sector and Business Impacts

The proposed standards would affect HVAC thermostat manufacturers, retailers, distributors, purchasers, utilities, and related service providers. Manufacturers would incur costs to add memory, software, cybersecurity, communications, testing, certification, and other required capabilities. Staff assumes these costs are reflected in the estimated $12 incremental retail price and does not add them again as separate statewide costs.

Retailers and distributors may incur limited administrative costs to confirm that covered products are certified and listed in the Energy Commission's database. These costs are expected to be small and, to the extent they are reflected in the retail markup, are included in the $12 per-unit estimate.

Purchasers of compliant thermostats would pay a higher initial purchase price but may receive savings on electricity bills by shifting electricity use to lower-priced hours. Staff estimates that lifetime utility-bill savings exceed the incremental purchase cost for participating customers.

The proposed standards are not expected to materially change the total number of thermostats sold or require the creation or closure of businesses. The standards may increase demand for software, cybersecurity, certification, testing, communications, and demand-response services.

Utilities are not expected to experience an annual loss in electricity sales or revenue because the standards shift electricity use within the same day without reducing total annual consumption. Utilities may benefit from lower peak demand and avoided generation, transmission, distribution, and other electricity-system costs.

Appendix A provides detailed calculations and assumptions for private-sector costs and benefits, affected business categories, consumer savings, and utility economic impacts.

Utility Revenue and Electricity Sales

The proposed standards shift electricity use from autoflex peak hours to autoflex off-peak hours within the same day. The load-shifting model maintains the same total annual electricity consumption before and after the shift. Because annual electricity sales and physical generation are unchanged, staff assume that annual utility revenue loss is zero. Customer bill savings arise from changes in the timing of electricity use under time-varying rates, not from a reduction in total annual electricity consumption.

Energy Impacts and Senate Bill 49

Load-Shifting Capability

Senate Bill 49 directs the Energy Commission to develop flexible demand appliance standards that simplify the scheduling, shifting, or curtailment of appliance electricity demand. The proposed thermostat standards advance this purpose by enabling covered products to receive and use price, marginal greenhouse gas, demand-response, and other authorized grid signals.

The proposed capabilities allow covered thermostats to precondition a home, reduce heating or cooling demand during critical hours, and restore normal operation after the event. Consumers retain the ability to opt in, opt out, or override automated operations. The standards also include requirements for timekeeping, data retention, communications, cybersecurity, and consumer controls.

Energy Modeling Results

Staff compared baseline residential HVAC load shapes with reshaped load profiles for the staff proposal and two alternatives. The model shifts electricity use between hours while maintaining annual energy balance. The primary energy effect is therefore a change in when electricity is used, not a reduction in total annual electricity consumption.

Table 6-5 summarizes the estimated 8 p.m. hour load-shift potential on the highest-demand summer day (August 7) for Year 1 (2028) and Year 10 (2037) across the three scenarios. The

estimated load-shift potential is the same for all scenarios because the comparison is based on a single peak hour, which is identified as a load-reduction hour by the HDP and GHG control signals. In addition, the same load-shifting percentage is applied across all scenarios during this hour. Although the peak-hour load-shift potential is identical, the staff proposal identifies a greater number of suitable load-shifting hours throughout the year by combining HDP and GHG signals. As a result, it provides greater consumer utility bill savings and greenhouse gas reductions than either alternative, as shown in **Table 6-4**. Additional details on the load-shifting methodology for each scenario are provided in Section II of **Appendix A**.

Table 6-5: Key Energy Results Across Scenarios

	8 p.m. load-shift potential on highest-demand summer day - August 7th Weekday (MW)	
Scenarios	**Year 1 (2028)**	**Year 10 (2037)**
Staff Proposal: Autoflex HDP + GHG	78	780
Alternative 1: Autoflex HDP	78	780
Alternative 2: Autoflex GHG	78	780

Source: California Energy Commission

Contribution of the Staff Proposal to the Senate Bill 846 Load-Shift Goal of 7,000 MW by 2030

Senate Bill 846 established a statewide load-shift goal of 7,000 MW by 2030, as documented in the Senate Bill 846 Load-Shift Goal Report (May 2023).[99] To estimate the contribution of the staff proposal toward this goal, staff calculated the average load reduction during the 100 hours with the highest net system load for each analysis year. The hourly load impacts for 2028 (Year 1) and 2037 (Year 10) were obtained from the hourly energy impact analysis, while the corresponding top 100 net system load hours were identified using the NREL Cambium Mid Case dataset for each year.[100] The estimated contribution for 2030 was then obtained by linearly interpolating between the 2028 and 2037 results.

Table 6-6 summarizes the estimated contribution of the staff proposal to the statewide load-shift goal. The results indicate that the staff proposal is projected to contribute about 64 MW in 2028, 177 MW in 2030, and 572 MW in 2037, based on the average load reduction during the 100 highest net system load hours in each year.

99 Neumann, Ingrid and Erik Lyon. May 2023. *Senate Bill 846 Load-Shift Goal Report*. California Energy Commission.

100 National Renewable Energy Laboratory, "Cambium Scenario Viewer" (Mid-case Scenario, Hourly, GEA regions), https://scenarioviewer.nlr.gov.

Table 6-6: Estimated Contribution of the Staff Proposal to the Senate Bill 846 Load-Shift Goal of 7,000 MW by 2030

Year	Average HVAC Load Reduction During Top 100 Net System Load Hours (MW)
2028	63.7
2030	**176.7**
2037	572.2

Source: California Energy Commission

Grid and Consumer Benefits

Shifting residential HVAC load away from critical hours can reduce demand during higher-cost and higher-emission periods. The modeled benefits include avoided generation, transmission, distribution, losses, methane leakage, and other electricity-system costs. The results are summarized in **Table 6-7**. These benefits are reported separately from gross regulatory costs.

Table 6-7: Estimated Avoided Electricity-System Costs

Avoided-cost category	2028 ($ millions)	2037 ($ millions)
Generation Capacity	$10.07	$29.65
Transmission	$3.22	$35.10
Distribution	$0.07	$34.27
Ancillary Services Procurement	$0.00	$0.00
Losses	$0.27	$4.92
Methane Leakage	$0.40	$24.24

Source: California Energy Commission.

Staff concludes that the proposed standards comply with and advance Senate Bill 49 because they establish practical capabilities that allow covered thermostats to schedule, shift, or curtail electricity demand while preserving consumer control.

Environmental Impacts

Greenhouse Gas Emissions and Climate Benefits

Electricity generation has different greenhouse gas impacts depending on the hour and the marginal generating resource. By shifting electricity use from higher-emission hours to lower-emission hours, the proposed standards are expected to reduce statewide greenhouse gas emissions without reducing annual electricity consumption.

Table 6-8 shows the estimated annual GHG emissions avoided under the staff proposal and two alternatives in 2028 and 2037. Staff calculated climate benefits by multiplying avoided greenhouse gas emissions by the applicable social cost of carbon, and the results are summarized in **Table 6-9**.

Table 6-8: Key Emission Results Across Scenarios

	Annual GHG avoided (thousand metric tons)	
Scenarios	**Year 1 (2028)**	**Year 10 (2037)**
Staff Proposal: Autoflex HDP + GHG	28	50
Alternative 1: Autoflex HDP	22	39
Alternative 2: Autoflex GHG	24	44

Source: California Energy Commission

Table 6-9: Annual Statewide GHG Reductions and Climate Benefits

Year	Annual GHG Avoided (in Thousand Metric Tons)	Annual Climate Benefit of GHG Avoided (Millions, $2026/yr)
2028	27.8	$7.6
2037	50.5	$15.9

Source: California Energy Commission

Air Quality and Public Health

Staff used the U.S. Environmental Protection Agency's AVERT model to estimate changes in power-sector emissions and the COBRA model to estimate related public-health benefits. AVERT estimates physical emission changes, and COBRA estimates health effects and avoided health costs. The AVERT output for statewide criteria air pollutant (CAP) reductions is shown in **Table 6-10**.

Table 6-10: Statewide Air-Pollutant Reductions

Pollutant	2028 avoided (tons)	2037 avoided (tons)
PM2.5	0.73	6.27
SO2	0.94	7.61
NOx	4.44	36.12
VOC	0.25	2.26
NH3	0.53	4.95

Source: California Energy Commission

COBRA estimates combined avoided health costs of about $0.77 million in 2028 and $6.41 million in 2037 for fine particulate matter and ozone. These benefits include avoided mortality, hospital admissions, emergency-room visits, asthma impacts, work-loss days, and other health outcomes.

Some locations may show modeled increases in individual pollutants even when the statewide result is a net reduction. **Appendix A** documents the county-level review and supporting assumptions.

Product Life, Materials, and Waste

The proposed standards do not require consumers to replace existing thermostats before the end of the useful lives. Existing products may remain in use, and the standards do not establish an early-replacement requirement.

The standards do not require a specific housing material, manufacturing process, or product-body design. Most requirements relate to software, memory, communications, controls, cybersecurity, certification, and product marking. Staff does not expect these requirements to materially increase waste generation or demand for raw materials.

Required product information may be added using existing marking methods. Staff does not expect the marking requirement to cause a significant environmental effect.

CEQA Exemption Analysis

Basis for Exemption

Staff conclude that the proposed standards are exempt from the California Environmental Quality Act under the Class 7 and Class 8 categorical exemptions in CEQA Guidelines sections 15307 and 15308. These exemptions apply to regulatory actions taken to protect natural resources and the environment.

The proposed standards are intended to reduce greenhouse gas emissions and air pollution associated with electricity generation by shifting HVAC thermostat electricity use from higher-demand, higher-cost, or higher-emission periods to lower-demand or lower-emission periods. The standards also support grid reliability and the use of renewable and other lower-carbon electricity resources.

The proposed standards do not authorize construction, require early replacement of existing thermostats, mandate a specific product material, or require substantial changes to manufacturing plants or infrastructure. The expected physical environmental effects are beneficial.

The proposed standards also qualify for the common-sense exemption in CEQA Guidelines Section 15061(b)(3). Based on staff's analysis, it can be seen with certainty that the proposed regulatory action would not have a significant adverse effect on the environment.

Exceptions and Facts

Staff considered the exceptions to categorical exemptions listed in CEQA Guidelines section 15300.2 and found that none apply. The proposed standards:

- Do not authorize development in environmentally sensitive locations.
- Would not result in cumulatively considerable adverse effects.
- Do not involve unusual circumstances that create a reasonable possibility of a significant adverse environmental effect.
- Would not affect scenic resources, historical resources, or hazardous-waste sites.
- Do not require early product replacement or materially increase waste.
- Are expected to reduce statewide greenhouse gas and criteria air pollutant emissions.

Appendix A provides supporting calculations, assumptions, and model results for greenhouse gas emissions, air pollutants, public-health benefits, product useful life, materials, and waste.

CEQA Conclusion

Staff have tentatively concluded that the proposed standards are exempt from CEQA under CEQA Guidelines Sections 15307, 15308, and 15061(b)(3), and that none of the exceptions in Section 15300.2 apply.

ACRONYMS

AB	Assembly Bill
AMI	Advanced Metering Infrastructure
BEA	Bureau of Economic Analysis
California EPA	California Environmental Protection Agency
California ISO	California Independent System Operator
California HSC	California Health and Safety Code
CAP	criteria air pollutant
CARB	California Air Resources Board
CARE	California Alternate Rates for Energy
CCA	community choice aggregator
CCR	California Code of Regulations
CEC	California Energy Commission
CEQA	California Environmental Quality Act
CO_2	carbon dioxide elemental gas
CO_2e	carbon dioxide equivalent
CPUC	California Public Utilities Commission
DACAG	Disadvantaged Communities Advisory Group
DER	distributed energy resources
DR	demand response
EAD	Energy Assessments Division of the CEC
FDAS	Flexible Demand Appliance Standards
GHG	greenhouse gas
GWh	gigawatt-hour
IEPR	Integrated Energy Policy Report

IOU	investor-owned utility
kW	kilowatt
kWh	kilowatt-hour
LADWP	Los Angeles Department of Water and Power
LVT	low-voltage thermostat
LSE	load-serving entity
MCI	Modular Communications Interface
MIDAS	Market Informed Demand Automation Server
MT	metric ton
MW	megawatt
MWh	megawatt-hour
NO_2	nitrogen dioxide elemental gas
NO_x	oxides of nitrogen
NPV	net present value
NREL	National Renewable Energy Laboratory
OIR	order instituting rulemaking
OpenADR	open automated demand response
PG&E	Pacific Gas and Electric Company
PM	Particulate matter
POU	publicly owned utility
PST	Pacific Standard Time
RASS	Residential Appliance Saturation Study
RPS	Renewable Portfolio Standards
SB	Senate Bill
SCC	Social cost of carbon (SCC)
SCE	Southern California Edison

SDG&E	San Diego Gas & Electric
SGIP	Self-Generation Incentive Program
SMUD	Sacramento Municipal Utility District
SoCalGas	Southern California Gas Company
TCP/IP	Transmission Control Protocol/Internet Protocol Suite
TDV	time-dependent valuation
TOD	time-of-day
TOU	time-of-use
U.S. DOE	United States Department of Energy
U.S. EIA	United States Energy Information Administration
U.S. EPA	United States Environmental Protection Agency
UC	University of California

GLOSSARY

This glossary includes basic definitions of some of the terms used in this staff report.

A BALANCING AUTHORITY — An entity responsible for operating a transmission control area. It matches generation with load and maintains consistent electric frequency of the grid, even during extreme weather conditions or natural disasters. In California, there are eight balancing authorities, the largest of which are the California Independent System Operator, the Balancing Authority of Northern California, and Los Angeles Department of Water and Power.

ADVANCED METERING INFRASTRUCTURE (AMI) — An integrated system of smart meters, data management systems, and communication networks that enable two-way communication between the utilities and the customers. AMI makes two-way communications with customers possible and is the backbone of a smart grid.

ANNUAL STOCK SAVINGS — The annual benefits savings achieved after all existing stock in use complies with the proposed standards, in this case, in 2037.

APPLICATION PROGRAM INTERFACE (API) — An interface that is accessible from application programs or user code and provides well-defined functionality.

AUTOFLEX — An operating mode of an appliance that automatically generates and implements an autoflex operating schedule.

AUTOFLEX DATASET — The dataset currently used for the generation of an autoflex operating schedule. The appliance may update the autoflex Dataset using the MIDAS application programming interface when internet connectivity is enabled and available. The autoflex Dataset shall consist of either the MIDAS static dataset or the most recent MIDAS dynamic dataset corresponding to the default RIN or the most recent MIDAS dataset corresponding to the active RIN.

AUTOFLEX OPERATING SCHEDULE — An operating schedule that adjusts how and when associated equipment operates to reduce electricity usage during peak hours, can be modified or disabled by the consumer, and is based on an autoflex dataset. The autoflex operating schedule may increase the electricity usage during off-peak hours to reduce overall costs.

BLOCKCHAIN — A growing list of records, called *blocks*, that are linked together. Each block contains a hash of the previous block, a timestamp, and transaction data.

BRITISH THERMAL UNIT (BTU) — A unit of heat energy. One Btu is equal to the amount of energy required to raise the temperature of 1 pound of water by 1 degree Fahrenheit at sea level. One Btu is equivalent to 252 calories, 778 foot-pounds, 1,055 joules, or 0.293 watt-hours.

CALENVIROSCREEN — A screening method that can be used to help identify California communities that are disproportionately burdened by multiple sources of pollution. The CalEnviroScreen tool combines different types of census tract-specific information into a score to determine which communities are the most burdened or disadvantaged.

CALIFORNIA ENVIRONMENTAL QUALITY ACT (CEQA) — A California statute passed in 1970 that requires disclosure to the public of the significant environmental effects of a proposed discretionary project, through the preparation of an initial study, negative declaration, mitigated negative declaration, or environmental impact report.

CARBON INTENSITY — A measure of greenhouse gas emissions by weight per unit of energy. A common measure of carbon intensity is grams of carbon dioxide equivalent greenhouse gases per megajoule of energy (gCO_2e/MJ).

CARBON NEUTRALITY — means the point at which the removal of carbon pollution from the atmosphere meets or exceeds emissions.

CLEAN ENERGY RESOURCE — For this report, sustainable and renewable clean energy resources include solar, wind, geothermal, and hydropower.

CO_2e (CARBON DIOXIDE EQUIVALENT) — A measure used to compare emissions from various greenhouse gases based upon the related global warming potential. The carbon dioxide equivalent for a gas is derived by multiplying the mass of the gas by the associated global warming potential.

COMMUNITY CHOICE AGGREGATOR (CCA) — Entities that serve electricity needs of customers within their jurisdiction through the aggregation of those customers' electric loads, as defined in Public Utilities Code Section 331.1.

CONNECTED DEVICE — Any device that can be wired or wireless and communicate via open standards with entities outside the device by means of integrated or separate communications hardware or software. A device that is able to receive but not send communication is not a connected device. Connected devices can connect to the internet.

CONSUMER – The end user of an appliance; a consumer may also be a customer of an electric utility. See also "customer".

CRITERIA AIR POLLUTANT — An air pollutant for which acceptable levels of exposure can be determined and for which the U.S. Environmental Protection Agency has set an ambient air quality standard. Examples include ozone (O_3), carbon monoxide (CO), nitrogen oxides (NO_x), sulfur oxides (SO_x), and particulate matter (PM_{10} and $PM_{2.5}$).

CTA 2045 — ANSI/CTA 2045 specifies a modular communications interface (MCI) to facilitate communications with residential devices for applications such as energy management.

CURTAIL – A temporary and immediate action taken to reduce or restrict use of electricity. Flexible demand standards for appliances provide a means to meaningfully shift load-take to periods where renewable electricity generation is abundant. Current practice is to curtail excess renewable supply to the grid, favoring non-renewable generation.

CUSTOMER – A purchaser of service from an electric utility; a customer may also be the consumer of an appliance. See also "consumer".

CYBERSECURITY — A set of practices to protect computers, digital devices, and networks from digital attack.

DEFAULT RIN — The Commission-designated RIN corresponding to the MIDAS dynamic dataset. Used when a consumer-entered RIN is not available.

DECARBONIZATION — Activities that reduce GHG emissions, such as reducing or removing fossil gas use in buildings or replacing fossil fuel-generated electricity with renewable electricity from sources like solar or wind.

DEMAND FLEXIBILITY — The practice of managing customer electricity usage in response to economic incentives, as well as avoidance of greenhouse gas emissions.

DEMAND RESPONSE — The capability to reduce, increase, or shift electric loads in response to authorized demand response events. This capability includes, but is not limited to, automatically adjusting set points, schedules, or operating modes.

DEMAND RESPONSE EVENT — A time-limited signal initiated by a utility, grid operator, or authorized program administrator in response to electric grid stress, peak demand conditions, or system congestion. Events may include a preconditioning period, a load reduction period, and a recovery period.

EQUITY — The fair treatment, meaningful involvement, and strategic investment of resources through clean transportation programs, incentives, and processes for all Californians so that race, color, national origin, or income level are not barriers to increased opportunities and participation.

ESTIMATED USEFUL LIFE (EUL) — The average period that a product class of appliances or devices will perform the intended function fully, given proper care and maintenance.

FLEX ALERT — A demand response event called by the California Independent System Operator to request that customers reduce demand in response to a reliability event such as exceptionally high system load or a transmission emergency.

FLEXIBLE DEMAND — The capability to schedule, shift, or curtail the electrical demand of a load-serving entity's customer through direct action by the customer or through action by an appliance in autoflex mode, a third party, a load-serving entity, or a grid balancing authority, with the customer's consent.

FOSSIL GAS — A hydrocarbon gas found in the earth composed of methane, ethane, butane, propane, and other gases.

GIGATON — A unit of weight equal to 1 billion tons.

GIGAWATT-HOUR (GWh) — A unit of energy representing 1 billion (1,000,000,000) watt-hours and is equivalent to 1 million kilowatt-hours. A single watt-hour is a measure of electrical energy equivalent to a power consumption of 1 watt for 1 hour. A kilowatt-hour (kWh) is a unit of energy equal to 1 kilowatt of power sustained for 1 hour or to 3,600 kilojoules (3.6 megajoules). 1 million watt-hours = 1 megawatt-hour (MWh).

GLOBAL WARMING POTENTIAL — a metric that allows comparisons of the global warming impacts of different gases. It is a measure of how much energy the emissions of 1 ton of a gas will absorb over a given period, relative to the emissions of 1 ton of carbon dioxide. The larger

the global warming potential, the more that a given gas warms the Earth compared to carbon dioxide over that period.

GREENHOUSE GAS (GHG) — Any gas that absorbs infrared radiation in the atmosphere. Common examples of greenhouse gases include water vapor, carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), halogenated fluorocarbons (HCFCs), ozone (O_3), perfluorinated carbons (PFCs), and hydrofluorocarbons (HFCs).

GRID — An interconnected network for electricity delivery from the place of generation to end-use devices. The power grid includes the combined transmission and distribution network.

GRID HARMONIZATION — Strategies and measures that harmonize customer-owned distributed energy resources with the grid to maximize self-utilization of PV array output and limit grid exports to periods beneficial to the grid and the ratepayer.

GRID RELIABILITY — The capability of an electric system to deliver continuous, affordable electricity while maintaining balance between supply and demand, especially during periods of peak load, high renewable generation variability, or unexpected outages.

HDP — High dynamic price signal means an hourly electricity price signal that may change each hour and vary from day to day, reflecting changes in the value or cost of electricity over time, and is used to identify periods in which electricity consumption may be economically beneficial to shift.

HVAC THERMOSTAT — In this report, an appliance, or a combination of appliances, that controls electric and immobile heating, ventilation, and air conditioning equipment and is within the scope of the proposed standards.

INCREMENTAL CONSUMER COST — The additional cost (average) at retail that a consumer would pay for an appliance that meets the flexible demand standard. This cost is the difference between an existing base model and the same model that has the added functionality to comply with the new appliance standards for flexible demand.

IN-SCOPE DEVICES — Appliances or equipment that fall under the Flexible Demand Appliance Standards (FDAS) because they are electric, have significant load-shift potential, and can be controlled or scheduled.

INTEROPERABLE DEVICE — An open standard device that can exchange information with external entities using hardware or software and can use the information that has been exchanged for flexible demand capabilities, regardless of the manufacturer or underlying technology.

INVESTOR-OWNED UTILITY (IOU) — A private company that provides a utility, such as water, fossil gas, or electricity, to a specific service area. The California Public Utilities Commission regulates investor-owned utilities that operate in California.

JUSTICE COMMUNITIES — a broad umbrella term outlined in the CEC's Justice Access Equity Diversity Inclusion (JAEDI) Framework encompassing disadvantaged communities (pursuant to SB 535, De León, 2012, and designated by the CalEPA), low-income communities and

households (pursuant to AB 1550, Gomez, 2016), underserved communities (pursuant to AB 841, Ting, 2020), and people living with disabilities as defined by the American Disabilities Act.

LIFE-CYCLE CONSUMER SAVINGS — A 3 percent annual discount rate applied to the savings, allowing incremental costs and savings to be compared in terms of net present value to consumers.

LOAD MANAGEMENT STANDARDS (LMS) — Regulations adopted by the CEC that require electric utilities and other regulated entities to implement load management programs and provide or support time-dependent, including highly dynamic, electricity rates to encourage customers to shift electricity use to different times of the day.

LOW-INCOME HOUSEHOLDS (LIHH) — According to CCR, Title 25, Section 6928 (a): "Persons and families whose gross incomes do not exceed the qualifying limits for lower income families as established and amended from time to time pursuant to Section 8 of the United States Housing Act of 1937. The qualifying limits are set forth in CCR, Title 25, Section 6932. These limits are equivalent to 80 percent of the area median income, adjusted for family size and other adjustment factors by the United States Department of Housing and Urban Development."

MARGINAL GHG EMISSIONS RATE — Power plants are dispatched by increasing marginal cost. When electricity demand is increased, the first power plant to increase production is the last dispatched one; the electricity requested will come from the cheapest power plant that still has spare capacity. The marginal emissions rate for a given location is calculated by multiplying the average emissions rate for the marginal unit by the corresponding percentage for that unit. These rates are added together to create the marginal emissions rate for the given location. The marginal emissions rate is the amount of emissions avoided for a reduction of one unit of electricity use.

MARKET INFORMED DEMAND AUTOMATION SERVER (MIDAS) — The CEC's publicly accessible database and API that provides access to current, forecasted, and historical time-varying electricity rates, GHG emissions associated with electrical generation, and Flex Alert signals.

MEGAJOULE — One million joules. A joule is a unit of work or energy equal to the amount of work done when the point of application of force of 1 newton is displaced 1 meter in the direction of the force. One British thermal unit is equal to 1,055 joules.

METRIC TON — A unit of weight equal to 1,000 kilograms (2,205 pounds).

MIDAS DATASET — A dataset made available through MIDAS and corresponding to a RIN. A MIDAS dataset may be a MIDAS static dataset, a MIDAS dynamic dataset, or a MIDAS dataset corresponding to a customer-entered RIN. MIDAS datasets provide signals such as electricity highly dynamic price, marginal GHG emissions attributable to electricity generation, Flex Alerts, electricity export price, and peak demand charges.

MIDAS DYNAMIC DATASET — A MIDAS dataset that is regularly updated and retrievable by an appliance when connectivity is enabled and available.

MIDAS STATIC DATASET — A MIDAS dataset designated for factory installation but updatable with consumer consent and stored in the appliance's non-volatile integral memory.

NET LOAD — The total electric demand in the system minus wind and solar generation. The net load represents the demand that California ISO must meet with other, dispatchable sources such as fossil gas, hydropower, and imported electricity from outside the system.

NO_X — Oxides of nitrogen, a chief component of air pollution commonly produced by the burning of fossil fuels.

OFF-PEAK HOURS — The hours within a calendar day during which signals of the active MIDAS dataset have lower values compared to those during the peak hours of the same day.

OpenADR — A research and standards development effort for energy management led by North American research labs and companies. The typical use is to send information and signals to cause electrical power-using devices to curtail or shift during periods of high demand.

OUT-OF-SCOPE DEVICES — Appliances or equipment that are excluded from FDAS because they are non-electric, have limited or no flexible demand capability, or are otherwise not covered by the regulation.

PARTICULATE MATTER — Any material, except pure water, that exists in a solid or liquid state in the atmosphere. The size of particulate matter can vary from coarse, wind-blown dust particles to fine-particle combustion products.

PEAK HOURS — The hours within a calendar day during which signals of the active MIDAS dataset have one or more of the highest values.

PRE-SAVED DATA SETS – Data stored within a device's integral memory before shipping or installation, containing information such as year ahead forecasted pricing and GHG signals, that can be used to create schedules and operate the device without an active network connection.

RATE IDENTIFICATION NUMBER (RIN) — A code used to retrieve a specific time-dependent retail electricity rate or other CEC-approved dataset made available through MIDAS.

READILY ACCESSIBLE — means a consumer can obtain information through an integral physical user interface and can directly view or reach it from the primary status or settings screen using no more than two consumer navigation actions. Scrolling within a displayed screen does not constitute a consumer's navigation action.

RENEWABLE PORTFOLIO STANDARD (RPS) — One of California's key programs for advancing renewable energy. The program sets continuously escalating renewable energy procurement requirements for the state's load-serving entities. Generation must be procured from RPS-certified facilities.

SCHEDULE — A means to intentionally program operation of a device through use of an onboard astronomical time clock or other such internal mechanism; one that is not necessarily connected or dependent upon a Wi-Fi or FM signal.

SHIFT — An action taken manually by the consumer, automatically via a signal, or through use of a program or schedule, to operate an electric powered appliance during periods when the price of electricity is cheaper or that power is clean or from a renewable source or both.

SOCIAL COST OF CARBON (SCC) — An estimate, in dollars, of the economic damages that would result from emitting one additional metric ton of carbon dioxide into the atmosphere. The SCC quantifies impacts that result from climate change in economic terms to help policymakers and other decision-makers understand the economic impacts of decisions that would either increase or decrease GHG emissions.

TCP/IP (Transmission Control Protocol/Internet Protocol Suite) — A comprehensive set of rules including UDP/IP that governs the connection of computer systems to the internet.

TERAWATT — A unit of power equal to 1 trillion watts (10^{12} W).

TIME-OF-USE (TOU) RATE — The price consumers pay for electricity that varies by the time periods, such as peak, off-peak, and mid-peak hours.

APPENDIX A:
STAFF ASSUMPTIONS AND CALCULATION METHODS

Overview

This appendix documents the assumptions, data sources, methods, calculations, and model outputs used to evaluate the proposed flexible demand appliance standards for residential HVAC thermostats. It provides technical support for the economic, energy, and environmental findings presented in **Chapter 6**. The analysis covers the staff proposal and two regulatory alternatives. Results are presented for the first compliance year, 2028, and the full stock-turnover year, 2037. **Chapter 6** presents the principal findings in plain language, while this appendix provides the supporting calculations, assumptions, model inputs, and technical results.

For the major-regulation threshold analysis, staff evaluate gross regulatory costs before benefits. Consumer utility-bill savings, avoided electricity-system costs, climate benefits, health benefits, reliability benefits, and broader economic impacts are calculated and reported separately.

Section I describes the residential product stock, energy-load data, control signals, electricity rates, incremental costs, and participation assumptions. Section II explains the load-shifting, consumer-bill, avoided-cost, emissions, health, reliability, gross-cost, and economic-impact calculations. Section III presents the economic, business, energy, and environmental results and separates private-sector costs and benefits from utility-system and societal benefits. Section IV documents the gross-cost major-regulation threshold analysis. Section V presents additional supporting research and analyses conducted by staff to inform the assumptions, methodologies, and conclusions presented in this report.

Calculation Block Diagram

Figure A-1 illustrates the various inputs, processes, condition checks, intermediate outputs, and final outputs used to calculate the key metrics and benefits of the staff proposal and the two alternatives. Important inputs are shown as green rectangles and include in-scope HVAC stock from the 2019 Residential Appliance Saturation Study (RASS), electric HVAC load shapes from the Hourly Electricity Load Model (HELM), control signals consisting of hourly greenhouse gas (GHG) emission intensities and highly dynamic pricing (HDP), time-of-use (TOU) electricity

rates, incremental costs, participation rates, and the Social Cost of Carbon.[101] The hourly GHG emission intensity values are used both to identify hours during which load is shifted and to calculate resulting GHG emissions reductions.

The calculation processes are shown as yellow ovals (or rounded rectangles) in **Figure A-1**. These processes include simple mathematical operations such as summation, subtraction, multiplication, and division; load-shifting functions used to determine load reduction potential during peak periods; and analytical models implemented through software tools. The software tools include the California Public Utilities Commission's (CPUC) Avoided Cost Calculator (ACC), which provides hourly avoided costs across six categories; the U.S. Environmental Protection Agency's (EPA) AVoided Emissions and geneRation Tool (AVERT) and CO-Benefits Risk Assessment Health Impacts Screening and Mapping Tool (COBRA), which estimate emissions reductions and associated monetized health benefits; and Lawrence Berkeley National Laboratory's (LBNL) Interruption Cost Estimate (ICE) Calculator, which estimates avoided interruption benefits. Condition checks used to verify calculation results are shown as purple diamonds.

Intermediate outputs and final outputs are shown as blue and orange rectangles, respectively. Energy impact, calculated as the difference between the baseline load and the shifted load, is a key intermediate output and serves as an input to the ACC, AVERT, COBRA, ICE, and other calculations. Final outputs are divided into monetary benefits, shown as dashed outlined orange rectangles, and other key metrics, shown as solid outlined orange rectangles. These outputs are presented and discussed in detail in the following sections of this appendix.

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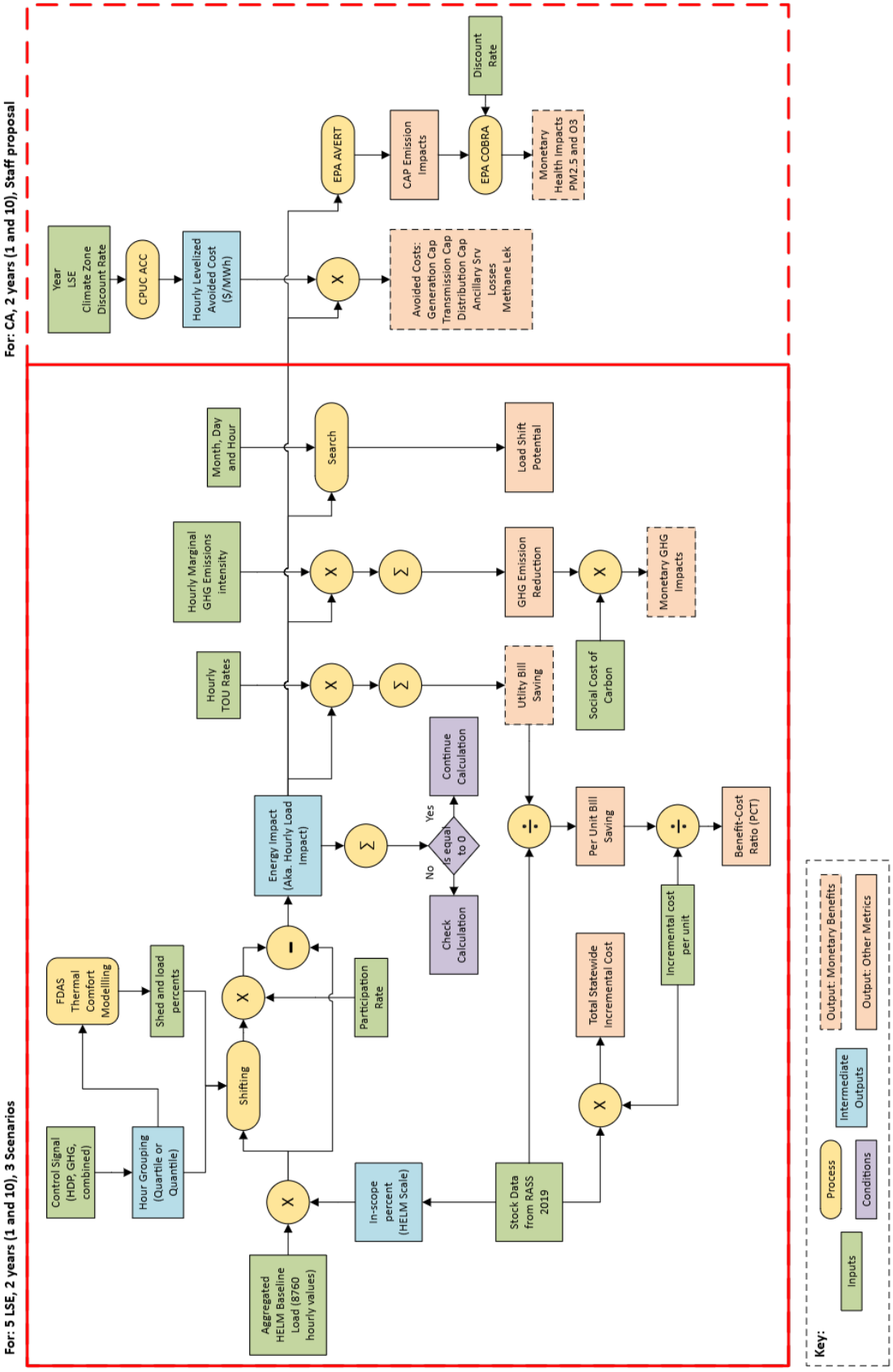
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Figure A-1: Block Diagram of Calculations



Source: California Energy Commission

Section I - Data and Assumptions

This section presents the key inputs and assumptions used in the analysis, including residential product stock, energy-load data, control signals, electricity rates, incremental costs, and participation assumptions.

The analysis is limited to residential applications. It includes in-scope low-voltage and proprietary thermostats for central air conditioners, furnaces, and heat pumps. Commercial and other non-residential applications are not included. The stock, shipment, cost, energy, emissions, and economic calculations use this same residential scope.

Residential Product Stock and Shipments - RASS 2019

Total stock of in-scope HVAC thermostats is used to calculate bill savings on a per-customer basis, and in-scope devices percentage form the total (in-scope and out-of-scope) electric HVAC HELM load. Count of in-scope HVAC thermostats are calculated from electric space cooling and heating appliances stock data from the 2019 RASS survey. The 2019 RASS is a statewide survey conducted by the CEC to collect detailed information on home characteristics, appliance ownership, usage patterns, and energy consumption in California households. The study surveyed roughly 300,000 households, providing statistically representative data across LSEs, climate zones, building types, and demographics. The RASS survey contains around 100 questions and includes questions on space-heating and cooling characteristics. **Tables A-1 and A-2** link the type of thermostats to electric space cooling and heating appliance types, respectively. Here, household count is assumed to be approximately equal to appliance count, and one thermostat is assumed for each space conditioning type. Household counts given in the table are approximately equal to thermostat counts. The Hourly Electricity Load Model (HELM) gives load shapes for all electric heating and cooling appliance loads for each LSE for 2028 (year 1) and 2037 (year 10). **Tables A-3 and A-4** are counts of electric heating and cooling appliances for each LSE, filtered from RASS data. The corresponding in-scope and out-of-scope percentages are calculated for each LSE in **Tables A-5 and A-6.** Even though these percentages are for 2019, staff also assume these percentages for 2028 since, even though stock might have increased from 2019 to 2028, corresponding percentages should remain the same. But for 2035's HELM heating percentages, staff assume that as older houses are replaced with energy efficient houses, the share of resistance (baseboard, ceiling, floor, wall) heaters will decrease and will be replaced by heat pumps. For example, the electric space heating weighted RASS percentage of in-scope devices for SCE will increase from 71.7% to 93.8% since the share of resistance heaters (22.1%) will be replaced by heat pumps. Stock count for various in-scope devices for 2028 and 2037, shown in **Tables A-8 and A-9**, are obtained by multiplying the corresponding ratios for each year from **Table A-7**, obtained from the California Department of Finance (DOF) population projections.[102] And sales (or shipments) for each year are obtained by dividing the corresponding year's stock by 10. These stock and sales projections are used to calculate bill savings on a per-customer basis. Staff

102 California Department of Finance. Demographic Research Unit. 2024. "Report P-1A: Total Population Projections, California, 2020-2070." Available at https://dof.ca.gov/forecasting/demographics/projections/.

also accounted for thermostats that control both heating and cooling equipment to avoid double counting the total in-scope thermostat stock when estimating per-unit bill savings.

Table A-1: 2019 Statewide Stock of Various Primary Electric Space Cooling Appliance Types and Their Corresponding Controlling Thermostats from RASS

Primary Electric Space Cooling	Statewide Household Count	Weighted Percentage	Controlled by
Central Air Conditioning	6,151,532	86.0%	Low-voltage thermostat (in-scope)
Central Evaporative cooler	229,995	3.2%	Out of Scope
Central Heat pump	656,654	9.2%	Low-voltage, Proprietary thermostat (in-scope)
Mini-split or "ductless"	114,988	1.6%	Proprietary thermostats (in-scope)
Total Electric Space Cooling	7,153,170	100.0%	
Total In-Scope Electric Space Cooling	6,923,175	96.8%	

Source: California Energy Commission and RASS 2019

Table A-2: 2019 Statewide Stock of Various Primary Electric Space Heating Appliance Types and Their Corresponding Controlling Thermostats from RASS

Primary Electric Space Heating	Statewide Household Count	Weighted Percentage	Controlled by
Resistance (baseboard/ceiling/floor/wall)	471,963	20.5%	Out of Scope
Central forced air furnace	851,675	37.0%	Low-voltage thermostat (in-scope)
Central heat pump	398,898	17.3%	Low-voltage, Proprietary thermostat (in-scope)
Through-the-wall heat pump	93,269	4.1%	Out of Scope
Portable heaters	412,743	17.9%	Out of Scope
Other system type	72,696	3.2%	Out of Scope
Total Electric Space Heating	2,301,244	100.0%	
Total In-Scope Electric Space Heating	1,250,573	54.40%	

Source: California Energy Commission and RASS 2019

Table A-3: 2019 Stock (in Thousands) of Various Primary Electric Space Cooling Appliance Types Within Each LSE from RASS

	SCE	PGE	LADWP	SDGE	SMUD
Central air conditioning	2599	2055	532	573	392
Central evaporative cooler	110	72	31	2	14
Heat pump	234	211	91	64	57
Mini-split or ductless	41	34	12	23	6
Total Electric Space Cooling	2983	2372	666	662	469
Total In-Scope Electric Space Cooling	2874	2300	635	660	455

Source: California Energy Commission and RASS 2019

Table A-4: 2019 Stock (in Thousands) of Various Primary Electric Space Heating Appliances Type Within Each LSE from RASS

	SCE	PGE	LADWP	SDGE	SMUD
Resistance (baseboard/ceiling/floor/wall)	163	180	52	65	12
Central forced air furnace	268	376	54	93	60
Central heat pump	130	100	72	46	51
Through-the-wall heat pump	31	32	7	22	1
Portable heaters	131	127	72	64	20
Other system type	15	39	8	11	0
Total Electric Space Heating	738	854	265	301	144
Total In-Scope Electric Space Heating	398	476	126	139	111

Source: California Energy Commission and RASS 2019

Table A-5: RASS Weighted Percentage of In-scope Devices Within Each LSE for Electric Space Cooling

	SCE	PGE	LADWP	SDGE	SMUD
Central air conditioning	87.1%	86.6%	79.9%	86.6%	83.5%
Central evaporative cooler	3.7%	3.1%	4.7%	0.4%	3.1%
Heat pump	7.8%	8.9%	13.7%	9.6%	12.2%
Mini-split or ductless	1.4%	1.4%	1.7%	3.4%	1.2%
Total Electric Space Cooling	100.0%	100.0%	100.0%	100.0%	100.0%
Total In-Scope Electric Space Cooling	96.3%	96.9%	95.3%	99.6%	96.9%

Source: California Energy Commission and RASS 2019

Table A-6: RASS Weighted Percentage of In-scope Devices Within Each LSE for Electric Space Heating

	SCE	PGE	LADWP	SDGE	SMUD
Resistance (baseboard/ceiling/floor/wall)	22.1%	21.1%	19.9%	21.5%	8.1%
Central forced air furnace	36.4%	44.0%	20.5%	31.0%	41.6%
Central heat pump	17.6%	11.7%	27.2%	15.2%	35.4%
Through-the-wall heat pump	4.1%	3.8%	2.5%	7.4%	1.0%
Portable heaters	17.8%	14.8%	27.1%	21.3%	13.5%
Other system type	2.0%	4.5%	2.9%	3.7%	0.3%
Total Electric Space Heating	100.0%	100.0%	100.0%	100.0%	100.0%
Total In-Scope Electric Space Heating	53.9%	55.8%	47.7%	46.1%	77.1%

Source: California Energy Commission and RASS 2019

Table A-7: California State Population Projection

Year	State Population	Ratio with respect to 2019 population
2019	39,437,610	1.0000
2028	39,536,054	1.0025
2037	40,645,256	1.0306

Source: CA DOF

Table A-8: Projected Residential Stock and Sales, Thermostats for Electric Cooling Space-conditioning Appliances Per Utility

Utility	Stock, pre-regulation (2019)	Stock, first year of regulation (2028)	Sales, first year of regulation (2028)	Stock, year of full turnover (2037)	Sales, year of full turnover (2037)
SCE	2,873,548	2,880,721	288,072	2,961,541	296,154
PGE	2,299,890	2,305,631	230,563	2,370,317	237,032
LADWP	634,803	636,387	63,639	654,242	65,424
SDGE	659,948	661,595	66,160	680,157	68,016
SMUD	454,986	456,122	45,612	468,919	46,892
Total	6,923,175	6,940,457	694,046	7,135,176	713,518

Source: 2019 RASS data and CEC staff projection

Table A-9: Projected Residential Stock and Sales, Thermostats for Electric Heating Space-conditioning Appliances Per Utility

Utility	Stock, pre-regulation (2019)	Stock, first year of regulation (2028)	Sales, first year of regulation (2028)	Stock, year of full turnover (2037)	Sales, year of full turnover (2037)
SCE	528,039	529,357	52,936	544,209	54,421
PGE	603,150	604,656	60,466	621,620	62,162
LADWP	197,556	198,049	19,805	203,605	20,361
SDGE	203,395	203,903	20,390	209,623	20,962
SMUD	131,177	131,504	13,150	135,194	13,519
Total	1,663,317	1,667,469	166,747	1,714,251	171,425

Source: 2019 RASS data and CEC staff projection

HELM

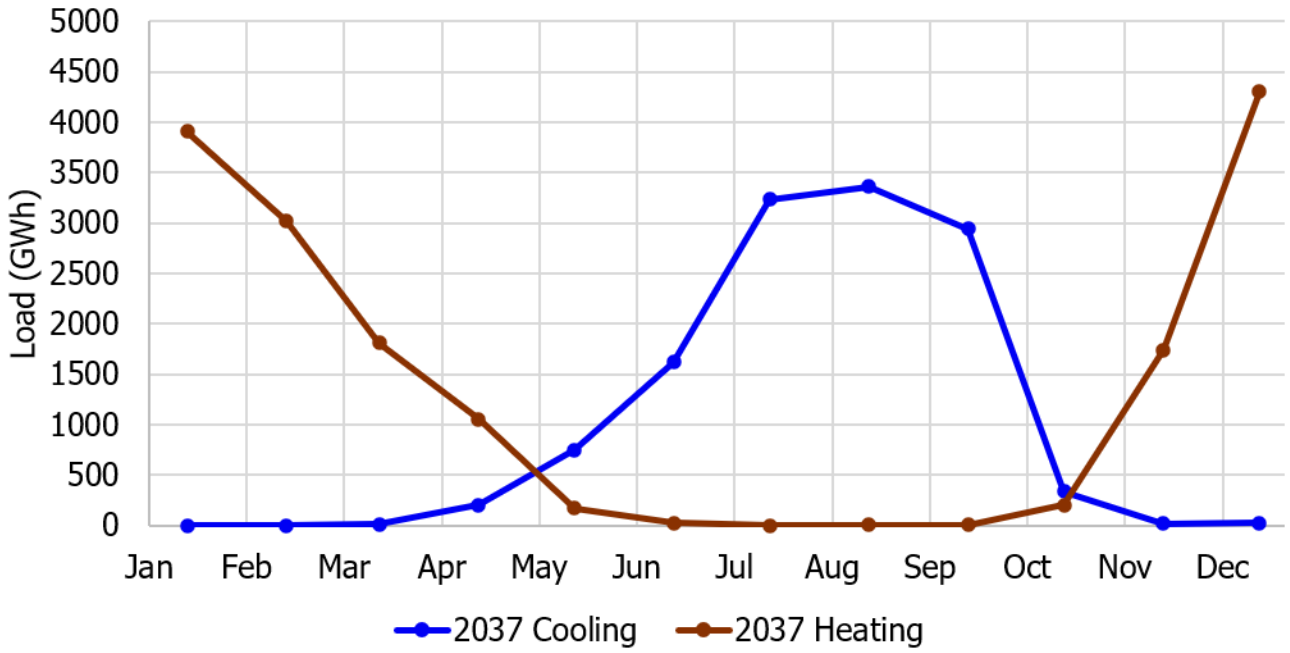
The Hourly Electric Load Model (HELM) is the CEC's tool for estimating hourly electricity load shapes for residential heating, cooling, and furnace fan use, developed under contract with ADM Associates, Inc. HELM uses historical AMI data and weather data to understand how households respond to temperature changes and to separate heating and cooling loads from the normal baseline household load. The Energy Assessments Division of the CEC use HELM to produce future-year HVAC load projections, including 2028 and 2037 values, which are provided to the FDAS Unit to support regulatory analysis and program development.

To identify HVAC usage, HELM compares each day's average temperature with that day's total household electricity use. The day with the lowest energy use is assumed to have no heating or cooling, and that temperature becomes the balance point. Days warmer than this balance point are treated as cooling days, and days colder are treated as heating days. HELM subtracts this base load from other days to isolate HVAC use and then uses temperature–energy relationships (heating and cooling degree-days) to create HVAC load shapes for future years under different climate conditions. This approach ensures future HVAC shapes remain weather-responsive and grounded in real customer behavior.

The HELM dataset provided includes residential heating and cooling load projections for California's five largest load-serving entities: SCE, PG&E, SDG&E, LADWP, and SMUD. The data is aligned with the IEPR forecast zones associated with each LSE and is provided for two forecast years, 2028 and 2037. Only the residential sector is included, using the Mid energy-demand case and the Base AAEE case, and both single-family and multifamily building types are represented. For each LSE, heating and cooling loads were calculated by summing the MW values across all relevant forecast zones and both SF and MF building types. This produced total heating and cooling load estimates for each of the five LSEs for both 2028 and 2037,

which serve as the basis for the analysis. Staff did not consider a non-residential application because the projected participation rate was low.[103]

Figure A-2: 2037 Statewide Monthly Heating and Cooling Loads (GWh)

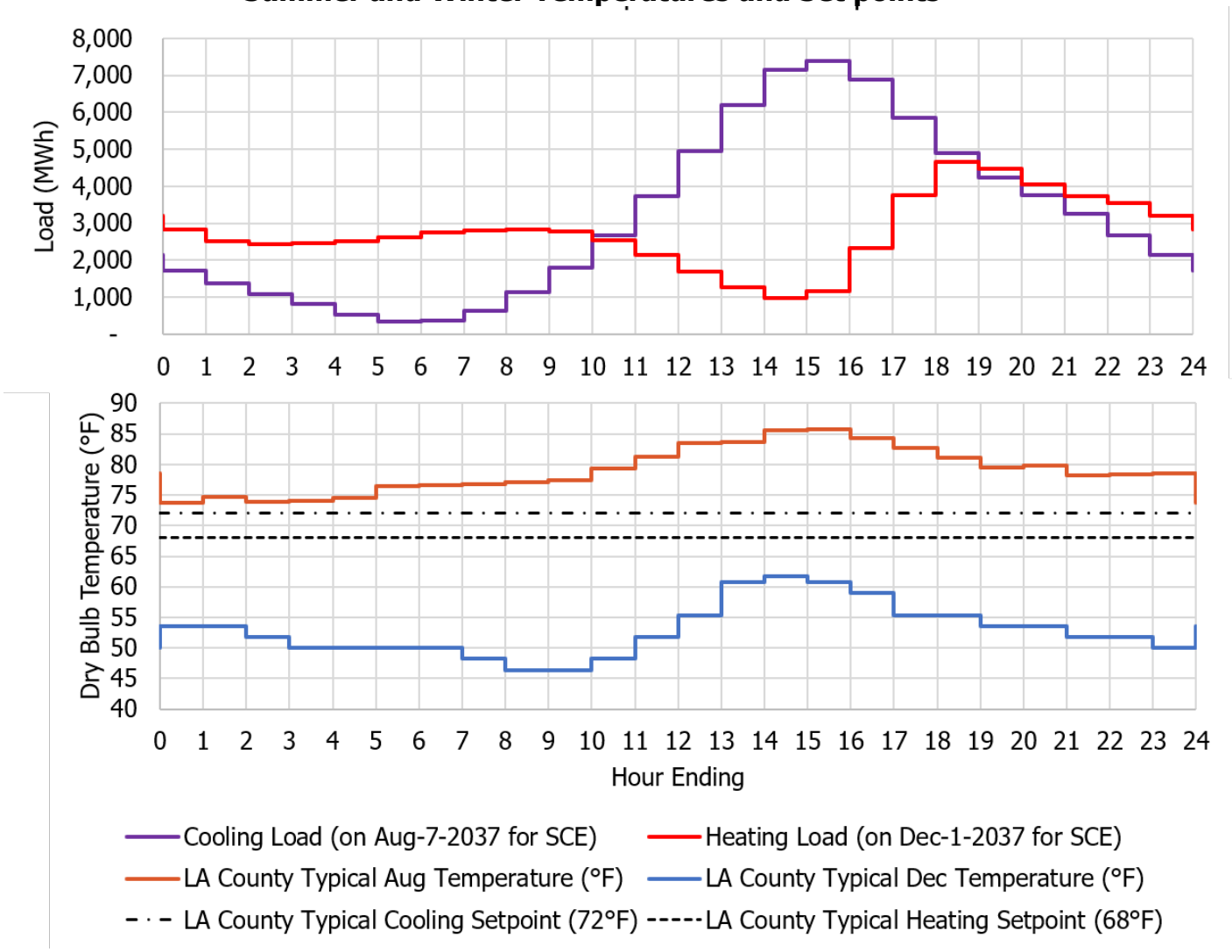


Source: California Energy Commission

Figure A-2 shows California's projected 2037 statewide monthly heating and cooling electricity loads, with heating displayed in orange and cooling in blue. Heating demand is highest in December and January and cooling demand peaks in July, August, and September. Because these months represent the times of greatest seasonal demand, a typical high cooling day from August and a typical high heating day from December are used for the detailed hourly load shape figures presented in the following section. This seasonal pattern reflects California's climate where the warmest conditions occur in late summer and the coldest conditions occur in early winter.

103 Canadian Standards Association (CSA Group). 2019. "Performance Requirements For Line Voltage Thermostats Used With Individual Room Electric Space Heating Devices." Available at https://www.techstreet.com/standards/csa-c828-19?product_id=2089271.

Figure A-3: Comparison of 2037 SCE Maximum HVAC Load with Typical LA County Summer and Winter Temperatures and Set points



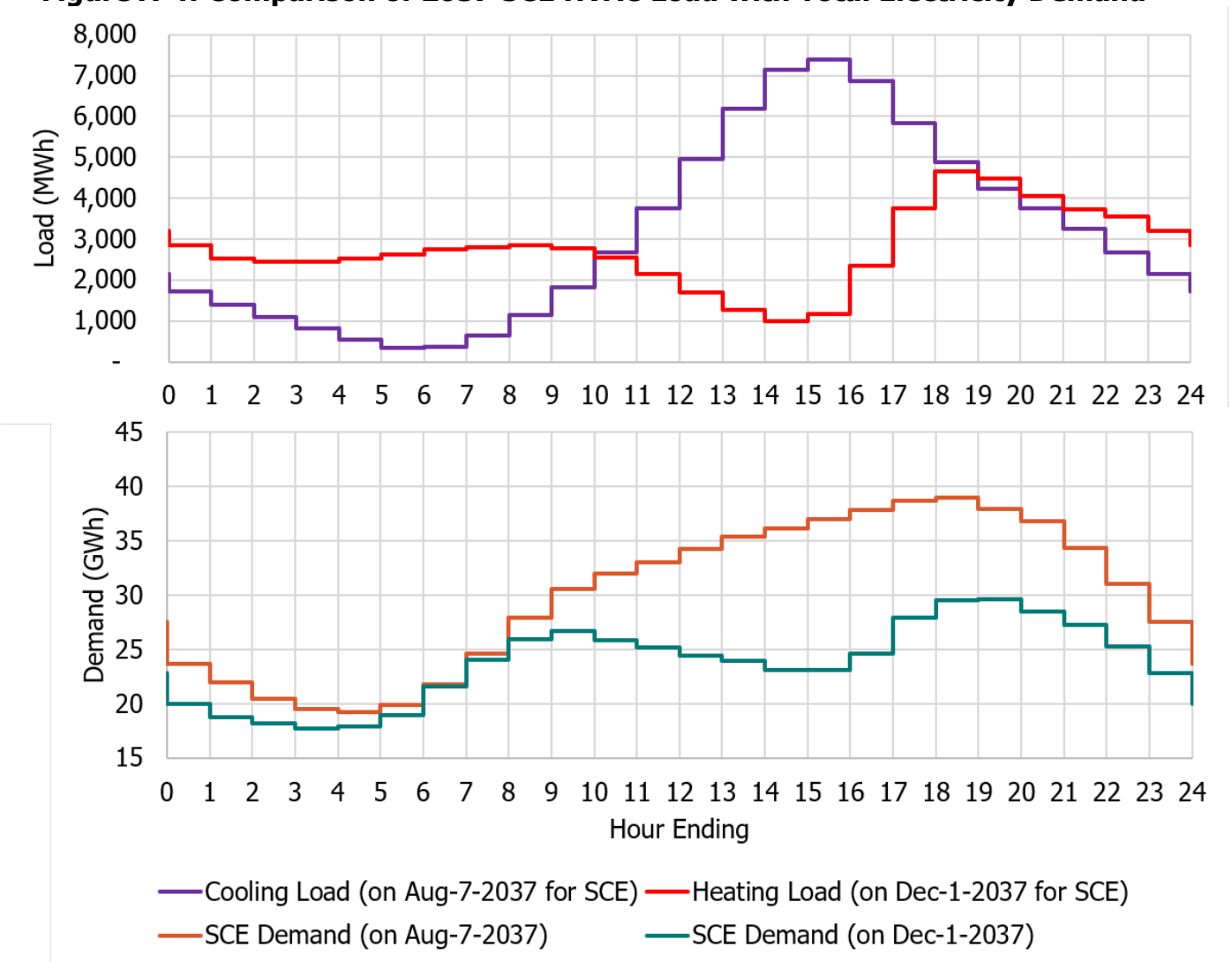
Source: California Energy Commission

Figure A-3 compares SCE's projected maximum hourly cooling load on a typical hot summer day (August 7, 2037) with the maximum hourly heating load on a cold winter day (December 1, 2037). The upper graph shows that cooling load (blue) rises sharply in the afternoon as outdoor temperatures climb well above the typical cooling set point of 72°F, while heating load (red) increases in the early morning and evening when temperatures fall below the typical heating set point of 68°F. The lower graph displays the corresponding LA County temperature profiles for a typical August and December day, using county-level weather data obtained from the NREL ResStock Dataset 2024.2 TMY3 Data Repository, along with the set points reported in the 2019 RASS survey. [104] Los Angeles County was selected as a representative county for

104 National Renewable Energy Laboratory (NREL), "ResStock Dataset 2024.2 – TMY3 Weather Data Repository," Open Energy Data Initiative (OEDI), Data Repository, ResStock Datasets. Available at https://www.techstreet.com/standards/csa-c828-19?product_id=2089271.

SCE temperature profiles because its large population and building stock make it the largest contributor to residential HVAC load within SCE's service territory. Cooling demand closely follows the portion of the orange August temperature curve that exceeds the 72°F set point, and heating demand mirrors the difference between the 68°F set point and the colder December temperature curve. This results in cooling peaking between 2 and 4 p.m., heating peaking between 6 and 8 p.m., and a secondary morning heating peak from 7 to 9 a.m. These relationships show that the HELM-generated hourly loads are consistent with expected heating and cooling behavior based on temperature and thermostat set points.

Figure A-4: Comparison of 2037 SCE HVAC Load with Total Electricity Demand

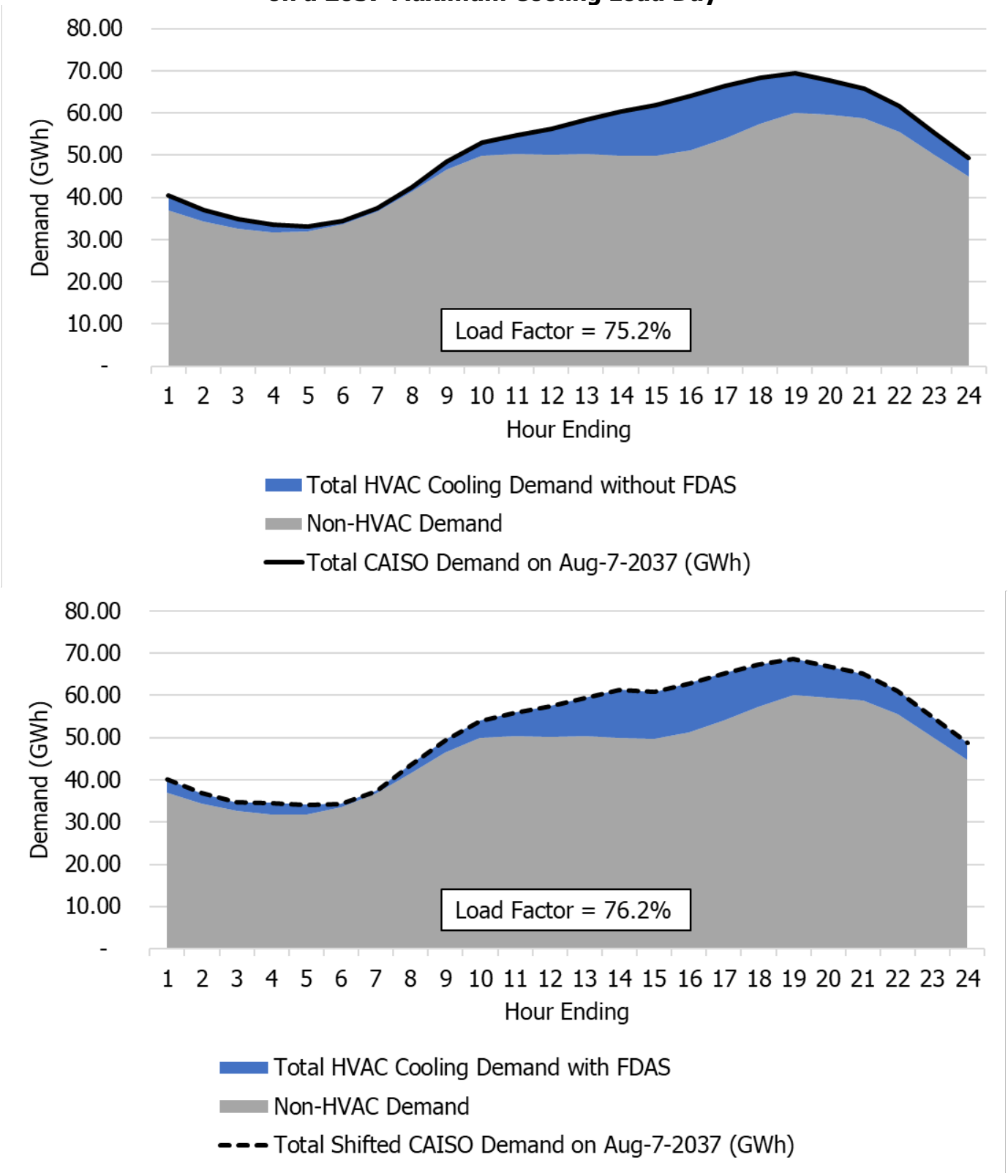


Source: California Energy Commission

Figure A-4 compares hourly HVAC loads in the SCE service area with total electricity demand on representative hot and cold days in 2037. The upper graph shows cooling load on a typical hot August day and heating load on a cold December day, while the lower graph shows the corresponding total system demand for those same days using values from the NREL Cambium 2024 dataset. The August demand curve peaks between 5 and 7 p.m. and partially overlaps with the cooling load, which peaks earlier between 2 and 5 p.m., yet cooling still contributes

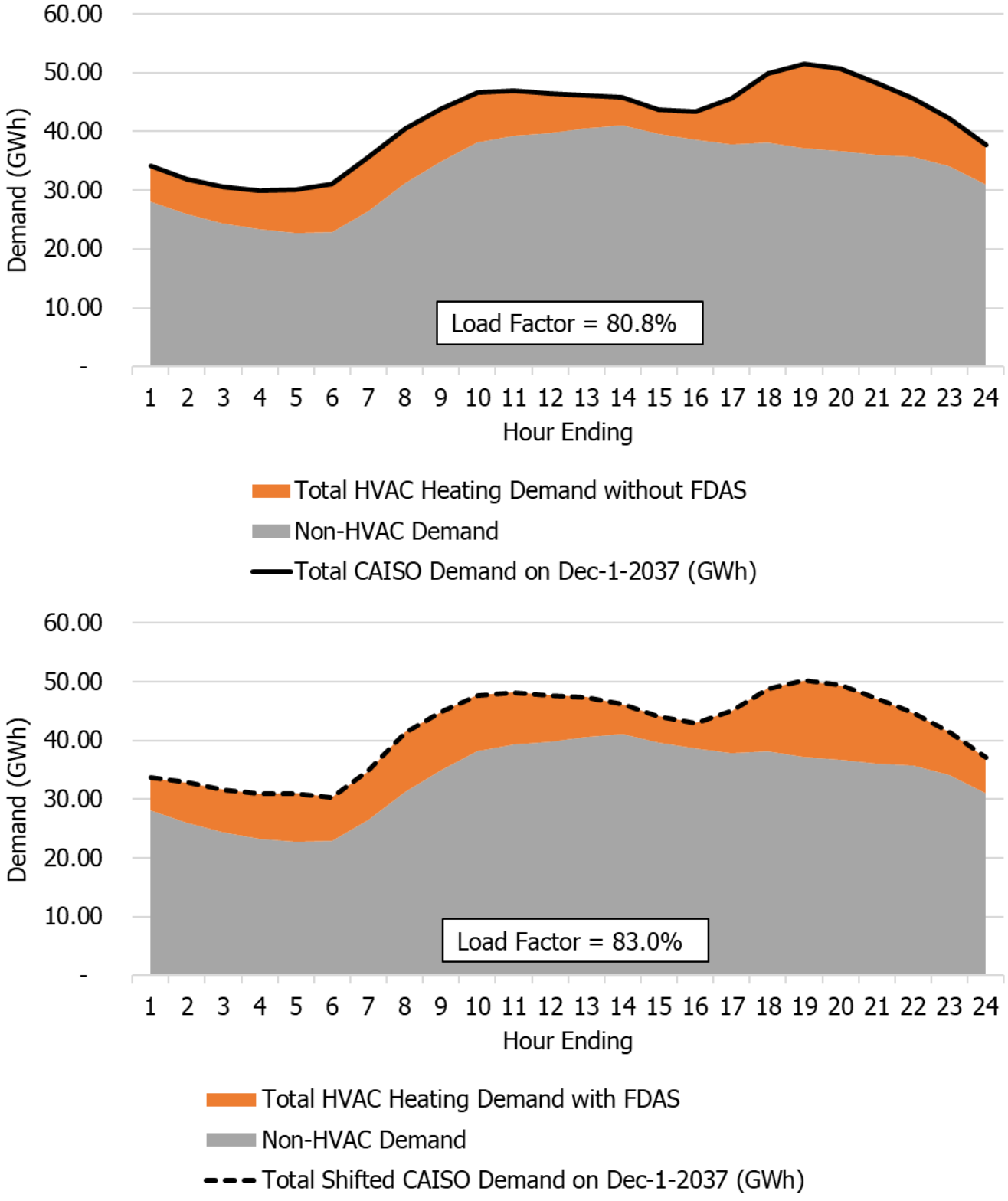
significantly to the system during the extended evening demand period. The heating load in December aligns even more closely with system needs, matching both the morning peak around 9 a.m. and the evening peak around 7 p.m. This alignment shows that HVAC loads follow system-critical periods and demonstrates their strong potential for load flexibility strategies.

Figure A-5: Load Factor Improvements from HVAC Cooling Load Shifting for CAISO on a 2037 Maximum Cooling Load Day



Source: California Energy Commission

Figure A-6: Load Factor Improvements from HVAC Cooling Load Shifting for CAISO on a 2037 Maximum Heating Load Day

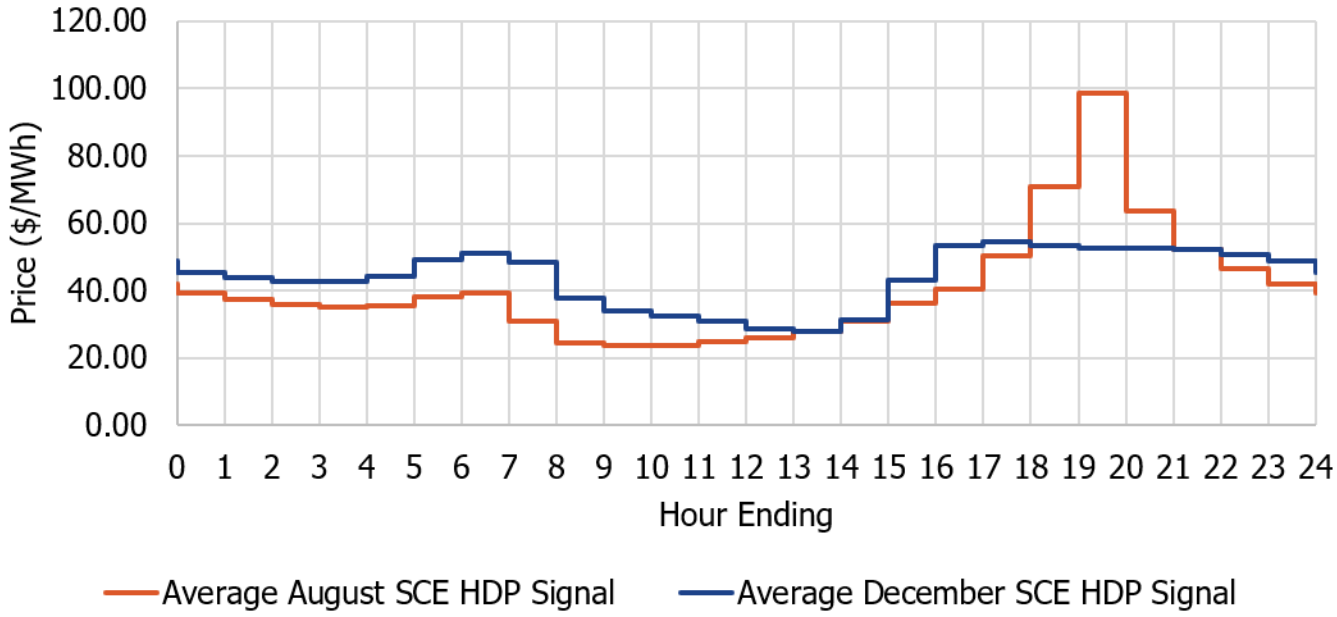


Source: California Energy Commission

Control Signal: HDP from the MIDAS Static Dataset

Highly dynamic price (HDP) signals from the MIDAS static dataset are used in this analysis both as a control signal for determining optimal load shifting periods and as an input for estimating total statewide bill savings. These prices represent hourly price variation that customers would respond to under a highly time-differentiated rate structure. To develop these price profiles, historical wholesale market prices from the CAISO OASIS database are first normalized and then scaled to match the total retail electricity rates for each utility. This approach preserves the hourly shape of wholesale price fluctuations while aligning them with utility-specific retail rate levels, allowing for realistic estimation of customer bill impacts from load shifting.

Figure A-7: Comparison of 2037 SCE Average HDP from the MIDAS Static Dataset for August and December Months



Source: California Energy Commission

Figure A-7 compares the projected 2037 average hourly highly dynamic price (HDP) signals from the MIDAS static dataset for SCE in August and December. Both months show higher HDP values during the early morning around 7 a.m. and in the evening around 8 p.m., reflecting periods when system demand is typically higher and renewable generation, especially solar, is lower. However, the August curve exhibits a much sharper and higher peak between 7 p.m. and 8 p.m. compared to December, which shows a broader but lower evening peak. This difference occurs because August evenings in California experience very high residual electricity demand after sunset, when air-conditioning loads remain elevated while solar generation rapidly declines. In contrast, December has minimal cooling demand and overall lower system load, so although renewable output remains low in the evening, the resulting price signal is less extreme. As a result, the August HDP curve reflects stronger upward price pressure due to higher net load conditions, whereas the December curve captures a more moderate evening peak shaped by winter demand patterns.

Control Signal: GHG from the MIDAS Static Dataset

GHG emission intensities are used as a control signal for determining when load shifting should occur and as a key input for calculating total statewide GHG emission reductions. The emission intensities are based on the Self Generation Incentive Program (SGIP) GHG signal obtained from WattTime, which provides an hourly measure of the marginal GHG emissions data at the time load shifting would take place. For more information on how the SGIP GHG signals are calculated, refer to Chapter 2 subsection SGIP GHG Signals. Because California's electric grid is expected to include a much larger share of renewable resources in the future, these SGIP values are scaled downward using Long-Run Marginal Emission Rates (LRMER) from the NREL Cambium 2024 Mid-case scenario. This adjustment ensures that the 2037 GHG emission intensities used in the analysis reflect the anticipated future decarbonization of the grid and provide a more accurate estimate of avoided emissions from load shifting.

Figure A-8: Month-Hour Average of Greenhouse Gas Emission Intensity Attributed from California's Electricity Generation, 2025 ($MTCO_2e/MWh$)

Time of the Day	Hour	Winter			Spring			Summer			Fall		
		Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
12:00 AM to 7:59 AM	0	0.44	0.46	0.41	0.44	0.44	0.37	0.42	0.50	0.48	0.51	0.46	0.48
	1	0.43	0.44	0.39	0.41	0.41	0.34	0.40	0.47	0.44	0.48	0.43	0.45
	2	0.42	0.43	0.39	0.39	0.40	0.31	0.37	0.44	0.43	0.45	0.42	0.44
	3	0.41	0.44	0.40	0.39	0.40	0.30	0.36	0.44	0.41	0.43	0.41	0.44
	4	0.41	0.45	0.41	0.40	0.42	0.31	0.36	0.44	0.42	0.44	0.41	0.46
	5	0.44	0.48	0.44	0.45	0.45	0.34	0.38	0.46	0.46	0.47	0.44	0.49
	6	0.48	0.50	0.47	0.48	0.49	0.32	0.33	0.45	0.50	0.51	0.50	0.54
	7	0.48	0.50	0.39	0.40	0.28	0.12	0.16	0.38	0.38	0.41	0.51	0.42
8:00 AM to 3:59 PM	8	0.40	0.41	0.27	0.24	0.16	0.08	0.15	0.34	0.29	0.25	0.36	0.28
	9	0.35	0.38	0.23	0.19	0.14	0.07	0.16	0.32	0.28	0.24	0.28	0.24
	10	0.32	0.34	0.19	0.13	0.09	0.07	0.18	0.32	0.29	0.25	0.28	0.22
	11	0.31	0.31	0.18	0.09	0.10	0.07	0.19	0.34	0.30	0.26	0.29	0.22
	12	0.28	0.29	0.18	0.09	0.08	0.06	0.20	0.37	0.31	0.27	0.30	0.21
	13	0.27	0.29	0.19	0.09	0.09	0.07	0.22	0.41	0.32	0.29	0.31	0.21
	14	0.26	0.31	0.21	0.09	0.07	0.08	0.24	0.43	0.35	0.33	0.31	0.22
	15	0.38	0.36	0.23	0.12	0.08	0.09	0.24	0.47	0.37	0.35	0.31	0.35
4:00 PM to 11:59 PM	16	0.49	0.48	0.39	0.17	0.09	0.10	0.24	0.45	0.36	0.35	0.36	0.52
	17	0.48	0.52	0.49	0.31	0.14	0.13	0.29	0.49	0.43	0.47	0.54	0.53
	18	0.47	0.50	0.49	0.45	0.36	0.31	0.43	0.53	0.50	0.55	0.53	0.51
	19	0.47	0.51	0.49	0.48	0.47	0.44	0.55	0.59	0.54	0.52	0.50	0.52
	20	0.48	0.51	0.49	0.48	0.46	0.44	0.53	0.57	0.51	0.51	0.50	0.53
	21	0.48	0.51	0.48	0.48	0.46	0.41	0.50	0.57	0.51	0.52	0.53	0.53
	22	0.47	0.48	0.44	0.46	0.44	0.40	0.46	0.55	0.51	0.51	0.50	0.52
	23	0.46	0.44	0.39	0.44	0.43	0.39	0.43	0.52	0.48	0.50	0.47	0.50

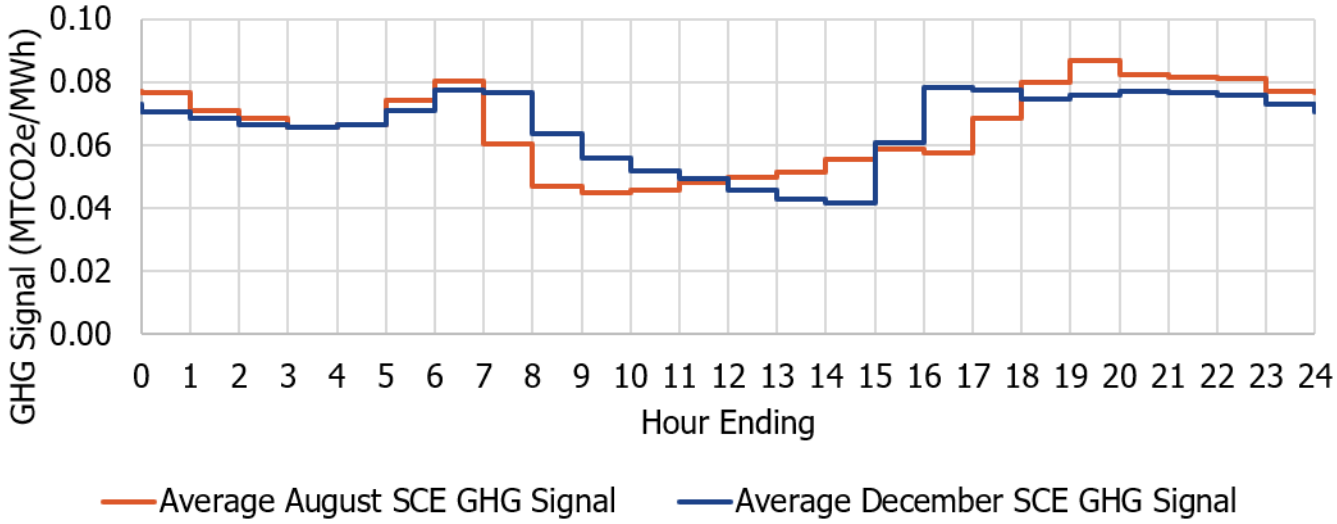
Source: California Energy Commission

Average monthly-hourly greenhouse gas (GHG) emission intensities for California electricity generation in 2025 are shown in **Figure A-8**, expressed in metric tons of carbon dioxide equivalent per megawatt-hour ($MTCO_2e/MWh$). Red shading indicates hours with above-

average GHG emission intensity, while green shading indicates hours with below-average GHG emission intensity. The figure illustrates how the carbon intensity of electricity varies by season and time of day.

Lower GHG emission intensities generally occur during midday hours in the spring and summer months due to increased generation from renewable resources, particularly solar generation. Higher GHG emission intensities typically occur during morning and evening hours when a larger share of electricity demand is served by conventional generation resources. The proposed Flexible Demand Appliance Standards (FDAS) are designed to encourage load shifting from periods with relatively high GHG emission intensity to periods with lower GHG emission intensity. By shifting electricity consumption away from higher-emission hours and toward lower-emission hours, the proposed standards can reduce the overall GHG emissions associated with appliance operation while supporting California's clean energy and decarbonization goals.

Figure A-9: Comparison of 2037 SCE Average GHG Emission Intensity from the MIDAS Static Dataset for August and December Months

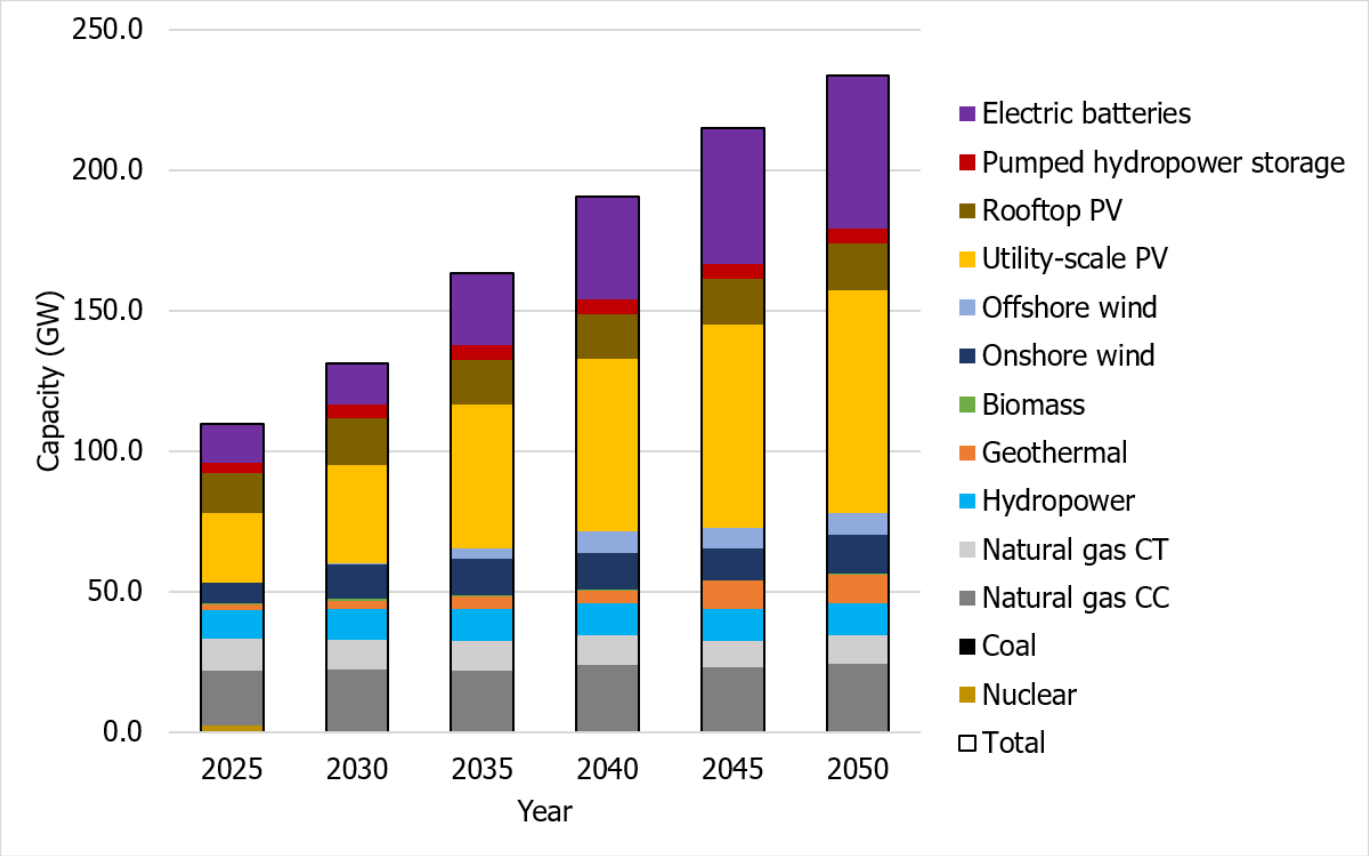


Source: California Energy Commission

Figure A-9 presents the projected 2037 average hourly GHG emission intensities for the SCE service area, with August values shown in orange and December values shown in blue. Both curves illustrate that emission intensities are lowest during midday hours when solar generation is abundant and renewable penetration is high, and highest during evening, nighttime, and early-morning hours when solar output falls and the grid relies more heavily on thermal generation. This pattern is consistent with the statewide future capacity and generation mix shown in **Figures A-10** and **A-11**, which indicate a growing share of renewable resources in California's electricity portfolio from 2025 to 2050 based on the NREL Cambium 2024 Mid-case scenario. Because renewable penetration is expected to increase substantially in the future, it is important to incorporate these trends into GHG estimates. For this reason, staff used Long-Run Marginal Emission Rates (LRMER) from the NREL Cambium

dataset when constructing the 2037 hourly emission intensities, ensuring that the values shown here reflect the expected long-term decarbonization of California's electric grid.[105]

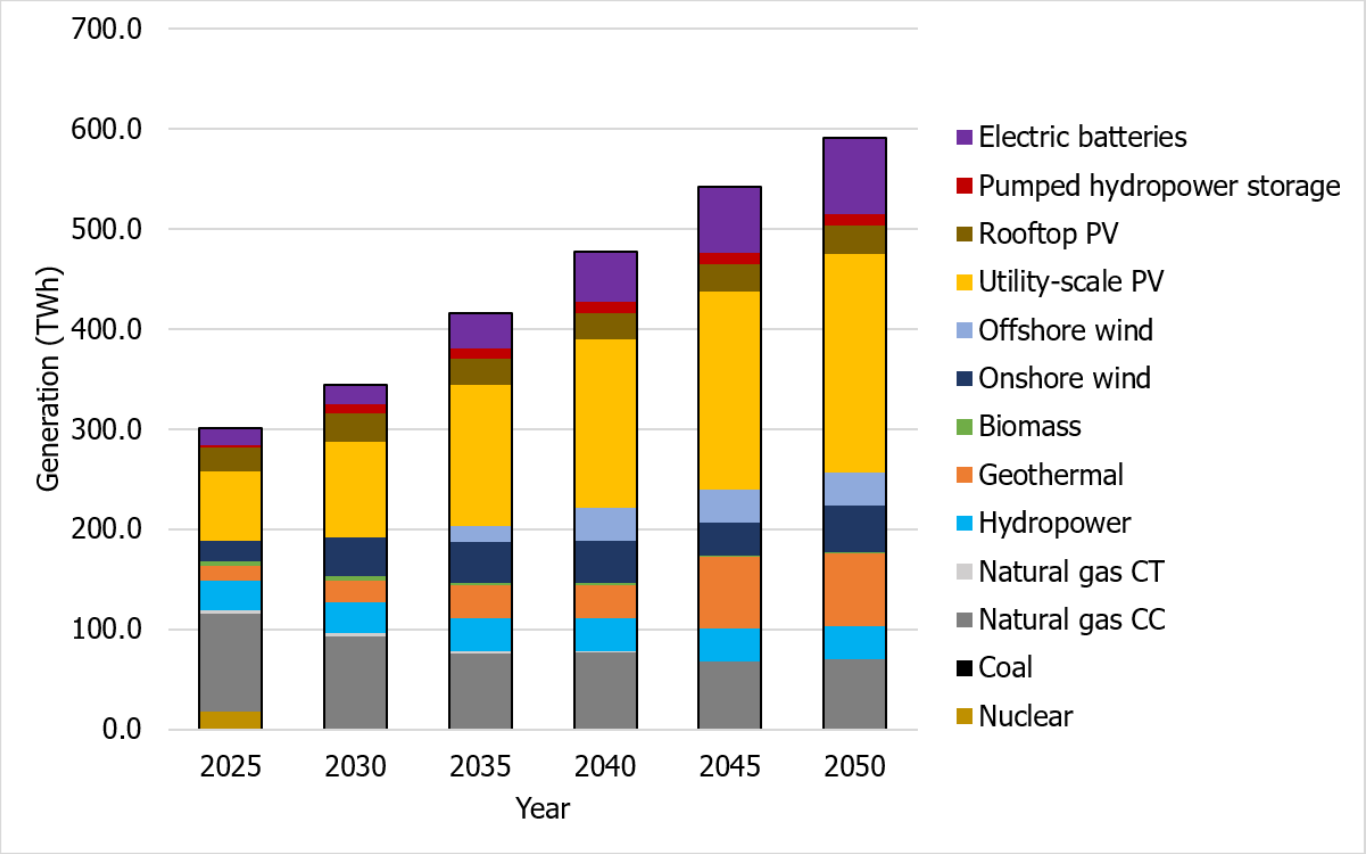
Figure A-10: CA Future Capacity (GW) Mix



Source: California Energy Commission, Data: NREL Cambium 2024 Mid-case scenario

105 National Renewable Energy Laboratory, *Cambium Scenario Viewer* (Mid-case Scenario, Hourly, GEA regions). Available at https://scenarioviewer.nlr.gov.

Figure A-11: CA Future Generation (TWh) Mix



Source: California Energy Commission, Data: NREL Cambium 2024 Mid-case scenario

TOU Rates

Table A-10 presents the hourly time-of-use (TOU) electricity rates for the year 2028 across the five major load-serving entities (SCE, PG&E, SDG&E, LADWP, and SMUD). The table shows how TOU rates vary by season and by day-type, with separate rate structures for Winter, Summer, and transitional seasons as well as for weekdays and weekends (or holidays, as shown in table). **Table A-12** summarizes how each LSE defines its Winter, Summer, and transitional seasons based on calendar months. Across all utilities, these seasonal and day-type differences result in approximately 26 distinct TOU rate patterns. A color-coded scheme at the bottom of the table identifies each hour as Super-Off-Peak, Off-Peak, Mid-Peak, or On-Peak. **Table A-11** provides the same information for 2037. Both the 2028 and 2037 TOU rate projections were developed and provided by staff from the Energy Assessments Division of the California Energy Commission. A statewide annual electricity rate escalation of 2% from 2028 through 2037 was applied based on the 2024 IEPR Electricity Rate Forecast, which also provides detailed escalation rates for each load-serving entity.[106]

106 California Energy Commission. 2024. *2024 IEPR Electricity Rate Forecast*. Docket 24-IEPR-03, Electricity Demand Forecast, TN 260210. November 21, 2024. Sacramento, CA. Available at: https://efiling.energy.ca.gov/Lists/DocketLog.aspx?docketnumber=24-IEPR-03.

On-Peak periods show the highest prices across all utilities, typically occurring in late afternoon and early evening when solar generation declines and system demand remains high, while Super-Off-Peak hours appear mostly overnight when demand is lowest. Seasonal and utility-specific differences are also evident, with summer months showing sharper price peaks driven by cooling demand and weekends (or holidays) generally having simpler, less variable TOU structures.

Table A-10: Electricity TOU Rates Summary 2028

LSE Name	Season	Day type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
LADWP	Winter	Weekday	25.4 ¢									28.3 ¢				28.3 ¢				28.3 ¢			25.4 ¢			
		Holiday	25.4 ¢																							
	April-May	Weekday	24.1 ¢									27.0 ¢				27.0 ¢				27.0 ¢			24.1 ¢			
		Holiday	24.1 ¢																							
	June	Weekday	23.6 ¢									27.0 ¢				34.2 ¢				27.0 ¢			23.6 ¢			
		Holiday	23.6 ¢																							
	Summer	Weekday	25.9 ¢									29.3 ¢				36.5 ¢				29.3 ¢			25.9 ¢			
		Holiday	25.9 ¢																							
PGE	Winter	Weekday	41.8 ¢																	45.9 ¢				41.8 ¢		
		Holiday	41.8 ¢																	45.9 ¢				41.8 ¢		
	Summer	Weekday	45.6 ¢																	58.4 ¢				45.6 ¢		
		Holiday	45.6 ¢																	58.4 ¢				45.6 ¢		
SCE	Winter	Weekday	39.0 ¢									34.9 ¢								53.6 ¢				39.0 ¢		
		Holiday	39.0 ¢									34.9 ¢								53.6 ¢				39.0 ¢		
	Summer	Weekday	36.1 ¢																	61.5 ¢				36.1 ¢		
		Holiday	36.1 ¢																	48.7 ¢				36.1 ¢		
SDGE	Winter	Weekday	44.6 ¢									46.6 ¢								53.6 ¢				46.6 ¢		
		Holiday	44.6 ¢														46.6 ¢			53.6 ¢				46.6 ¢		
	March-April	Weekday	30.3 ¢							44.0 ¢			30.3 ¢				44.0 ¢			70.0 ¢				44.0 ¢		
		Holiday	30.3 ¢														44.0 ¢			70.0 ¢				44.0 ¢		
	Summer	Weekday	30.3 ¢							44.0 ¢										70.0 ¢				44.0 ¢		
		Holiday	30.3 ¢														44.0 ¢			70.0 ¢				44.0 ¢		
SMUD	Winter	Weekday	12.7 ¢																	17.6 ¢			12.7 ¢			
		Holiday	12.7 ¢																							
	Summer	Weekday	15.7 ¢													21.7 ¢				38.2 ¢			21.7 ¢			
		Holiday	15.7 ¢																							

Color Code	Super-Off-Peak	Off-Peak	Mid-Peak	On-Peak

Source: California Energy Commission

Table A-11: Electricity TOU Rates Summary 2037

LSE Name	Season	Day type	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
LADWP	Winter	Weekday	45.0 ¢									50.2 ¢				50.2 ¢				50.2 ¢				45.0 ¢		
		Holiday	45.0 ¢																							
	April-May	Weekday	42.6 ¢									47.8 ¢				47.8 ¢				47.8 ¢				42.6 ¢		
		Holiday	42.6 ¢																							
	June	Weekday	41.8 ¢									47.8 ¢				60.6 ¢				47.8 ¢				41.8 ¢		
		Holiday	41.8 ¢																							
	Summer	Weekday	45.8 ¢									51.8 ¢				64.6 ¢				51.8 ¢				45.8 ¢		
		Holiday	45.8 ¢																							
PGE	Winter	Weekday	59.8 ¢																	64.6 ¢				59.8 ¢		
		Holiday	59.8 ¢																	64.6 ¢				59.8 ¢		
	Summer	Weekday	65.8 ¢																	80.8 ¢				65.8 ¢		
		Holiday	65.8 ¢																	80.8 ¢				65.8 ¢		
SCE	Winter	Weekday	55.6 ¢									49.7 ¢								76.3 ¢				55.6 ¢		
		Holiday	55.6 ¢									49.7 ¢								76.3 ¢				55.6 ¢		
	Summer	Weekday	51.3 ¢																	87.6 ¢				51.3 ¢		
		Holiday	51.3 ¢																	69.3 ¢				51.3 ¢		
SDGE	Winter	Weekday	61.8 ¢									64.6 ¢								74.3 ¢				64.6 ¢		
		Holiday	61.8 ¢														64.6 ¢			74.3 ¢				64.6 ¢		
	March-April	Weekday	42.0 ¢									60.9 ¢				42.0 ¢				60.9 ¢				96.9 ¢		
		Holiday	42.0 ¢														60.9 ¢			96.9 ¢				60.9 ¢		
	Summer	Weekday	42.0 ¢									60.9 ¢								96.9 ¢				60.9 ¢		
		Holiday	42.0 ¢														60.9 ¢			96.9 ¢				60.9 ¢		
SMUD	Winter	Weekday	20.1 ¢																	27.7 ¢				20.1 ¢		
		Holiday	20.1 ¢																							
	Summer	Weekday	24.8 ¢													34.3 ¢				60.3 ¢				34.3 ¢		
		Holiday	24.8 ¢																							

Color Code	Super-Off-Peak	Off-Peak	Mid-Peak	On-Peak

Source: California Energy Commission

Table A-12: Seasonal Change of TOU Rate for Each Month for 5 Major LSEs

	1	2	3	4	5	6	7	8	9	10	11	12
Months	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**
LADWP	Winter			April-May		June	Summer			Winter		
PG&E	Winter					Summer				Winter		
SCE	Winter					Summer				Winter		
SDGE	Winter		March-April		Winter	Summer					Winter	
SMUD	Winter					Summer				Winter		

Source: California Energy Commission

Social Cost of Carbon

The Social Cost of Carbon (SCC) represents the estimated economic damages associated with emitting one additional metric ton of greenhouse gases, including impacts to public health, agriculture, property, ecosystems, and overall economic productivity. The SCC is commonly used in policy analysis to monetize the climate benefits of reducing GHG emissions and to allow consistent comparison across programs and regulatory options. In this analysis, the SCC is applied to calculate total statewide avoided GHG monetary benefits by multiplying the total statewide avoided GHG emissions by the selected SCC values.

Table A-13 presents SCC values obtained from the U.S. Environmental Protection Agency (EPA) report, "Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances" (November 2023) and highlights, in bold, the SCC values expressed in 2020 dollars that are selected for the analysis years 2028 and 2037 using a 2 percent near-term Ramsey discount rate.[107] **Table A-14** converts these SCC values from 2020 dollars to 2026 dollars using the CPI Inflation Calculator, and the inflation-adjusted values are used in the avoided GHG benefit calculations.

Table A-13: Social Cost of Carbon, 2020-2040 (In $2020 per MTCO2)

Emission Year	Near-term Ramsey Discount Rate		
	2.5%	**2.0%**	1.5%
2020	$ 117	$ 193	$ 337
2021	$ 119	$ 197	$ 341
2022	$ 122	$ 200	$ 346
2023	$ 125	$ 204	$ 351
2024	$ 128	$ 208	$ 356
2025	$ 130	$ 212	$ 360
2026	$ 133	$ 215	$ 365
2027	$ 136	$ 219	$ 370
2028	$ 139	**$ 223**	$ 375
2029	$ 141	$ 226	$ 380
2030	$ 144	$ 230	$ 384
2031	$ 147	$ 234	$ 389
2032	$ 150	$ 237	$ 394
2033	$ 153	$ 241	$ 398
2034	$ 155	$ 245	$ 403
2035	$ 158	$ 248	$ 408
2036	$ 161	$ 252	$ 412
2037	$ 164	**$ 256**	$ 417
2038	$ 167	$ 259	$ 422
2039	$ 170	$ 263	$ 426
2040	$ 173	$ 267	$ 431

Source: EPA Report on the Social Cost of Greenhouse Gases

Table A-24 (see page A-40) summarizes the estimated annual statewide GHG emissions reductions and associated climate benefits resulting from the staff proposal in 2028 and 2037.

107 U.S. Environmental Protection Agency, *Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances*, Office of Policy, National Center for Environmental Economics and Office of Air and Radiation, Climate Change Division, November 2023. Available at https://www.epa.gov/system/files/documents/2023-12/epa_scghg_2023_report_final.pdf.

The Annual Climate Benefit of GHG Avoided is calculated by multiplying the Annual GHG Avoided values by the corresponding Social Cost of Carbon values, expressed in 2026 dollars, from **Table A-14**.

Table A-14: Social Cost of Carbon for 2028 and 2037 In Original $2020 and $2026 per MTCO2 after adjusting for inflation

Year	SC-CO2 in $2020 per $MTCO_2$	SC-CO2 in $2026 per $MTCO_2$
2028	$ 223	$ 275
2037	$ 256	$ 315

Source: California Energy Commission

In addition to evaluating the benefits associated with avoided greenhouse gas emissions, staff evaluated the incremental costs necessary for manufacturers to comply with the proposed standards. The following section describes the methodology used to estimate these costs at the manufacturer and retail levels.

Incremental Cost

Staff estimated the incremental cost associated with complying with the proposed standards using a bottom-up engineering assessment of the additional hardware, software, cybersecurity, communications, and compliance-related functionality. Staff reviewed publicly available component pricing, thermostat product information, product teardown studies, manufacturer-to-retail markup methodologies, and feedback from interested parties.[108]

Available market information indicates that smart thermostats represent the predominant segment of the California thermostat market and already incorporate many of the core capabilities required by the proposed standards, including communications hardware, microcontrollers, memory, and software platforms.[109] Therefore, staff based the incremental

108 Electronics360. "Teardown: Nest Learning Thermostat." Electronics360, October 12, 2017. Available at https://electronics360.globalspec.com/article/9493/teardown-nest-learning-thermostat.

LV. "Nest Thermostat E Teardown and On Making Beautiful Devices for the Home." Medium, September 4, 2017. Available at https://justlv.medium.com/nest-thermostat-e-teardown-and-on-making-beautiful-devices-for-the-home-ae6ada01bb26.

TechInsights. "Deep Dive Teardown: ecobee Smart Thermostat ECB601 Home Thermostat." TechInsights. Available at https://www.techinsights.com/blog/deep-dive-teardown-ecobee-smart-thermostat-ecb601-home-thermostat.

AGS Devices. "How Much Does It Cost to Build a Smart Thermostat?" AGS Devices. Available at https://www.agsdevices.com/bom-cost/.

iFixit. "Tado Smart Radiator Thermostat Teardown." iFixit Guide No. 129731. Available at https://ifixit-guide-pdfs.s3.amazonaws.com/pdf/ifixit/guide_129731_en.pdf.

109 Grand View Research. *Thermostat Market Size, Share & Trends Analysis Report By Product (Smart Thermostat, Mechanical Thermostat), By End Use (Industrial, Commercial, Residential), By Region, And Segment Forecasts, 2025–2030*. Grand View Research. Available at https://www.grandviewresearch.com/industry-analysis/thermostat-market-report.

cost assessment on a representative smart thermostat and estimated the additional functionality required to comply with the proposed standards.

Staff identified several categories of incremental cost, including memory upgrades, clock and persistence functionality, cybersecurity implementation, OpenADR 3.1 compliance, dataset retrieval and integrity functions, user interface modifications, testing and certification activities, and other compliance-related software development. The estimated incremental costs to consumer (at the manufacturer-level) are summarized in **Table A-15**.

Firmware development costs were estimated by amortizing one-time engineering costs over the expected production volume. As an example of the lower-bound estimate, a one-time firmware development cost of $100,000 amortized over 100,000 units results in an incremental cost of approximately $1.00 per unit. Based on this amortization approach, staff estimated a per-unit firmware development cost ranging from $1.00 to $5.00.[110]

Table A-15: Summary of Estimated Manufacturer-Level Incremental Costs

FDAS Requirement Category	Lower-Range Estimate ($2026 / unit)	Higher-Range Estimate ($2026 / unit)	Reference
Integral memory upgrades	$ 0.00	$ 0.70	DigiKey Memory Product List
Clock & persistence	$ 0.20	$ 0.60	Real-Time Clocks (RTCs) & Timers (Product selection table), DigiKey Real-Time Clock (RTC) List
Cybersecurity	$ 0.10	$ 4.00	AWS IoT Device Defender Pricing, DigiKey Authentication Chip
OpenADR 3.1 compliance	$ 0.10	$ 0.50	OpenADR 3 Certification Testing and Process
Dataset retrieval & integrity (firmware/cloud)	$ 1.00	$ 5.00	Firmware Development Costs 2025
Autoflex functionality	(included above)	(included above)	

110 Promwad, *How Much Does It Cost to Build a Custom Embedded System in 2025? From PoC to Mass Production*, August 8, 2025. Available at https://promwad.com/news/how-much-does-it-cost-to-build-a-custom-embedded-system-in-2025-from-poc-to-mass-production.

UI modifications	$ 0.30	$ 1.00	BLS Software Developers Staff Cost, LCD and OLED Graphic Displays, Tactile Switches
DR schedule functionality	(included above)	(included above)	
Certification & testing	$ 0.30	$ 0.50	BLS Certification Data Entry Staff Cost
Labeling & marking	$ 0.00	$ 0.00	
Total	**$ 2.00**	**$ 12.30**	

Source: California Energy Commission

Table A-16: Estimated Retail Incremental Cost Components for Proposed Standards Requirements

	Incremental Manufacturing Cost	Retail Impact (x1.68)
Low-end	$ 2.00	$ 3.36
High-end	$ 12.30	$ 20.66
Average	**$ 7.15**	**$ 12.00**

Source: California Energy Commission

The estimated incremental cost to consumer (at the manufacturer-level) ranges from approximately $2.00 to $12.30 per thermostat, with a midpoint estimate of approximately $7.15 per thermostat. Consistent with methodologies used by the U.S. Department of Energy (DOE) for consumer products sold through retail distribution channels, staff applied an incremental retail markup factor of 1.68 to estimate the retail price impact on consumers.[111]

Applying the retail markup factor results in an estimated retail-level incremental cost to consumer range of approximately $3.36 to $20.66 per thermostat, yielding a midrange incremental retail cost estimate of $12.00 per thermostat as shown in **Table A-16**.

Based on the engineering assessment, manufacturer-to-retail markup analysis, available market information, and feedback from interested parties, staff arrived at an incremental retail cost to consumer of $12 per thermostat for the statewide benefits-cost analysis. Staff consider this value to be a reasonable and representative estimate of the incremental retail cost associated with complying with the proposed standards.

111 U.S. Department of Energy (DOE). *Technical Support Document: Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment: Room Air Conditioners*. March 2023. Table 6.5.1, "Summary of Markups," p. 6-6. Available at https://www.regulations.gov/document/EERE-2014-BT-STD-0059-0053.

Participation Rate

Table A-17: Annual Cumulative Stock accounting for opt-out rate

Year No.	Year	Percentage Of Compliant Stock Installed Each Year	Cumulative Stock Without Accounting for Opt-out Rate	Yearly Program Opt-out Rate	Yearly Program Opt-out Rate	Corresponding Cumulative Stock	Corresponding Cumulative Stock
				Lower Range	Higher Range	Lower Range (For Higher Opt-out)	Higher Range (For Lower Opt-out)
0	2027	0%	0%	4%	8%	0%	0%
1	2028	10%	10%	4%	8%	9%	10%
2	2029	10%	20%	4%	8%	18%	19%
3	2030	10%	30%	4%	8%	25%	28%
4	2031	10%	40%	4%	8%	33%	36%
5	2032	10%	50%	4%	8%	39%	44%
6	2033	10%	60%	4%	8%	45%	52%
7	2034	10%	70%	4%	8%	51%	60%
8	2035	10%	80%	4%	8%	56%	67%
9	2036	10%	90%	4%	8%	61%	74%
10	2037	10%	100%	4%	8%	65%	80%

Source: California Energy Commission

Table A-17 shows the assumed annual market adoption trajectory for FDAS-compliant equipment, including annual new installation and replacement rates and cumulative stock levels with and without accounting for program opt-out. The adoption assumptions are based on a 10-year estimated useful life, with 10% of the stock assumed to be replaced annually, resulting in full stock turnover (100%) after completing 10 years from the regulation's effective date. The table also presents lower- and higher-bound opt-out assumptions and the resulting corresponding cumulative participation ranges used in the analysis. The adoption assumptions also account for compliance rates and include households without internet access, whose HVAC thermostats automatically operate in autoflex mode using the MIDAS static dataset. Based on RECS 2020 data, this includes approximately 4.5% of households, with particular relevance for justice communities that may lack reliable internet connectivity.[112]

112 U.S. Energy Information Administration (EIA), *2020 Residential Energy Consumption Survey (RECS)*, Available at https://www.eia.gov/consumption/residential/data/2020/

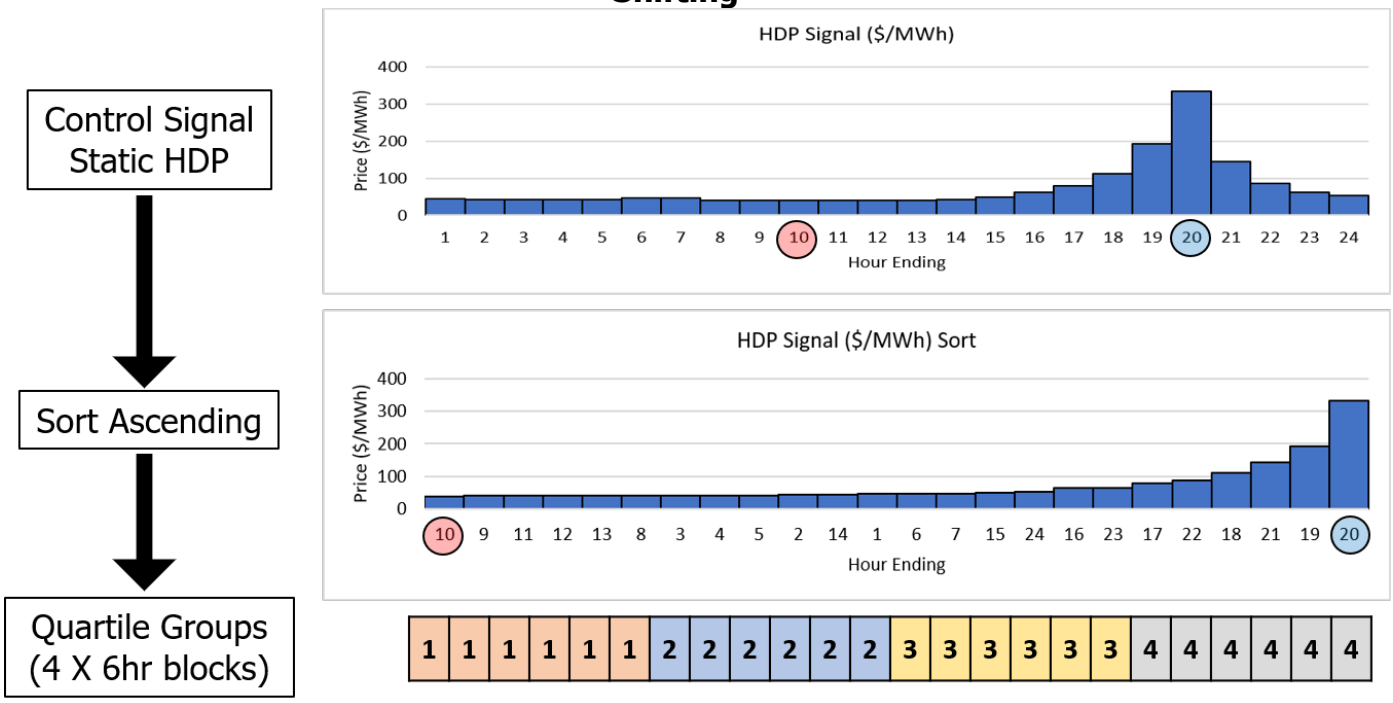
Section II - Calculation Methodology

This section describes the methodologies and calculations used to estimate load shifting, consumer bill savings, avoided costs, emissions reductions, health benefits, reliability benefits, gross costs, and economic impacts.

Load Shifting

This section describes the methodology used to convert control signals into hourly load-shifting schedules.

Figure A-12: Quartile-Based Classification of Hourly Control Signals for Load Shifting

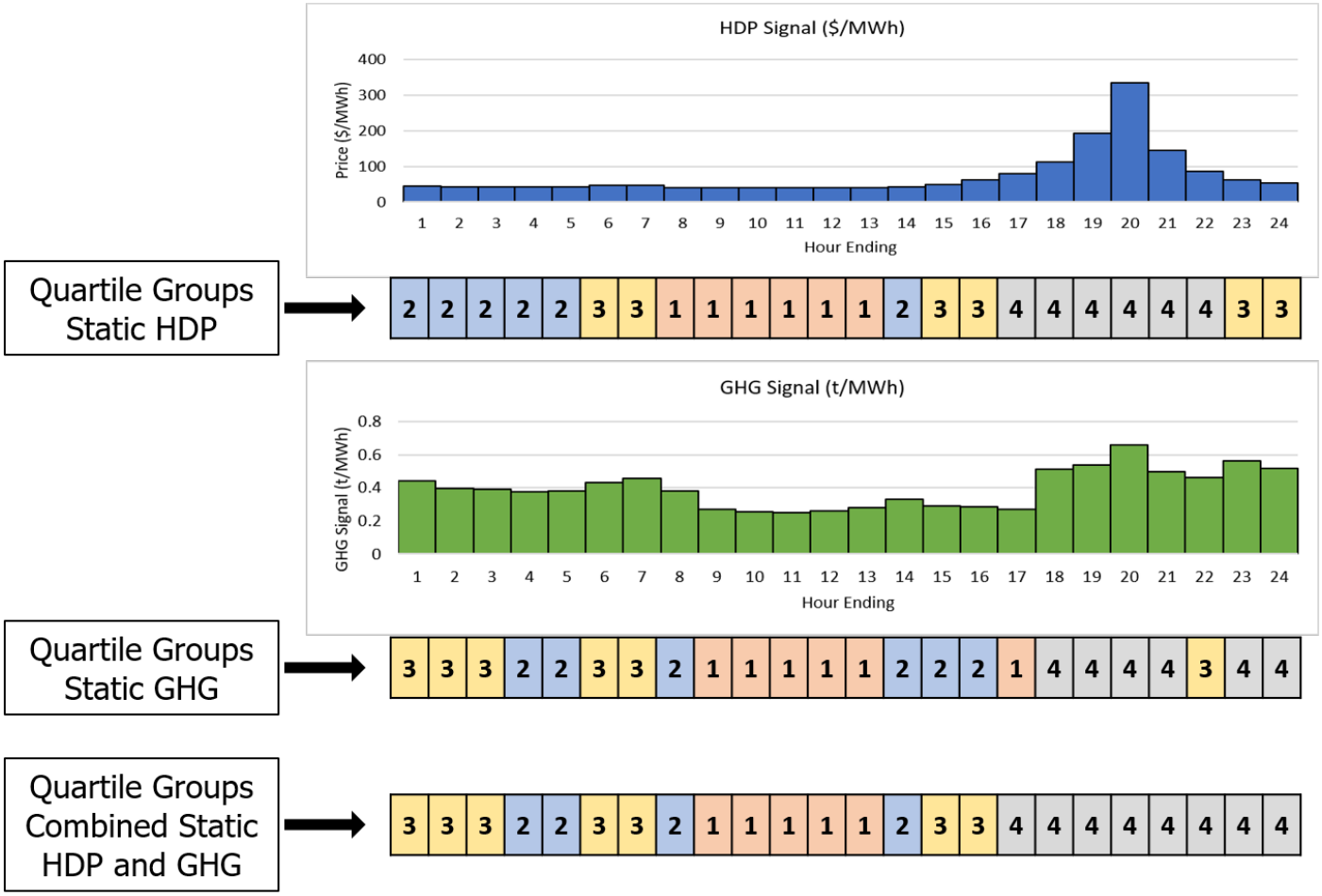


Source: California Energy Commission

Figure A-12 illustrates the method used to create quartile groups for a 24-hour control signal, using the highly dynamic price (HDP) signal from the MIDAS static dataset as an example. Quartile grouping is used to convert a continuous hourly control signal into discrete categories that will be used in the load shifting logic. The process begins by sorting the hourly control signal values in ascending order while retaining the original hour associated with each value.

The sorted hours are then divided into four equal groups of six hours each, such that all 24 hours are assigned to a quartile. Quartile values from 1 to 4 are assigned in increasing order, where Quartile 1 represents hours with the lowest control signal values and Quartile 4 represents hours with the highest values. Once assigned, these quartile values are mapped back to their original hourly positions, producing an hourly quartile signal that preserves the original time ordering. These quartile group assignments are then used directly in the load shifting framework, with lower quartiles indicating hours more suitable for load increases and higher quartiles indicating hours more suitable for load reductions.

Figure A-13: Combined HDP and GHG Signal Quartiles from the MIDAS Static Dataset



Source: California Energy Commission

Table A-18: Combined Control Signal Quartile Assignment Matrix for HDP and GHG Signals from the MIDAS Static Dataset

		GHG			
		1-Low Hr	2-Low-Med Hr	3-Hi-Med Hr	4-Hi Hr
HDP	1-Low Hr Gp	1	2	3	4
	2-Low-Med Hr Gp	2	2	3	4
	3-Hi-Med Hr Gp	3	3	3	4
	4-Hi Hr Gp	4	4	4	4

Source: California Energy Commission

Figure A-13 and **Table A-18** together describe the method used to generate hourly load-shifting schedules for the staff proposal scenario – combined HDP and GHG. First, the Highly HDP signal and the GHG emission intensity signal from the MIDAS static dataset are each independently converted into quartile groups based on their relative hourly rankings, as described in the previous paragraph (see also **Figure A-12**). This step standardizes the two

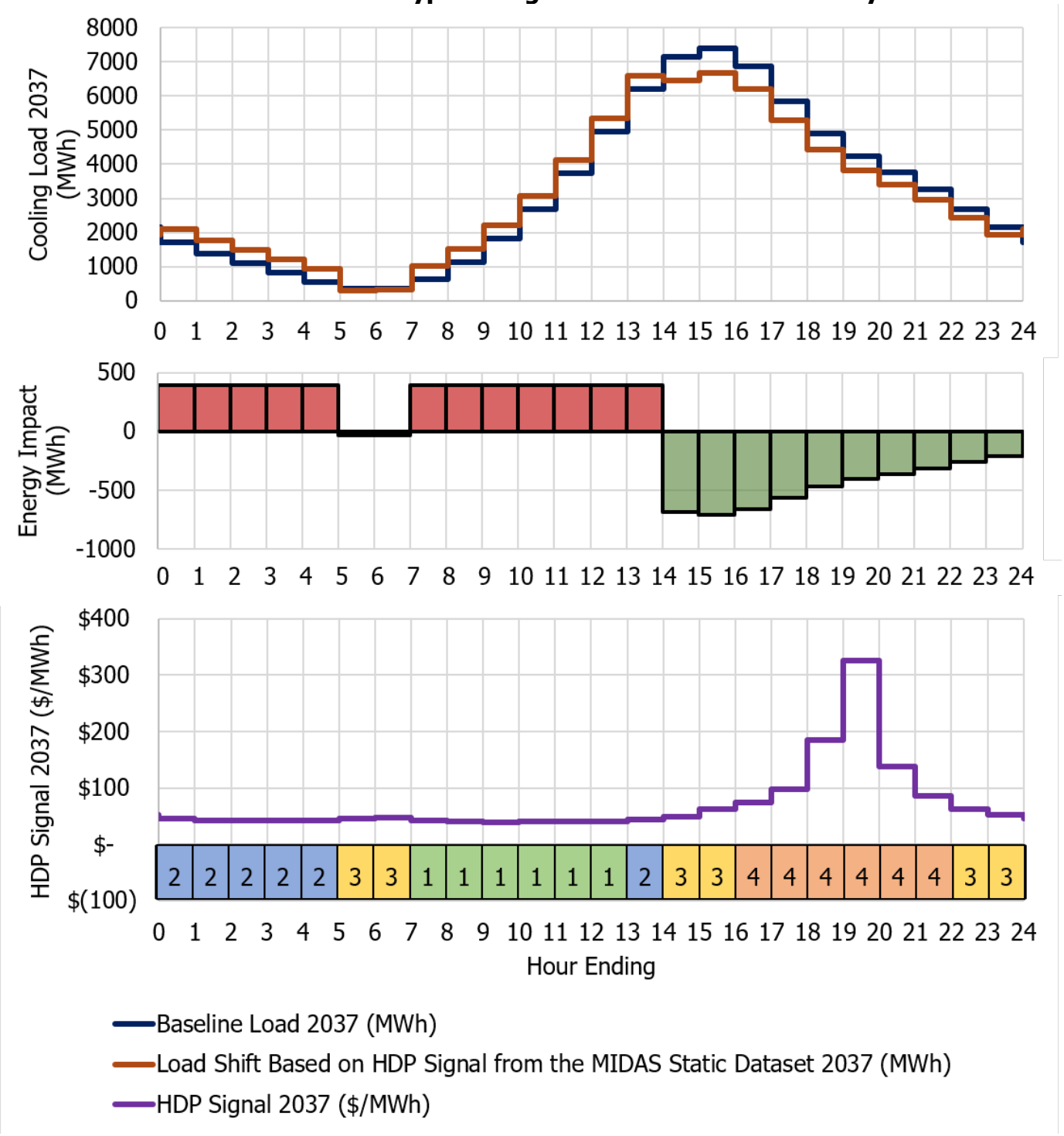
control signals and allows them to be compared on a common ordinal scale rather than relying on absolute values.

Once quartile groups are assigned, the HDP and GHG quartiles for each hour are combined using the lookup table shown in **Table A-18**. The lookup table defines the final hourly load-shifting group by considering both economic and emissions signals simultaneously. Hours with higher HDP and higher GHG quartiles are assigned higher load-shifting groups, indicating greater suitability for load reduction, while hours with lower quartiles are assigned lower groups, indicating greater suitability for load increase. And for combinations involving mid and higher quartiles of either control signal, higher final quartiles are favored. This design intentionally identifies and includes a broader set of hours that are critical for load shifting, particularly those with elevated prices, elevated emissions, or both. By prioritizing these hours, the combined HDP and GHG scenario staff proposal captures more opportunities for economically and environmentally beneficial load reductions. As a result, the staff proposal is expected to be more cost-effective and to achieve greater GHG reductions than the price-only or emissions-only alternatives, as demonstrated in the Key Energy and Emissions Results subsection of Section III below.

To ensure that the proposed load-shifting strategy maintains occupant comfort, staff limited the load-shifted for each participating thermostat to no more than 12 percent of its space-conditioning load. **Figure D-9**, located in Appendix D, illustrates the relationship between thermostat temperature offset strength and the percentage of cooling load shifted during representative maximum cooling days across California climate zones. The figure shows that a 12 percent load shift corresponds to a thermostat temperature offset of approximately 0.5°F, even under maximum cooling conditions. Based on staff's building thermal simulations, this conservative offset ensures that, even for homes with relatively poor insulation on hot summer days, the resulting increase in maximum indoor temperature is generally limited to no more than approximately 2°F. By limiting the amount of load shifted, the proposed standards are expected to produce small and generally indiscernible changes in indoor comfort while still providing meaningful load-shifting, consumer bill savings, and greenhouse gas reduction benefits.

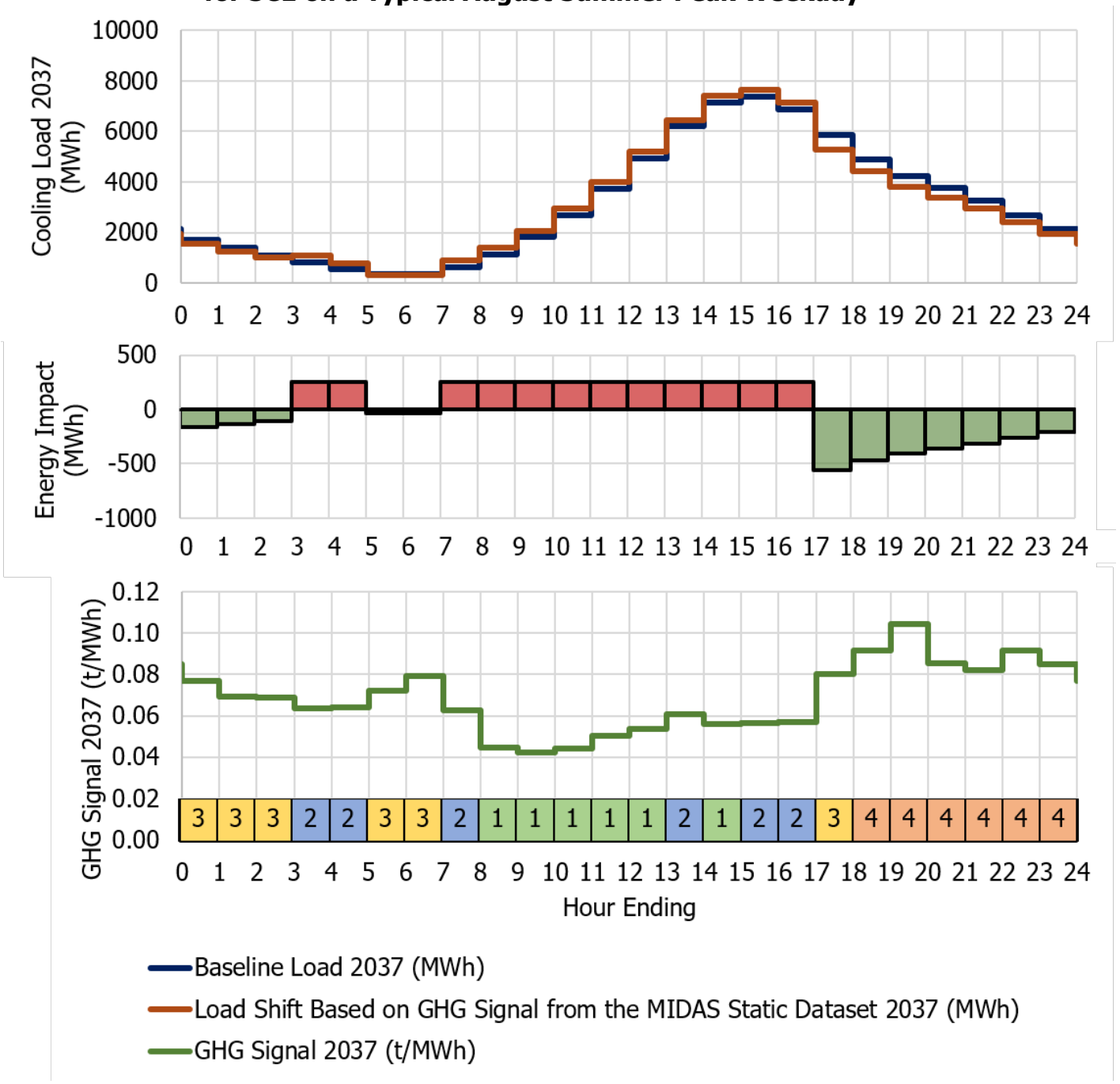
Staff also verified that the selected 12 percent load-shifting level does not exceed the maximum power ratings of representative HVAC systems. The representative HVAC system power ratings considered in the analysis are described in the following subsection, "HVAC System Power Ratings and Load-Shifting Constraints."

Figure A-14: Load Shifting Based on Autoflex HDP Signals from the MIDAS Static Dataset for SCE on a Typical August Summer Peak Weekday



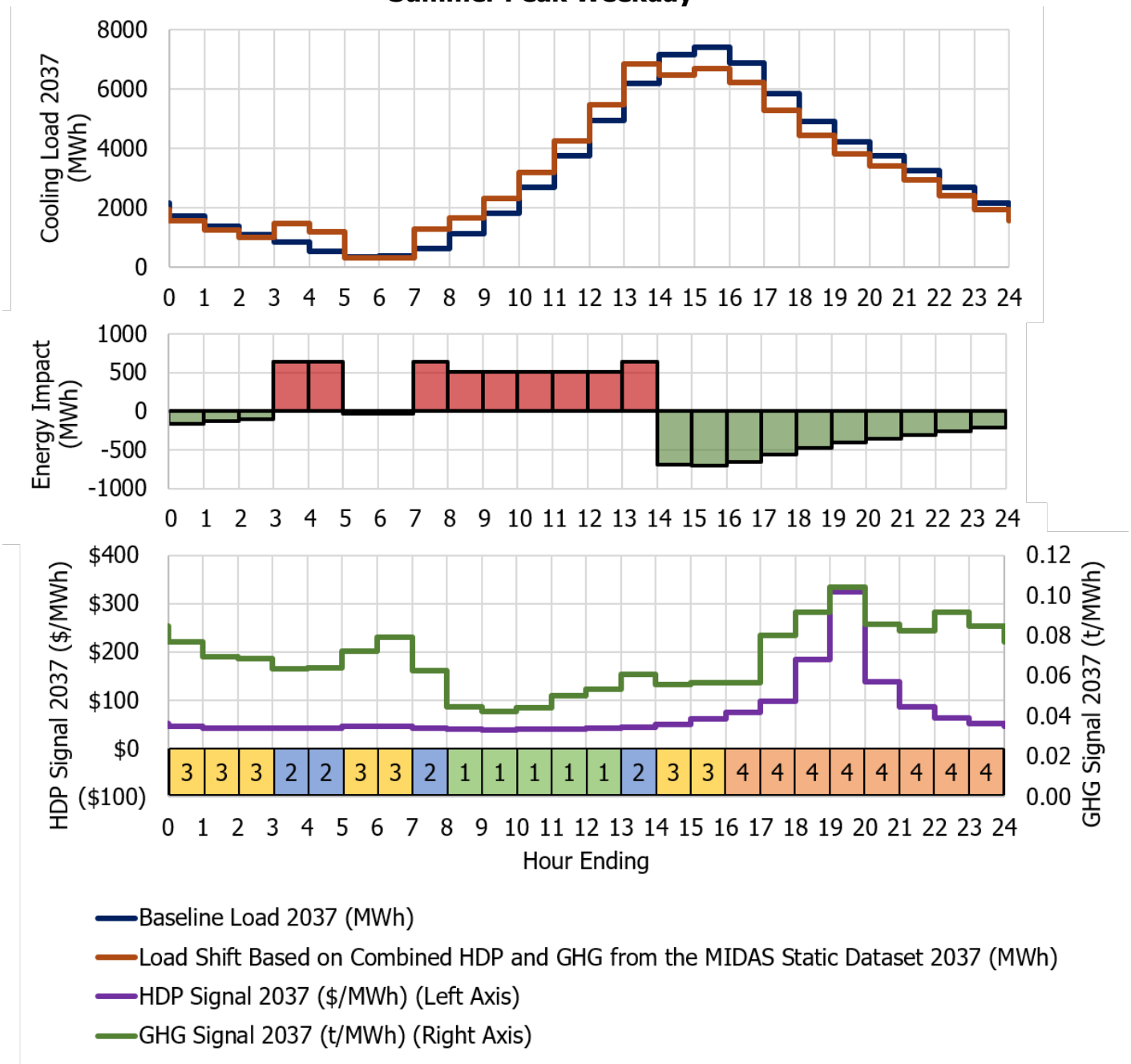
Source: California Energy Commission

Figure A-15: Load Shifting Based on Autoflex Static GHG Marginal Emission Rates for SCE on a Typical August Summer Peak Weekday



Source: California Energy Commission

Figure A-16: Load Shifting Based on Autoflex Combined Static and Highly Dynamic Electricity Prices and GHG Marginal Emission Rates for SCE on a Typical August Summer Peak Weekday



Source: California Energy Commission

HVAC System Power Ratings and Load-Shifting Constraints

To ensure that load-shifting strategies remain technically feasible and do not result in unrealistic operating conditions, staff constrained the shifted HVAC load to the maximum power rating of the underlying HVAC equipment. When load is moved from one hour to another, the resulting power demand cannot exceed the capacity of the HVAC system to deliver heating or cooling. Therefore, knowledge of the power consumption and capacity of

the major HVAC system components is necessary to establish reasonable upper limits for load shifting. The following paragraphs summarize the typical power ratings of various residential HVAC systems and their major components, which were used to inform the load-shifting constraints applied in the analysis.

Appliances do not use electricity the same way to heat and cool homes. Staff identified three broad system categories for central electric space-conditioning appliances: air-conditioning systems, heat pumps, and electric resistance heater.

Staff gathered information from published HVAC manufacturer product specification documents. Product literature provided load information on components such as resistive elements, heat pump elements, and HVAC controls. **Table A-19** and **Table A-20** show a sample of the information used to verify the staff analysis. For Table A-20, staff used an average daily operating time of 0.2 hours (12 minutes) for electric heat strips used during the defrost cycle, representing operation on a typical winter heating day in California.[113]

Table A-19: Controlled Rated Nominal Capacity 3-ton Air-conditioning System

Electric Central Air Conditioner	Typical Power Range (kW)	Average Daily Operating Time (h)	Daily Energy (kWh)
Refrigerant Compressor (3-ton)	1 to 1.5	6	6 to 9
Fans, Condenser and evaporator	0.5	6	3

Source: California Energy Commission

Table A-20: Controlled Rated Nominal Capacity 3-ton Heat Pump System

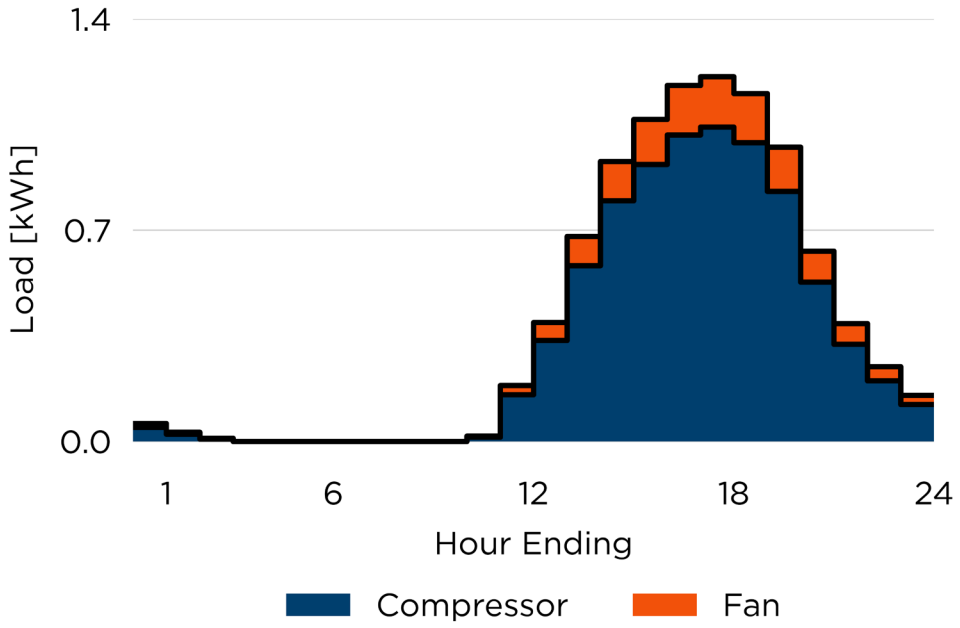
Electric Central Heat Pump	Typical Power Range (kW)	Average Daily Operating Time (h)	Daily Energy (kWh)
Refrigerant Compressor (3-ton)	1 to 1.5	6	6 to 9
Fans, Condenser and evaporator	0.5	6	3
Electric Heat Strips (used during defrost cycle)	8 to 10	0.2	1.6 to 2

Source: California Energy Commission

113 Lennox. 2025. "Understanding the Heat Pump Defrost Cycle." November 10, 2025. Accessed September 4, 2026. Available at https://www.lennox.com/residential/lennox-life/consumer/heat-pump-defrost-cycle

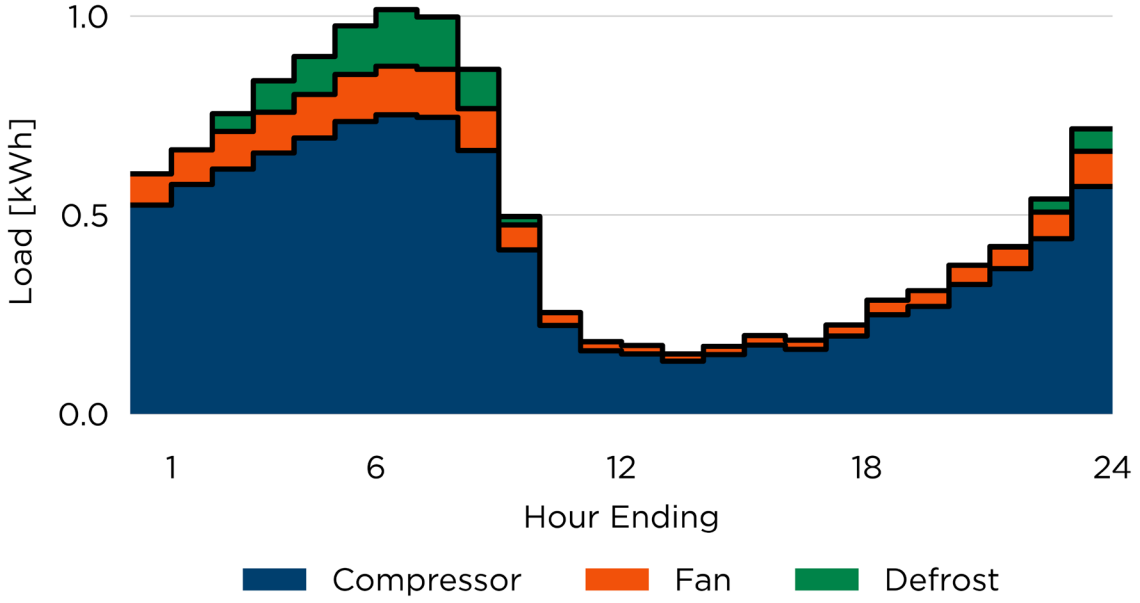
Staff also modeled the central space-conditioning systems in the CEC's California Building Energy Code Compliance software (CBECC). Additional details on the modeling are provided in **Appendix D**. The data shown in this section corresponds to a newly constructed SF1250 prototype located in Sacramento (CZ12). CBECC can provide hourly breakdowns of electric space-conditioning load by the main components: compressors in air-conditioning systems and heat pumps, electric heat strips in electric furnaces and heat pumps, and fans in all ducted central systems. **Figure A-17** through **Figure A-19** show a sample of the modeled data staff used to verify the analysis.

Figure A-17: Modeled Air-conditioning System Load Distribution, Aug 1st (Cooling)



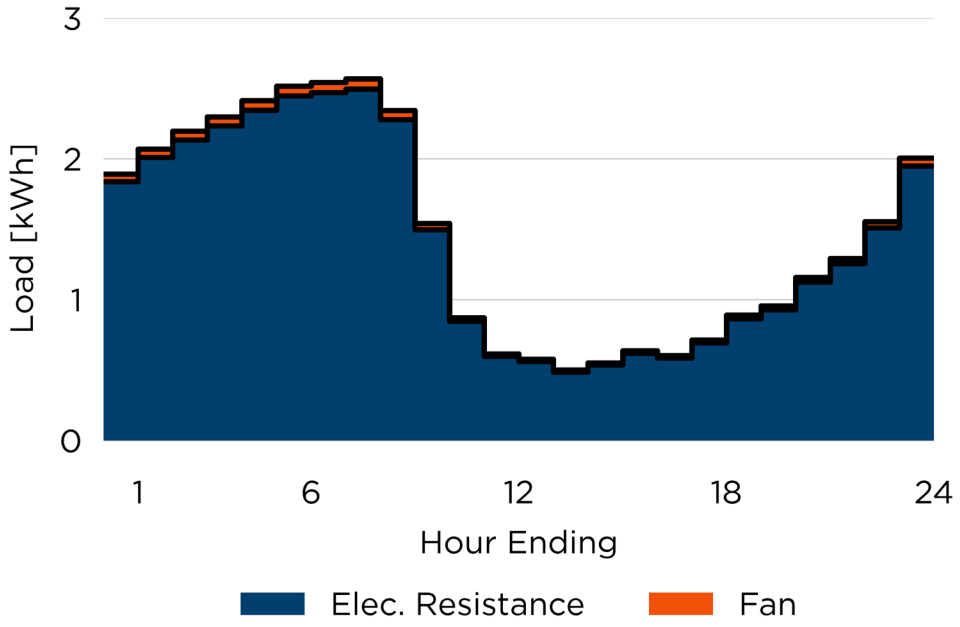
Source: California Energy Commission

Figure A-18: Modeled Heat Pump System Load Distribution, Feb 1st (Heating)



Source: California Energy Commission

Figure A-19: Modeled Electric Resistance Furnace System Load Distribution, Feb 1st (Heating)



Source: California Energy Commission

CPUC ACC

The California Public Utilities Commission's (CPUC) Avoided Cost Calculator (ACC) is a statewide tool used to estimate the value to the state's electric grid system of reducing or shifting electricity demand. The ACC provides hourly avoided costs for several components of

the electric system, including generation capacity, transmission and distribution capacity, ancillary services procurement, energy losses, and methane leakage. These avoided costs reflect the system-level benefits that occur when electricity demand is reduced or shifted away from peak periods. For this analysis, the ACC is used to quantify the hourly and total avoided costs associated with residential HVAC load flexibility in future forecast years.

To generate avoided cost values, the model is run separately for each load-serving entity (LSE) and for the two analysis years, 2028 and 2037. The inputs selected in the ACC include a levelization period of one year, the "base" social cost of carbon case, and the Societal Cost Test (SCT) with a 2% discount rate. The ACC outputs hourly avoided cost values for each climate zone, which are then weighted and averaged based on the share of each LSE's service territory across its climate zones. Finally, the hourly energy impacts from load shifting are multiplied by the corresponding hourly ACC values for each LSE and summed to produce statewide avoided costs for all six categories: generation capacity, transmission capacity, distribution capacity, ancillary services, losses, and methane leakage.

EPA AVERT and COBRA

The U.S. Environmental Protection Agency's (EPA) Avoided Emissions and Generation Tool (AVERT) and Co-Benefits Risk Assessment (COBRA) models are used together to estimate air quality and health benefits resulting from changes in electricity generation. AVERT quantifies reductions in non-GHG criteria air pollutants ($PM_{2.5}$, SO_2, NO_x, VOC, and NH_3) that occur when electricity demand is reduced or shifted, particularly reductions from fossil gas power plant combustion in California. For this analysis, the key input to the AVERT 2023 Desktop Edition is the hourly energy impact from load shifting. When the model is run with the California regional data file, AVERT produces statewide annual reductions in fuel-combustion emissions associated with the electric power sector.

The emission reductions from AVERT serve as inputs to EPA's COBRA Web Edition, which estimates the economic value of avoided health impacts from improved air quality. In COBRA, the California state geography and the "fuel combustion: electric utility" source category are selected to translate the avoided emissions into monetized health benefits, including benefits related to fine particulate matter ($PM_{2.5}$) and ground-level ozone (O_3). By combining AVERT's emission estimates with COBRA's health-impact valuation, the analysis provides statewide avoided health costs associated with HVAC load shifting.

Gross Compliance-Cost Calculation

Total annual gross economic cost equals the sum of incremental covered-product cost and separate costs outside the incremental cost estimate. Benefits are not subtracted from this calculation, and costs already included in the incremental retail cost estimate are not counted again.

Incremental covered-product cost equals annual covered thermostat shipments multiplied by the $12 incremental retail cost.

Incremental covered-product cost
= Annual covered thermostat shipments × $12
= 694,046 × $12

= $8.33 million

Separate costs outside the incremental cost estimate include the cost for retailers or manufacturers to ensure that a product is listed in the CEC database. Retailers are responsible for ensuring that flexible demand appliances sold, offered for sale, or leased in California comply with state law and are listed in the CEC database. Retailers may verify product certification directly in the database or rely on manufacturers, distributors, or contractual arrangements to confirm compliance.

To estimate this cost, CEC staff assumes that verification requires one hour of employee labor per HVAC thermostat model at a labor rate of $50 per hour. Based on information from the CEC database, staff estimates that approximately 1,000 in-scope flexible demand appliance models will require verification. This results in an estimated statewide verification cost of $50,000 over the product life cycle.

Separate costs outside the incremental cost estimate
= Number of in-scope models requiring verification × Hourly employee labor rate × Labor hours per model
= 1,000 × $50 × 1
= $0.05 million

Total gross economic cost
= Incremental covered-product cost + Separate costs outside the incremental cost estimate
= $8.33 million + $0.05 million
= $8.38 million

Section III - Economic, Business, Energy, and Environmental Results

This section presents the economic, business, energy, and environmental results and separates private-sector costs and benefits from utility-system and societal benefits.

Key Energy and Emissions Results

The results below summarize load-shifting capability, greenhouse gas reductions, and customer utility-bill savings for the staff proposal and two alternatives in 2028 and 2037. These metrics are based on the same residential stock, participation, and hourly load-shifting assumptions described in Sections I and II.

Table A-21 presents the estimated load shift potential during the highest-demand summer day, annual GHG emissions reductions, and annual consumer utility bill savings for the staff proposal and two alternative scenarios in both the first year of full implementation (2028) and at full stock turnover (2037). The annual consumer utility bill savings, load-shifting potential, and annual GHG emissions avoided for each scenario are presented in the Economic Impacts, Energy Impacts, and Environmental Impacts sections of **Chapter 6**, respectively.

Table A-21: HVAC Thermostat Staff Proposal and Alternatives

Scenario	Staff Proposal: Autoflex HDP + GHG		Alternative 1: Autoflex HDP		Alternative 2: Autoflex GHG	
Year	**Year 1 (2028)**	**Year 10 (2037)**	**Year 1 (2028)**	**Year 10 (2037)**	**Year 1 (2028)**	**Year 10 (2037)**
Load shift potential during 8 PM hour for the highest demand summer day (MW)	78	780	78	780	78	780
Annual GHG Avoided (in Thousand Metric Tons)	28	50	22	39	24	44
Annual Consumer Utility Bill Savings (M$)	7.4	79.5	6.7	71.6	5.1	57.6

Source: California Energy Commission

Table A-22 summarizes the estimated statewide load shifted from the 8 p.m. hour (8:00–9:00 p.m.) by HVAC thermostats in 2037 for the staff proposal and two alternative approaches. The table reports load shifted during a single representative summer weekday (August 7, 2037), a single representative winter weekday (December 1, 2037), and the cumulative load shifted during the 8 p.m. hour across all days in 2037. The representative summer and winter weekdays were identified using modeled hourly projections for the California electricity sector developed using the National Renewable Energy Laboratory's Cambium Mid-case Scenario with typical meteorological year (TMY) weather data.[114] These dates were selected because they represent periods when the California Independent System Operator (CAISO) grid experiences some of its highest levels of stress during the respective summer and winter seasons.

The values are calculated using the hourly energy impacts estimated for each scenario. The load shifted during the 8 p.m. hour on the representative summer and winter days is equal to the corresponding reduction in electricity consumption during that specific hour. The annual value is calculated by summing the load shifted during the 8 p.m. hour across all days in 2037. The results are similar across the three scenarios because they evaluate the same critical peak hour and therefore have similar participation rates and load-shifting percentages during that period. Consequently, the estimated load shifted during the representative summer and winter

114 National Renewable Energy Laboratory, *Cambium Scenario Viewer* (Mid-case Scenario, Hourly, GEA regions). Available at https://scenarioviewer.nlr.gov.

peak hours is nearly identical across all scenarios. The difference in annual load shifting between the staff proposal and Alternative 2 arises from differences in the identification of peak and off-peak hours throughout the year. Under the quartile-based methodology, peak and off-peak hours are determined using the selected control signal. Because hourly marginal GHG emission rates and highly dynamic electricity prices produce different hourly rankings, Alternative 2 identifies a different set of peak and off-peak hours than the staff proposal. In contrast, the staff proposal and Alternative 1 identify a similar set of peak and off-peak hours, resulting in nearly identical annual load-shifting estimates.

Table A-22: Estimated HVAC Thermostats Statewide Load Shift from Peak hour

Proposal	Load Shifted During 8 p.m. Hour for A Single Winter Weekday 12/1/2037 (GWh)	Load Shifted During 8 p.m. Hour for A Single Summer Weekday 8/7/2037 (GWh)	Average Load Shifted During 8 p.m. Hour Daily, 2037 (GWh)
Staff Proposal: Autoflex Using the Combined HDP and GHG Signals from the MIDAS static dataset	1.35	0.78	178
Alternative 1: Autoflex Using the HDP Signal from the MIDAS static dataset	1.35	0.78	178
Alternative 2: Autoflex Using the GHG Signal from the MIDAS static dataset	1.35	0.78	154

Source: California Energy Commission

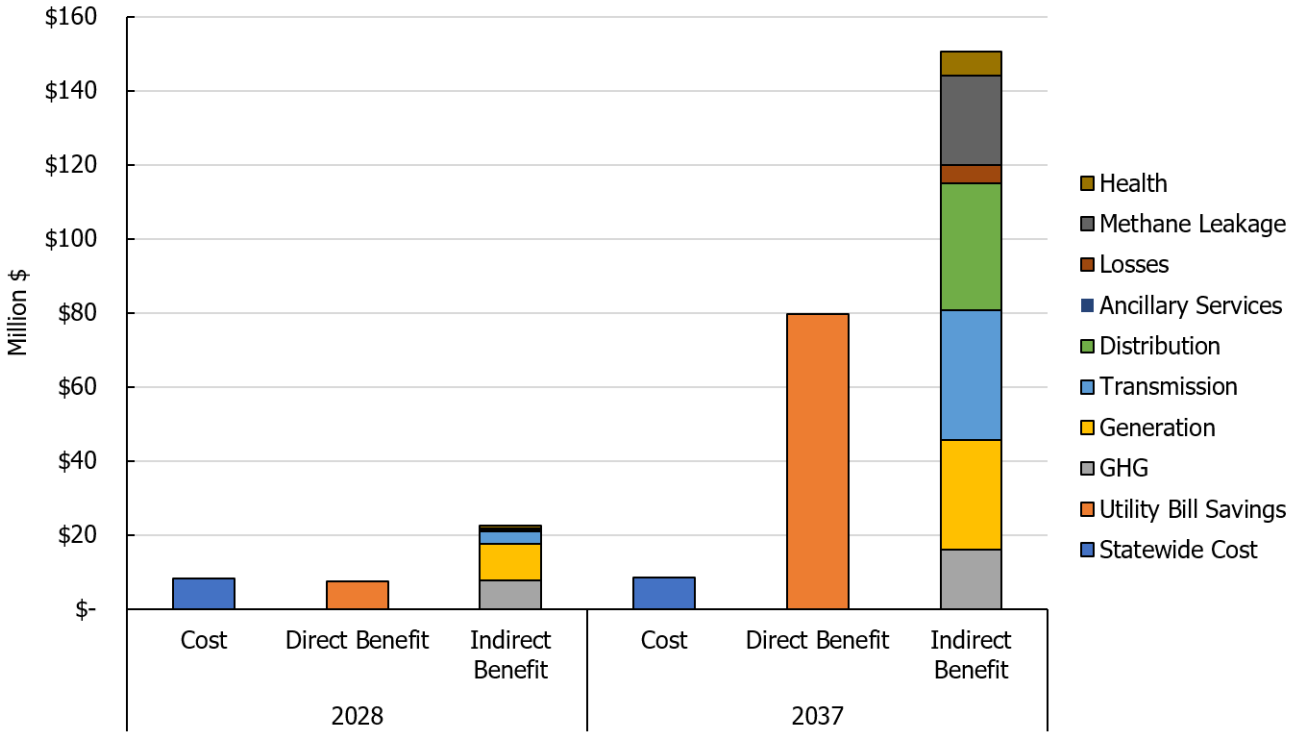
Utility-System and Societal Benefits

This subsection reports benefits that extend beyond the direct financial effects on thermostat purchasers. These include avoided electricity-system costs, climate benefits, air-pollution reductions, public-health benefits, and an illustrative reliability benefit. These results are reported separately from private-sector costs and consumer bill savings to avoid double counting.

Figure A-20 summarizes all estimated total costs and monetary benefit outputs of the model for the staff proposal in the first year of full implementation (2028) and at full stock turnover (2037). The monetary benefits are divided into direct benefits, consisting of consumer utility bill savings, and indirect benefits, consisting of avoided GHG emissions, avoided generation

costs, avoided transmission costs, avoided distribution costs, avoided ancillary services costs, avoided losses, avoided methane leakage, and health benefits.

Figure A-20: Total Yearly Cost and Benefit



Source: California Energy Commission

Table A-23 summarizes the estimated annual statewide GHG emissions reductions and associated climate benefits resulting from the staff proposal in the first year of full implementation (2028) and at full stock turnover (2037). The GHG emissions reductions are calculated by multiplying the hourly energy impacts resulting from load shifting under the proposed standard by the corresponding hourly GHG emission intensities for each year and summing the results across all hours of the year. The resulting annual GHG emissions reductions are then multiplied by the corresponding Social Cost of Carbon values from **Table A-14**, expressed in 2026 dollars, to estimate the annual climate benefits.

Table A-23: Annual California Statewide GHG Avoided and Climate Benefits

Year	Annual GHG Avoided (in Thousand Metric Tons)	Annual Climate Benefit of GHG Avoided (Millions, $2026/yr)
2028	27.8	$7.6
2037	50.5	$15.9

Source: California Energy Commission

Table A-24 presents the estimated annual avoided costs for each ACC category in 2028 and 2037. The avoided cost values are calculated by multiplying the hourly energy impacts resulting from load shifting under the proposed standard by the corresponding hourly ACC

values for each category and summing the results across all hours of the year. The ACC values are sourced from the CPUC Avoided Cost Calculator discussed in the Process section above.

Table A-24: Yearly Avoided Cost based on ACC Categories

ACC Category	2028 Avoided Cost (M$)	2037 Avoided Cost (M$)
Generation Capacity	$10.07	$29.65
Transmission	$3.22	$35.10
Distribution	$0.07	$34.27
Ancillary Services Procurement	$0.00	$0.00
Losses	$0.27	$4.92
Methane Leakage	$0.40	$24.24

Source: California Energy Commission

Table A-25 presents the criteria air pollutant (CAP) emissions considered in the analysis and their potential contribution to fine particulate matter ($PM_{2.5}$) formation and ground-level ozone (O_3) formation. This information is used in the EPA AVERT and COBRA analysis to relate avoided emissions from electricity generation to corresponding air quality and health endpoints. **Table A-26** summarizes the estimated statewide emissions reductions resulting from the staff proposal in the first year of full implementation (2028) and at full stock turnover (2037). As described in the EPA AVERT and COBRA section above, the AVERT model uses the hourly energy impacts resulting from load shifting under the proposed standard to estimate annual avoided emissions of $PM_{2.5}$, SO_2, NO_x, VOC, and NH_3 associated with electricity generation in California.

Table A-25: Emission Pollutants and Their Contribution to Direct/Secondary PM2.5 and Ground-Level Ozone Formation

Emission	Source for Direct or Secondary $PM_{2.5}$	Source for Ground-level Ozone
$PM_{2.5}$	Yes (Direct)	No
SO_2	Yes (Secondary)	No
NO_X	Yes (Secondary)	Yes
VOC	Yes (Secondary)	Yes
NH_3	Yes (Secondary)	No

Source: California Energy Commission

Table A-26: HVAC Thermostats Statewide Air Pollutants Emissions Impacts

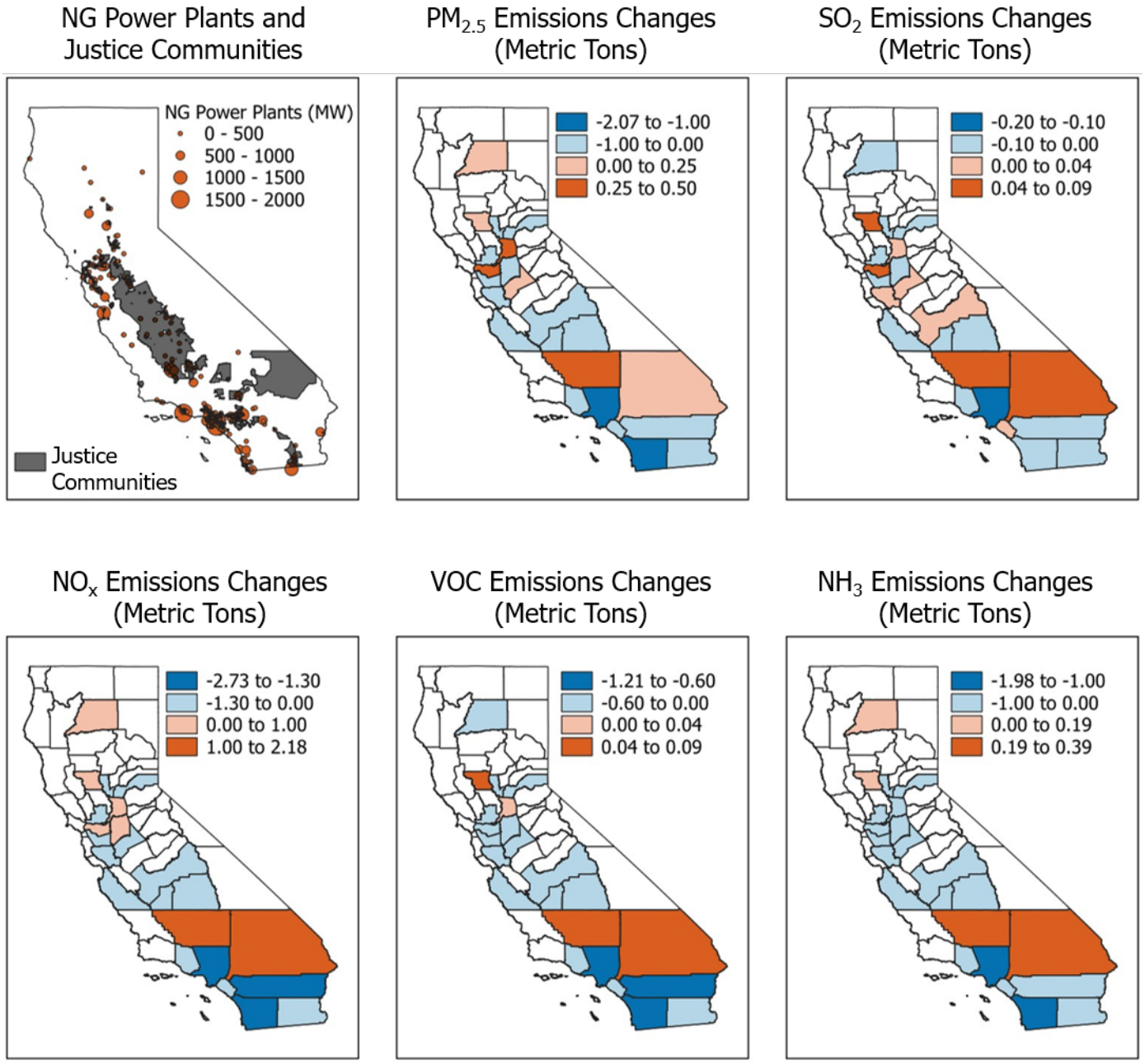
Emission	2028 Avoided (tons)	2037 Avoided (tons)
$PM_{2.5}$	0.73	6.27
SO_2	0.94	7.61
NO_X	4.44	36.12
VOC	0.25	2.26
NH3	0.53	4.95

Source: California Energy Commission

Figure A-21 presents county-level changes in CAP emissions in 2037 (stock turnover) resulting from the proposed standards. The upper-left map shows the locations and capacities of natural gas-fired power plants in California along with the boundaries of justice communities. The remaining maps show county-level changes in emissions of $PM_{2.5}$, SO_2, NO_x, VOC, and NH_3. These maps were developed by staff using QGIS and county-level emissions outputs generated by the U.S. Environmental Protection Agency's AVERT model.

As shown in the upper-left map, many natural gas-fired power plants are located within or near justice communities. The CAP emission maps indicate that most counties experience either no change (white) or reductions in emissions (blue). A small number of counties show modest increases in emissions (orange), reflecting shifts in electricity generation patterns resulting from load shifting. However, the magnitude and geographic extent of these increases are limited compared to the number of counties experiencing emission reductions and the magnitude of those reductions. As shown in **Table A-26**, the statewide net impact is a reduction in CAP emissions across California. The county-level results indicate that, while marginal increases may occur in a small number of counties, the proposed standards are projected to result in a net reduction in criteria air pollutant emissions statewide.

Figure A-21: County-Level Changes in Criteria Air Pollutant Emissions in 2037



Source: California Energy Commission

Table A-27 presents the estimated annual avoided health costs associated with improved air quality resulting from the staff proposal in the first year of full implementation (2028) and at full stock turnover (2037). The emissions reductions reported in **Table A-26** are used as inputs to EPA's COBRA model, which translates the avoided emissions into monetized health benefits associated with reductions in fine particulate matter ($PM_{2.5}$) and ground-level ozone (O_3). **Table A-28** summarizes the total avoided health costs across various health endpoints reported in the final row of **Table A-27** for $PM_{2.5}$ and O_3 in 2028 and 2037. The key results of

Statewide Air Pollutants Emissions Impacts and Annual Avoided Health Cost are shown in Environmental Impacts section of **Chapter 6**.

Table A-27: Annual Avoided Health Cost for 2037 Due to the Impact of Fine Particulate Matter (PM2.5) and Ozone (O3)

Health Endpoint	**2028 Avoided Health Cost Due to $PM_{2.5}$**	**2028 Avoided Health Cost Due to O_3**	**2037 Avoided Health Cost Due to $PM_{2.5}$**	**2037 Avoided Health Cost Due to O_3**
Mortality	$500,000	$219,500	$4,200,000	$1,777,000
Nonfatal Heart Attacks	$980	N/A	$8,200	N/A
Infant Mortality	$2,000	N/A	$17,000	N/A
Hospital Admits, All Respiratory	$52	$31	$430	$250
Emergency Room Visits, Respiratory	$20	$70	$170	$570
Asthma Onset	$4,100	$10,000	$34,000	$85,000
Asthma Symptoms	$6.40	$8,000	$54.00	$65,200
Emergency Room Visits, Asthma	N/A	$0.20	N/A	$1.70
Lung Cancer Incidence	$59	N/A	$500	N/A
Hospital Admits, Cardio-Cerebro/Peripheral Vascular Disease	$71	N/A	$590	N/A
Hospital Admits, Alzheimer's Disease	$140	N/A	$1,200	N/A
Hospital Admits, Parkinsons Disease	$23	N/A	$190	N/A
Stroke Incidence	$70	N/A	$590	N/A
Hay Fever/Rhinitis Incidence	$380	$990	$3,200	$8,100
Cardiac Arrest, Out of Hospital	$17	N/A	$140	N/A
Emergency Room Visits, All Cardiac	$11	N/A	$91	N/A
Minor Restricted Activity Days	$2,100	N/A	$17,000	N/A
School Loss Days	N/A	$22,000	N/A	$180,000
Work Loss days	$880	N/A	$7,400	N/A
Total Avoided Health Costs	**$510,909**	**$260,591**	**$4,290,755**	**$2,116,122**

Source: California Energy Commission

Table A-28: Annual Avoided Health Cost for 2028 and 2037

Air Pollutant	2028 Monetary Value of the Avoided Health Cost ($2023)	2037 Monetary Value of the Avoided Health Cost ($2023)
$PM_{2.5}$	$510,909	$4,290,755
O_3	$260,591	$2,116,122
Total	**$771,500**	**$6,406,877**

Source: California Energy Commission

Private-Sector Benefits

Private-sector benefits consist primarily of utility-bill savings received by participating residential customers. The following tables present annual per-unit savings, lifecycle savings, and the present value of those savings. Broader environmental and electricity-system benefits are reported separately above.

Table A-29 presents the calculation of per-unit annual utility bill saving benefits in 2026 dollars over an assumed 10-year thermostat lifetime. The per-unit annual benefit values for Year 1 and Year 10 were calculated by dividing the total statewide annual utility bill savings benefits by the total compliant thermostat stock for the corresponding year. The annual per-unit benefit values for Years 2 through 9 were then estimated using linear interpolation between the Year 1 and Year 10 values. The resulting annual values were summed across the 10-year lifetime to estimate the total per-unit lifetime utility bill saving benefit, which is approximately $109 per thermostat.

Table A-30 summarizes the costs and benefits considered in the cost-effectiveness analysis for the staff proposal and two alternative approaches. The total life-cycle benefit per HVAC thermostat is calculated as the consumer utility bill savings over the estimated useful life of the thermostat minus the one-time incremental consumer cost associated with complying with the proposed standards.

The results indicate that all three approaches produce positive net life-cycle benefits for consumers. The staff proposal yields the highest consumer utility bill savings and the greatest total life-cycle benefit per HVAC thermostat. The two alternatives also produce positive net benefits, but their estimated life-cycle benefits are lower than those of the staff proposal.

LBNL's California Price Response Potential Study estimated annual residential space-cooling bill savings of approximately $190 for PG&E customers, $125 for SCE customers, and $175 for SDG&E customers under its Full dynamic tariff scenario. Over an approximately 10-year thermostat life, these values correspond to roughly $1,250 to $1,900 in lifetime bill savings, averaging about $1,600. These estimates are higher than those in this analysis primarily because the LBNL study assumes automated response to a fully dynamic hourly tariff, while

the staff analysis uses a more conservative set of electricity-price assumptions based on time-of-use rates.[115]

Table A-29: Calculation of Per Unit Annual Benefits (In $2026)

Year	1	2	3	4	5	6	7	8	9	10	Total
Savings	$10.7	$10.7	$10.8	$10.8	$10.9	$10.9	$11.0	$11.0	$11.1	$11.1	$109.1

Source: California Energy Commission

Table A-30: Costs and Benefits Considered for Cost-Effectiveness per HVAC Controller

Proposal or Alternative	Estimated Useful Life (years)	Consumer Utility Bill Savings Over the Estimated Useful Life (In $2026)	Incremental Consumer Costs (In $2026)	Total Life-Cycle Benefit (In $2026)
Staff Proposal: Autoflex Using the Combined HDP and GHG Signals from the MIDAS static dataset	10	$109	$12	$97
Alternative 1: Autoflex Using the HDP Signal from the MIDAS static dataset	10	$98	$12	$86
Alternative 2: Autoflex Using the GHG Signal from the MIDAS static dataset	10	$77	$12	$65

Source: California Energy Commission

115 Smith, Sarah J., et al. 2026. *California Price Response Potential Study: Exploring the Potential Impacts of Widespread Load Response to Hourly Dynamic Prices Across Six Key End Uses*. Lawrence Berkeley National Laboratory. Figure 18. Available at https://eta-publications.lbl.gov/sites/default/files/2026-04/california_price_response_potential_study_final_2026-04-02.pdf

Statewide Private-Sector Cost-Effectiveness

This subsection compares annual statewide consumer utility-bill savings with annual gross thermostat costs. It does not combine climate, health, reliability, or avoided electricity-system benefits with the direct private-sector comparison.

Table A-31 summarizes the estimated annual statewide benefits of the staff proposal from the first year of full implementation (2028) through the tenth year of full stock turnover (2037) after the regulation goes into effect, as well as the cumulative benefits over the 10-year analysis period. The annual statewide benefits are calculated by multiplying the hourly energy impacts resulting from load shifting under the staff proposal by the corresponding time-of-use (TOU) rates for each of the five load-serving entities (LSEs) included in the analysis and summing the results to obtain a statewide value. Staff used linear interpolation to determine the data points between the first year and the tenth year.

Table A-31: Staff Proposal Statewide Annual Benefit for 2028-2037 (in millions $2026)

Year	1	2	3	4	5	6	7	8	9	10	Total
Benefits	$7.4	$15.4	$23.4	$31.4	$39.5	$47.5	$55.5	$63.5	$71.5	$79.5	$434.7

Source: California Energy Commission

Private-Sector Costs

Private-sector costs include the incremental retail cost paid by purchasers of compliant residential thermostats. Staff uses a base-case retail-level incremental cost of $12 per thermostat. This value includes the identified manufacturer, distribution, certification, testing, cybersecurity, software, and retail impacts reflected in the markup analysis. Those components are not added again as separate statewide costs. Annual gross compliance cost equals projected covered thermostat shipments multiplied by $12.

Table A-32 summarizes the estimated annual statewide costs of the staff proposal from 2028 through 2037, as well as the cumulative costs over the 10-year analysis period. The annual statewide costs are calculated by multiplying the estimated annual shipments of FDAS-compliant thermostats by the incremental cost per unit for each year. The first- and tenth-year values from **Tables A-31** and **A-32** are presented in **Table 6-4**.

Table A-32: Staff Proposal Statewide Annual Cost for 2028-2037 (in millions $2026)

Year	1	2	3	4	5	6	7	8	9	10	Total
Costs	$8.3	$8.4	$8.4	$8.4	$8.4	$8.5	$8.5	$8.5	$8.5	$8.6	$84.5

Source: California Energy Commission

Table A-33 summarizes the cumulative statewide benefits and costs for the staff proposal and two alternative approaches over the 2028–2037 analysis period. The cumulative statewide

benefits and costs for the staff proposal are derived from the annual benefits and costs presented in **Tables A-31** and **A-32**, respectively. Similar calculations were performed for the two alternatives using their corresponding annual benefits and costs. The results indicate that the staff proposal provides the highest cumulative statewide benefit while incurring the same cumulative statewide cost as the two alternatives. Consequently, the staff proposal yields greater net benefits and is more cost-effective than either alternative.

Table A-33: Cumulative Benefits and Costs for 2028–2037

HVAC Thermostats Option	Total Benefit (In millions $2026)	Total Cost (In millions $2026)
Staff Proposal: Autoflex Using the Combined HDP and GHG Signals from the MIDAS static dataset	$434.7	$84.5
Alternative 1: Autoflex Using the HDP Signal from the MIDAS static dataset	$391.1	$84.5
Alternative 2: Autoflex Using the GHG Signal from the MIDAS static dataset	$313.5	$84.5

Source: California Energy Commission

Business-Sector Impacts

The proposed standards affect thermostat manufacturers, retailers, distributors, purchasers, utilities, and related service providers. Manufacturers may incur costs for memory, software, cybersecurity, communications, testing, certification, and other required capabilities. These costs are reflected in the $12 retail-level incremental cost and are not counted again. Retailers and distributors may have limited administrative responsibilities associated with confirming that covered products are certified and listed in the Energy Commission database. The standards are not expected to materially change total thermostat sales or cause businesses to open or close. They may increase demand for software, cybersecurity, testing, certification, communications, and demand-response services. Because the standards shift electricity use within the same day without reducing total annual electricity consumption, staff assume no annual utility revenue loss. Utilities may benefit from lower peak demand and avoided generation, transmission, distribution, loss, and methane-leakage costs.

Models and Data Sources

The table below summarizes the models, data sources, and key input assumptions used to estimate each benefit included in the analysis. It also provides a useful reference for readers who wish to understand or recreate the modeling methodology.

Table A-34: Sources of Models and Key Inputs

S. No	Benefits	Source	Key Inputs and Notes
1	Statewide Utility Bill Savings	FDAS Energy Impact Model, CEC EAD TOU Rate projections	Note: both 2028 and 2037 TOU rates are in 2026 $ Values.
2	Social Cost of GHG Emissions	FDAS Energy Impact Model, November 2023 EPA Report on the Social Cost of GHG	Discount Rate = 2.5%
3	Generation	CPUC ACC	Start Year = 2028 and 2037, Cost Test = SCT, Levelization period = 1 yr, Discount Rate = 2.00%, SCC = Base, Weighted average of various CZ to represent different LSEs.
4	Transmission	CPUC ACC	As Above
5	Distribution	CPUC ACC	As Above
6	Ancillary Services	CPUC ACC	As Above
7	Losses	CPUC ACC	As Above
8	Methane Leakage	CPUC ACC	As Above
9	Health Impact	EPA AVERT -> EPA COBRA	AVERT: Region= California, CA-wide Energy Impact from Staff Proposal. COBRA: Sector - Fuel combustion Electric utility, CA wide Output from AVERT ($PM_{2.5}$, SO_2, NO_x, VOC) and output is $PM_{2.5}$ and O_3.

Source: California Energy Commission

Section IV - Major-Regulation Threshold Analysis

Staff evaluates the proposed standards using gross regulatory costs before benefits. The analysis does not subtract utility-bill savings, avoided system costs, climate benefits, health benefits, reliability benefits, or broader economic benefits from gross regulatory costs. Staff uses the filing, effective, full-implementation, and review-period dates shown below to define the period evaluated for the major-regulation determination.

Effective Date, Full Implementation, and Review Period

Staff assume that the adopted regulation will be filed with the Secretary of State in 2027, become effective in 2028, and be fully implemented in January 2029. For purposes of this analysis, the major-regulation review period begins in January 2028 and ends in January 2029.

Full implementation is different from full stock turnover. Full implementation identifies when the regulatory requirements apply fully to covered products. Full stock turnover is projected

for 2037 based on the assumed 10-year thermostat life. The 2037 results are used to evaluate long-term load shifting, consumer savings, emissions reductions, and economic effects, but they do not define the major-regulation review period.

The gross product cost is based on the projected annual shipments of covered residential thermostats and the $12 incremental retail cost. The $12 estimate includes the identified hardware, software, cybersecurity, certification, testing, reporting, and retail-distribution effects. These elements are not added again as separate statewide costs.

The estimated gross incremental covered-product cost is $8.33 million. Additional costs outside the incremental covered-product cost are estimated at $50,000, based on the cost to manufacturers to certify appliances in the first year. Assuming a certification cost of $50 per hour and 1,000 certifications in the first year results in an estimated indirect cost of $50,000. This results in a total gross cost of $8.38 million during the January 2028 through January 2029 review period. Because the total gross cost before accounting for benefits remains below the $50 million major-regulation threshold, staff concludes that the proposed standards do not constitute a major regulation during the defined review period.

Section V - Additional Research and Analysis

Market Research on Retail Prices of Various HVAC Controllers

Staff conducted market research by reviewing thermostat and HVAC controller products offered through major U.S. online retailers, including Home Depot, Lowe's, Ace Hardware, and Amazon. The results of this market research are presented in **Tables A-35** through **A-37**. The purpose of this review was to identify the various types of HVAC controllers currently available in the marketplace, including non-programmable, programmable, and smart Wi-Fi thermostats, and to understand their corresponding retail prices.

The market research provides insight into the range of products available to consumers and helps characterize the current thermostat market. The review also provides context regarding the retail prices of products with varying levels of functionality and connectivity. The representative products and retail prices presented in this section are intended to illustrate current market offerings and are not intended to represent market share, sales volume, or endorsements of specific manufacturers or products.

Table A-35: Representative Retail Prices of Non-Programmable Thermostats Available Through Major U.S. Retailers

Product	Retail Price ($)	Reference
Honeywell Home X1N Non-Programmable	$35	HD / Walmart / Honeywell Store
Honeywell Home RTH111B	$25	Amazon
Honeywell Home RTH5160	$53	Home Depot
White-Rodgers 1F86-344	$30	Value Controls

LUX P111 Digital Non-Programmable	$28	LUX Products
Suuwer Non-Programmable Thermostat	$27	Amazon
Heagstat Non-Programmable Thermostat	$27	Amazon
NonProgrammable Thermostat (generic)	$22	Amazon
Honeywell CT51N Mechanical Thermostat	$40	Honeywell Consumer Store
Honeywell CT87K Round Thermostat	$43	Home Depot / Lowe's

Source: California Energy Commission

Table A-36: Representative Retail Prices of Programmable Thermostats Available Through Major U.S. Retailers

Product	Retail Price ($)	Reference
Honeywell Home X2P Programmable	$60	Home Depot / Lowe's / Ace
Honeywell RTH2300B 5-2 Day	$40	Retail listings
White-Rodgers 1F80-0261	$47	Home Depot
Honeywell RTH6360D	$55	Home Depot
Honeywell RTH7600D	$70	Home Depot / Lowe's
Honeywell Home RTH221B	$40	Amazon / Home Depot
Honeywell Home RTH6580WF	$90	Home Depot
Emerson 1F80 Series	$50	HVAC suppliers
Braeburn 2020 Programmable	$55	HVAC distributors
LUX TX9600TS Programmable	$60	Amazon / Home Depot

Source: California Energy Commission

Table A-37: Representative Retail Prices of Smart Thermostats Available Through Major U.S. Retailers

Product	Retail Price ($)	Reference
Google Nest Thermostat	$100	Google Store / Home Depot
Ecobee Smart Thermostat Essential	$140	Home Depot / Best Buy
Honeywell Home T9	$180	Honeywell Store
Emerson Sensi Lite	$80	Amazon
Emerson Sensi Smart Thermostat	$120	Amazon / Home Depot
Amazon Smart Thermostat	$80	Amazon
Google Nest Learning Thermostat	$260	Home Depot / Google
Ecobee Smart Thermostat Premium	$250	Home Depot / Best Buy
Honeywell Home X2S Smart Thermostat	$80	Home Depot / Best Buy
Honeywell Home X8S Smart Thermostat	$220	Home Depot

Source: California Energy Commission

APPENDIX B: FEASIBILITY

Overview

Public Resources Code Section 25402(e)(1) requires flexible demand appliance standards to be feasible and attainable (see **Chapter 1**).

This appendix explains how staff verified with assumptions the proposed HVAC thermostat standards in Section 1693(c) against that requirement. Staff reviewed the HVAC thermostat market and other appliances that already have similar flexible features. Staff found that manufacturers can feasibly meet the proposed flexible capability and connectivity standards. These standards will let thermostats schedule, shift, or curtail heating and cooling to support the grid and cut greenhouse gas (GHG) emissions

Approach

Staff reviewed the following:

- HVAC thermostats now sold in California, including models certified to the CEC under the 2022 California Building Code Joint Appendix JA5;
- Connectivity standards and protocols listed in **Table 2-2**;
- Utility programs that already use HVAC thermostats to shift load; and
- Results from large field pilots that tested automated thermostat load shifting.

For each proposed requirement, staff identified what manufacturers would need to change in products on the market today. Every model will need a firmware or configuration update. Some models will also need new integral (non-volatile) memory hardware.

Staff also prepared a test procedure. Manufacturers and test labs can use it to confirm that a thermostat has the proposed capabilities before the manufacturer certifies it to the CEC.

The standards take effect one year after adoption. Staff projects an effective date of January 1, 2028, and shared this timeline with manufacturers.

Staff estimated the cost of these changes with a bottom-up engineering assessment. Manufacturer costs range from about $2.00 to $12.30 per thermostat and average about $7.15. With the U.S. Department of Energy retail markup, that comes to about $12 per thermostat at retail. **Appendix A**, **Tables A-15** and **A-16**, show the cost components and assumptions.

Market Baseline

Many HVAC thermostats already include preprogrammed operating modes. **Chapter 4** describes various thermostat types, their capabilities, and the technologies they employ. **Figure 4-8** shows thermostats with software scheduling.

JA5-certified thermostats show that connected smart thermostats are already on the market. JA5 sets the technical specifications for an Occupant Controlled Smart Thermostat (OCST). An OCST can be a single device or part of a control system with several devices. An OCST meets Title 24, Part 6, only after the manufacturer certifies it to the CEC under Section 110.0.

Staff reviewed JA5-certified thermostats now sold in California and found over 240 model numbers. These models communicate using open standards over wired or wireless connections and respond to information from the internet.[116]

Most in-scope thermostats already have the basic features the proposal builds on. Staff found that nearly 80 percent of in-scope HVAC thermostats on the market today have these features.[117] That includes 65 percent that are smart thermostats and 15 percent that are programmable. These features include connectivity, integral memory, and a user interface.

PG&E's Automated Response Technology program already uses HVAC thermostats to shift load.

Feasibility of Proposed Requirements

To comply, manufacturers need to update their thermostat firmware or configuration. Some models will also need new integral memory to store the required data. Four things support the feasibility of these changes:

- Thermostats on the market already schedule operations in software (Section Market Baseline).
- JA5-certified thermostats already restore their programmed settings after a power loss (JA5.2.2).[118]
- Memory components are widely available.
- In the field pilots (Section Field Pilot Study Support), app-based or in-device software controls shifted load on existing thermostats.

Appendix A, **Tables A-15** and **A-16**, include the cost of the memory hardware. Staff therefore finds that manufacturers can add the proposed flexible capability to in-scope HVAC thermostats within one year after adoption.

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116 CEC. 2025. "JA5 Occupant Controlled Smart Thermostats." Available at https://www.energy.ca.gov/sites/default/files/2025-03/OCST_listings_for_2022_Standards_ADA%202025.03.17.xlsx.

117 Grand View Research. *Thermostat Market Size, Share & Trends Analysis Report By Product (Smart Thermostat, Mechanical Thermostat), By End Use (Industrial, Commercial, Residential), By Region, And Segment Forecasts, 2025–2030*, https://www.grandviewresearch.com/industry-analysis/thermostat-market-report.

118 CEC. 2025. "JA5 Occupant Controlled Smart Thermostats," https://www.energy.ca.gov/rules-and-regulations/building-energy-efficiency/manufacturer-certification-building-equipment/ocst.

Connectivity

Two things support the connectivity requirements:

- the JA5-certified models (Section Market Baseline), and
- the standards and protocols (**Table 2-2)**.

In the PG&E pilot, thermostats from several manufacturers also exchanged signals with the grid operator at large scale. Staff therefore finds the connectivity standard feasible.

Additional Requirements

Table B-1 summarizes how current products compare with each of the remaining proposed requirements.

Table B-1: Feasibility of Proposed Requirements

Requirement	Current products	Staff finding
1693(c)(2)(B) Integral memory (non-volatile)	Some current models lack enough integral memory. Those models will need new memory hardware.	Feasible
1693(c)(2)(C) Autoflex operating mode	Current models have their own operating modes but not Autoflex. Manufacturers will need to add it.	Feasible
1693(c)(2)(D) MIDAS dataset retrieval and integrity	Current models don't retrieve or store MIDAS datasets. Manufacturers will need to add this.	Feasible
1693(c)(2)(E) Open standards communication (OpenADR 3.1)	Manufacturers will need to implement OpenADR 3.1.	Feasible
1693(c)(2)(F) Third-party demand response	Current models already support similar functions.	Feasible
1693(c)(2)(G) User interface and transparency	Current models already support similar functions.	Feasible
1693(c)(2)(H) Clock and persistence of settings	Current models already support similar functions.	Feasible
1693(c)(3) Testing (Section 1698(c))	Similar test procedures already exist.	Feasible
1693(c)(4) Firmware and ongoing compliance	Current models already receive firmware updates. Manufacturers will need to add amended certification and a written attestation for updates that affect flexible demand functions.	Feasible

1692(c) Cybersecurity	Current models already support similar functions.	Feasible
1694 Consumer consent	Current models already provide consent functions.	Feasible

Attainability by the Effective Date

The standards take effect one year after adoption, with a projected effective date of January 1, 2028. Staff shared this timeline with manufacturers. Most of the required changes are firmware or configuration updates. Some models will also need new integral memory, which uses widely available components. Staff has prepared the test procedure in Section 1698(c), so manufacturers can test and certify products to the CEC once the standards are adopted. Staff therefore finds the proposed standards attainable by the effective date.

Field Pilot Study Support

PG&E 2022–2023 Smart Thermostat Control Pilot

PG&E's 2022–2023 pilot showed that smart thermostats can shift load automatically and reliably, at scale, in real homes.[119]

- Scale. The pilot shifted load automatically in over 11,000 devices. Enrollment later grew to about 110,000 devices from several thermostat manufacturers.
- Daily load shifting. Automated daily time-of-use (TOU) shifting cut peak-hour demand by about 0.13 kW (130 watts) per home on average. These savings came on top of the savings from customers responding to TOU prices themselves. Software alone delivered them, with no hardware upgrades.
- Demand response events. On event days, each home cut demand by about 500 to 600 watts on average. During extreme heat, savings topped 1 kW per home.
- Predictability. Temperature, time of day, and event length explained over 90 percent of the variation in event savings. Savings peaked during the hottest periods and the first hours of each event. Thermostats shifted load during the critical 4 - 8 p.m. window. Because the results are this predictable, thermostats can use hourly price and GHG signals to plan when to shift load.
- Communication. CAISO connected with and dispatched thermostats from four brands (Nest, ecobee, Emerson, Honeywell Home) across several sub-LAPs. This gave the grid operator real-time, location-specific demand reduction.
- Customer experience. Thermostats pre-cooled homes before peak periods and reduced load during peak hours without ongoing customer input. Customers could still override

119 PG&E. 2024. *2022–2023 Load Impact Evaluation of Pacific Gas and Electric's Smart Thermostat Control Pilot.* Prepared by Demand Side Analytics, LLC. CALMAC ID: PGE0498.01. Available at https://www.cpuc.ca.gov/-/media/cpuc-website/divisions/energy-division/documents/demand-response/emergency-load-reduction-program/elrp-2023-ex-post-data/8-pge2023elrprptpublic.pdf

the thermostat at any time. This "set-and-forget" approach shows that the technology works and fits what customers expect.

Eco+ Thermostat Optimization Pilot (CalFlexHub, 2020)

A 2020 CalFlexHub report summarized the Eco+ pilot. It tested about 240,000 connected thermostats across North America in summer 2019. Thermostats pre-cooled homes and adjusted temperatures in response to time-varying rates, which cut peak cooling demand and customer cooling costs.[120]

Under the California tariffs studied:

- each thermostat cut on-peak demand by about 0.10 to 0.28 kW on average, and
- customers saved about 7 to 19 percent on cooling costs.

Together, these pilots show that today's smart thermostats can deliver both scheduled daily shifting and event-based demand response

Limitations of Field Pilot Study

Staff recognizes the following limitations in the evidence:

- Results vary with conditions. In the Eco+ pilot, results varied with climate, weather, tariff design, peak-period length, and customer participation. In the PG&E pilot, results varied with outdoor temperature, time of day, and event length.
- Evidence comes mostly from smart thermostats. Both pilots tested connected smart thermostats. They did not test programmable thermostats without an internet connection.
- Results depend on vendor algorithms. Each manufacturer uses its own control algorithm to turn grid signals and customer settings into operating schedules, so load-shift results will vary by product.

Conclusion

Staff finds the proposed flexible capability and connectivity requirements feasible and attainable. Staff bases this finding on:

- the products already on the market (Section Market Baseline),
- the review of each requirement (Section Feasibility of Proposed Requirements), and
- the field pilot results (Section Field Pilot Study Support).

These requirements will let HVAC thermostats schedule, shift, or curtail their operations to support grid reliability and cut GHG emissions, as Public Resources Code Section 25402(e)(1) requires. **Appendix A** quantifies the GHG reductions, and the Environmental Impacts section of **Chapter 6** discusses them.

120 CalFlexHub. 2020. *Eco+ Thermostat Optimization Pilot*. Lawrence Berkeley National Laboratory. Available at: https://calflexhub.lbl.gov/flex_library_item/ecothermostat-optimization-pilot/

APPENDIX C: ADDITIONAL ALTERNATIVES

Staff evaluated seven alternatives to our recommendation as part of developing the proposed flexible demand standards. Autoflex HDP (alternative one), autoflex GHG marginal emission rates (alternative two), and Staff proposal (combined autoflex HDP and GHG) were discussed in **Chapter 5**. This appendix describes the five additional alternatives evaluated by staff, as follows:

Alternative Three: Default Daily Pre-conditioning

Alternative Three requires a default daily preconditioning schedule. Pre-conditioning the habitable space prior to peak electricity prices shifts space-conditioning energy usage from the first two hours of electricity peak pricing to the two hours prior. While prescribing times at which pre-conditioning occurs would ensure load shift, ignoring specific building conditions such as local weather and thermal envelopes will likely lead to unnecessary increases in electricity usage. Thus, this strategy would likely lead to less consumer acceptance. Alternative Three is not the preferred option because of the significant tradeoff in consumer comfort for the additional utility bill savings.

Alternative Four: U.S. EPA Energy Star Smart Thermostat Specification

Alternative Four uses the U.S. ENERGY STAR© program specifications for minimum communication, interoperability, and demand-response requirements. This alternative is similar to Alternative One, but it adds specific performance criteria for demand-response signals. The U.S. EPA introduced the ENERGY STAR Connected Thermostat specification in 2016 and began revising it in July 2021.[121]

The CEC monitors and is engaged in the specification development for ENERGY STAR© devices and may incorporate elements of ENERGY STAR© product specifications into the standards for flexible demand functionality. Products that meet ENERGY STAR© connectivity specifications point toward future CEC staff proposals for flexible demand appliances. Staff has determined not to include the U.S. EPA ENERGY STAR©-Smart Thermostat specification as a flexible demand standard because simply requiring a scheduling and connected capability will allow industry innovations to continue to optimize controls for avoiding GHGs and reducing consumer utility bills while meeting the complex space conditioning needs of the consumer.

121 U.S. EPA. 2021. "Energy Star Version 2.0. Smart Thermostat Discussion Guide." Available at https://www.energystar.gov/sites/default/files/ENERGY%20STAR%20Version%202.0%20Smart%20Thermostat%20Discussion%20Guide%20Cover%20Memo.pdf.

Alternative Five: CTA 2045 Port

Alternative Five requires all HVAC thermostats to have a CTA 2045 port. This option allows an alternate path to the original equipment manufacturer-provided connectivity. A CTA 2045 port requires a certification process similar to the Open ADR program, provides a modular communications interface for energy management, and has prescriptive brand usage guidelines. The control algorithm logic communicated through the CTA 2045 port to the thermostats is at the discretion of a CTA 2045 module manufacturer or a third-party service interfacing with an CTA 2045 module. The control algorithm could be designed to prioritize customer bill savings without considering the avoidance of GHG emissions. Staff has determined not to include Alternative Five as a flexible demand standard because simply requiring the proposed flexible capabilities with connectivity would result in a greater avoidance of GHG emissions, lead to greater overall consumer monetary savings, guarantee minimal flexible capabilities are present in every HVAC thermostat, and remain unbiased toward the use of different technologies.

Alternative Six: Voluntary Standards

Alternative Six allows the requirements to be met on a voluntary basis. Previous feedback from interested parties included requests that the scope include only appliances marketed as capable of flexible demand, allowing nonflexible products to remain in the California marketplace, provided they are clearly identified to consumers.[122] Staff finds that proposing voluntary standards would duplicate existing voluntary programs, such as the U.S. Environmental Protection Agency (U.S. EPA) ENERGY STAR®-connected criteria, and would not be as effective at achieving the goals of SB 49. Staff have determined not to include Alternative Six as a flexible demand standard because setting voluntary standards would be a lost opportunity to reduce GHG emissions in California to the full extent of current technical feasibility and would not address the split incentive issue by ensuring all new appliances include flexible demand technologies. SB 49 requires that potential standards be adopted "by regulation," meaning they are to be adopted as mandatory standards to ensure the benefits of these standards are realized in full.

Alternative Seven: FM Connectivity with Optional Wi-Fi

Alternative Seven would require default connectivity through authenticated FM broadcast with optional remote control and data reporting via Wi-Fi, LTE, cable, or other technology. This alternative would use FM broadcast to notify homes of electricity prices and other grid signals using the optional data reporting method to provide an outbound confirmation of response.

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122 Association of Home Appliance Manufacturers. 2021. Comments to Docket 20-FDAS-01, TN 236600, Feb. 3, 2021, pages 4-5. Available at https://efiling.energy.ca.gov/GetDocument.aspx?tn=236600&DocumentContentId=69604.
California Investor-Owned Utilities. 2021. Comments to Docket 20-FDAS-01, TN 236618, Feb. 3, 2021. pg. 1-1. Available at https://efiling.energy.ca.gov/GetDocument.aspx?tn=236618&DocumentContentId=69626.
Air-Conditioning, Heating, & Refrigeration Institute. 2021. Comments to Docket 20-FDAS-01, Feb. 3, 2021, TN 236601, page 2-3. Available at https://efiling.energy.ca.gov/GetDocument.aspx?tn=236601&DocumentContentId=69607.

Staff decided not to include Alternative Seven as a flexible demand standard because FM broadcasting is not commonly used within the industry and provides a one-way communication pathway. Additional cost evaluation would be required for the impact on the state and consumers once it is implemented in an industry.

APPENDIX D: COMFORT ANALYSIS

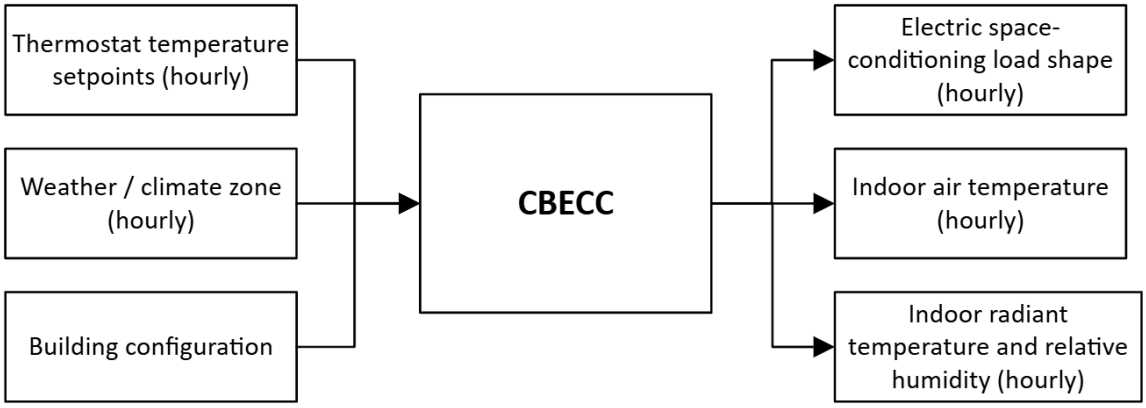
Staff evaluated the impact of the proposed standards on consumer comfort by simulating their influence on indoor conditions. Load shifting reduces the heating or cooling performed during periods of peak electricity demand. By cooling slightly more at earlier times, homes can remain comfortable on hot days while maintaining grid reliability and generating energy bill savings for residents. Similarly, pre-heating can shift load on cold days.

Staff used the 2025 version of the public domain California Building Energy Code Compliance (CBECC) software for their analysis.[123] Staff generated autoflex operating schedules with a rudimentary implementation of the proposed standards. These schedules shifted load by changing temperature set points in representative, single-family homes. Staff then used industry best practices to calculate how comfortable consumers would be under these conditions. Based on this analysis, staff concluded that consumers' comfort would not be significantly impacted by the proposed regulations. This appendix details staff assumptions, methods, and calculations.

CBECC

The CEC developed and approved CBECC to determine building compliance with Title 24, Part 6, California's Building Energy Efficiency Standards. Staff enabled certain features[124] of the software to perform their temperature and comfort analysis. **Figure D-1** shows a flowchart of the inputs and outputs for the staff analysis.

Figure D-1: Flowchart of Staff Temperature Analysis



Source: California Energy Commission

123 California Energy Commission. CBECC version 2025.2.1.1. https://www.energy.ca.gov/programs-and-topics/programs/building-energy-efficiency-standards/2025-energy-code-compliance-software.

124 Staff set EnableResearchMode=1, BypassRuleLimits=1 in the CBECC-25.ini file located in the CBECC Data folder.

CBECC takes inputs of temperature set points, climate zone (defined by Title 24), and building configuration. The software uses the California Simulation Engine (CSE) to perform energy balances on residential units. These energy balances include data for local weather, building air leakage, construction materials, and space-conditioning appliance specifications, among many others. The energy balances calculate and output the hourly electrical load needed to meet the inputs. Staff then used the outputted air temperature, radiant temperature, and relative humidity to calculate consumer comfort.

CBECC does not output hourly load, temperature, or relative humidity by default. A specified "report include file" gets CSE to export data "probes" into a CSV file. For the analysis in this report, staff exported hourly values for outdoor dry bulb temperature ($tDbO), zone cooling temperature set points (@zone["Conditioned-zn"].tzspC), zone dry bulb temperature (@zone["Conditioned-zn"].tz), cooling load (@meter["MtrElec"].H.clg/3412), cooling fan load (@meter["MtrElec"].H.fanC /3412), zone radiant temperature (@znres["Conditioned-zn"].H.tRad), and zone relative humidity (@zone["Conditioned-zn"].relHumlh). Information on the syntax of the "report include file" can be found in the CSE documentation.[125] Users of CBECC specify the report include file by double-clicking their Project and then navigating to the Analysis tab.

Representative California Single-family Homes

Staff used building prototypes from the California Prototypes Development Project.[126] The Northeast Energy Services Company (NORESCO) led the development while consulting a technical advisory group with members from the CEC, CPUC, SCE, Energy Solutions, and other national experts. The project aimed to provide a unified set of prototypes that represented the building stock in California. Staff used the four single-family prototypes detailed in **Table D-1** for their analysis. **Table D-2** shows the values used in CBECC for the construction assemblies, and **Table D-3** overviews other building and appliance properties.

Staff compared two building vintages, modern and pre-Building Energy Code (pre-BEC). Modern homes compliant with recent building energy codes have tight thermal envelopes, which reduces heat leakage in or out. Older homes built before building energy codes were implemented in 1978 have loose thermal envelopes. Preconditioning may be less effective in older homes; the energy used to precool or preheat the home may leak out before the peak period that the load shifting was meant to avoid. The modern vintage in the California Prototypes Development corresponds to the minimum requirements of the 2022 Building Energy Code.

125 CSE Documentation. Available at https://cse-sim.github.io/cse/index.html

126 CalBEM Prototypes Development Project. Available at https://calbem.ibpsa.us/calbem-prototypes/

Table D-1: Representative Single-family Home Prototypes

SF1250	Component (Count)	Description
Overall	Story (1)	--
	Bedroom (2)	1250 ft^2 conditioned area, 9 ft ceiling height
	Attic	Roof 4 in rise / 12 in run, 1250 ft^2 area
	Crawlspace	2 ft height, underground, 425 ft^2 area
Front wall	Window (1)	11.4 x 5 ft, 2.5 ft overhang
	Front door	40 ft^2
Left wall	Window (1)	5.7 x 5 ft, 2.5 ft overhang
Back wall	Window (1)	11.4 x 5 ft, 2.5 ft overhang
Right wall	Window (1)	5.7 x 5 ft, 2.5 ft overhang

SF1750	Component (Count)	Description
Overall	Story (1)	--
	Bedroom (3)	1752 ft^2 conditioned area, 9 ft ceiling height
	Attic	Roof 4 in rise / 12 in run, 1752 ft^2 area
	Crawlspace	2 ft height, underground, 595 ft^2 area
Front wall	Window (1)	13.5 x 5 ft, 2.5 ft overhang
	Front door	40 ft^2
Left wall	Window (1)	6.8 x 5 ft, 2.5 ft overhang
Back wall	Window (1)	13.5 x 5 ft, 2.5 ft overhang
Right wall	Window (1)	6.8 x 5 ft, 2.5 ft overhang

SF2250	Component (Count)	Description
Overall	Story (2)	--
	Bedroom (4)	2250 ft^2 conditioned area, 9 ft ceiling height
	Attic	Roof 8 in rise / 12 in run, 1125 ft^2 area
	Crawlspace	2 ft height, underground, 383 ft^2 area
Front wall	Window (1)	10.8 x 5 ft, 2.5 ft overhang
	Front door	40 ft^2
Left wall	Window (1)	5.4 x 5 ft, 2.5 ft overhang
Back wall	Window (1)	10.8 x 5 ft, 2.5 ft overhang
Right wall	Window (1)	5.4 x 5 ft, 2.5 ft overhang

SF2750	Component (Count)	Description
Overall	Story (2)	--
	Bedroom (4)	2750 ft^2 conditioned area, 9 ft ceiling height
	Attic	Roof 8 in rise / 12 in run, 1375 ft^2 area
	Crawlspace	2 ft height, underground, 468 ft^2 area
Front wall	Window (1)	12 x 5 ft, 2.5 ft overhang
	Front door	40 ft^2
Left wall	Window (1)	6 x 5 ft, 2.5 ft overhang
Back wall	Window (1)	12 x 5 ft, 2.5 ft overhang
Right wall	Window (1)	6 x 5 ft, 2.5 ft overhang

Source: California Energy Commission, California Prototypes Development Project

Table D-2: Construction Assemblies in Representative Modern [pre-BEC] Single-family Homes

Name	Locations	Properties
Tile roof	Attic	Asphalt shingle, wood decking, 2x4 @ 16 in. OC.
Ceiling below attic	Conditioned zone (unit 2, if applicable)	Wood framed, 2x4 @ 16 in. OC. R-28 [R-16]. Gypsum board inside finish.
Interior ceiling	Between unit 1 and 2, if applicable	Carpeted, wood decking, 2x4 @ 16 in. OC. R-28 [R-16]. Gypsum board ceiling below finish.
Floor over crawlspace	Conditioned zone (unit 1, if applicable)	Carpeted, wood decking, 2x4 @ 16 in. OC. R-17 [R-2].
Underground Wall	Crawlspace	Concrete, 4 in.
Exterior wall	Conditioned zone, crawlspace	Wood framed, 2x4 @ 16 in. OC. Gypsum board inside finish. R-17 [R-2]. 3-coat stucco exterior finish.
Window	Exterior wall	NFRC U-factor: 0.3 [0.78], Solar heat gain coefficient: 0.20 [0.44], Exterior shade: Insect screen
Door	Exterior wall	U-factor: 0.3

Source: California Energy Commission, California Prototypes Development Project

Table D-3: Building Properties in Representative Modern [pre-BEC] Single-family Homes

Name	Modern Properties	Pre-BEC Properties
Air leakage	5 ACH @ 50 Pa	16 ACH @ 50 Pa
Quality Insulation Installation	Yes	No
IAQ and cooling ventilation	None	None
Space-conditioning appliances	Central split heat pump, 36,000 Btuh @ 47 °F, EER2 11.9, 36,551 Btuh @ 95 °F	Central air conditioning, SEER2 8, 350 CFM/ton & non-heat pump electric heating
Duct leakage and insulation	6%, R-8	15%, R-2.1
Furnace fan efficiency	0.45 W/CFM	0.58 W/CFM

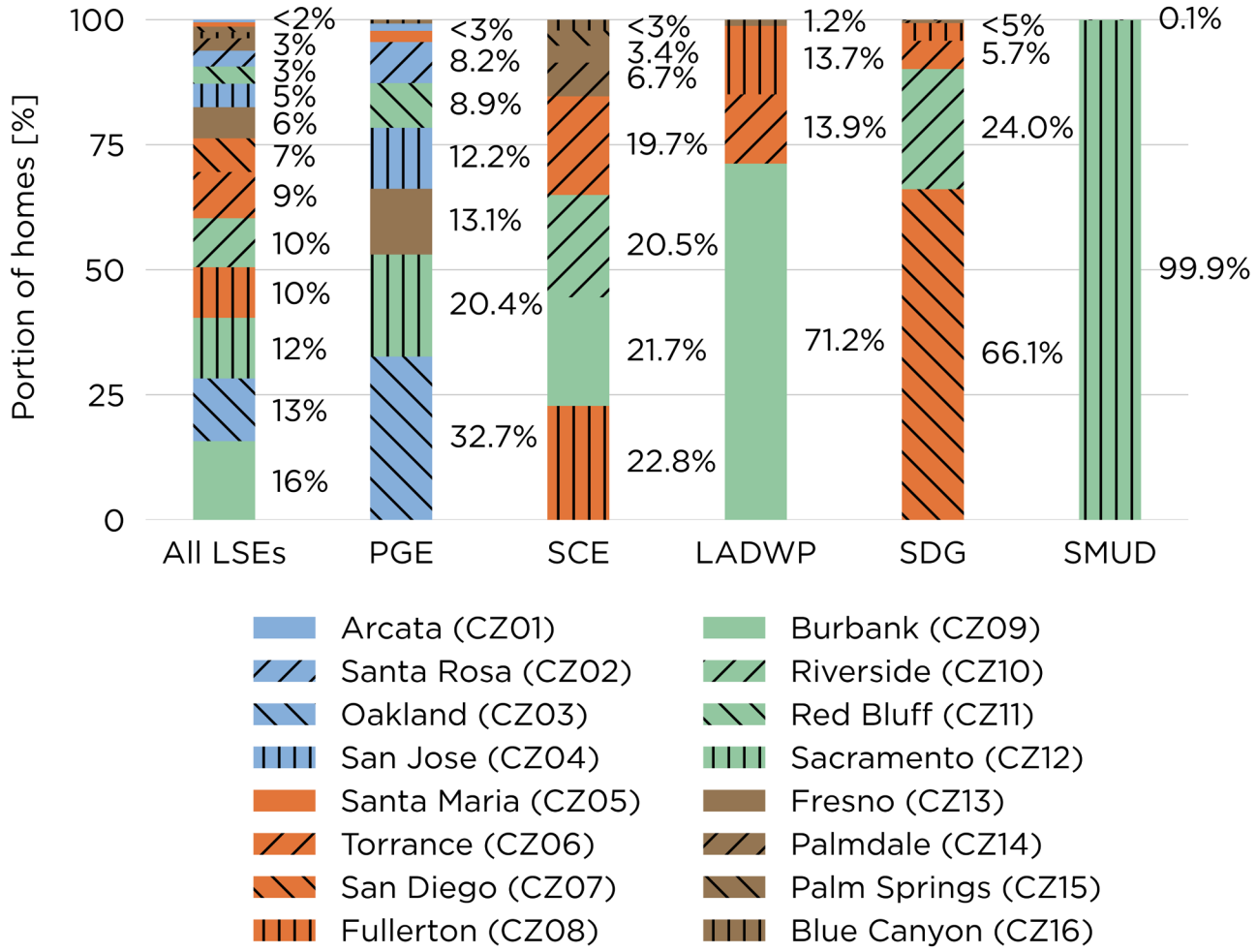
Source: California Energy Commission, California Prototypes Development Project

Using CBECC to Analyze Space-conditioning Load Shifts

Staff attributed changes in indoor temperature and comfort to the proposed standards by simulating various homes and conditions in CBECC. Staff created baselines that used thermostat schedules with two constant set points: one for cooling and one for heating, with different set points for each climate zone. Staff ran CBECC for every combination of building prototype, building year, and climate zone to create the baseline data. Staff compared data from the baselines with those using hourly temperature set points created using price and GHG signals.

Space-conditioning heavily depends on the local weather. CBECC contains 16 weather files, one for each Title 24 climate zone. **Figure D-2** shows the spread of the climate zones within the 5 major LSEs. Weather data, such as the outdoor temperature, relative humidity, and sun exposure, are used in the energy balances.

Figure D-2: Distribution of Climate Zones Among LSEs



Source: California Energy Commission, data from RASS 2019

Staff estimated the ideal temperature set points for each climate zone. Staff used CBECC and ASHRAE Standard 55-2023 to find the set points that kept potential mean vote (PMV) closest

to zero.[127] For the cooling set points, staff calculated the ideal set points for the middle of summer. Staff did the same for the middle of winter for the ideal heating set points. Staff used these set points to model the baseline for homes with thermostats incapable of load shifting. **Table D-4** lists the baseline set points used by staff for cooling while **Table D-5** lists those for heating. Cooling set points ranged from 74 to 76 °F and heating set points ranged from 68.5 to 70 °F. These set points are consistent with other building energy modeling studies.[128]

Table D-4: Ideal Thermostat Temperature Set points by Climate Zone, Cooling

Climate Zone	Ideal Set point (°F)	Climate Zone	Ideal Set point (°F)	Climate Zone	Ideal Set point (°F)	Climate Zone	Ideal Set point (°F)
CZ01	75.0	CZ05	74.0	CZ09	75.0	CZ13	75.5
CZ02	75.0	CZ06	75.0	CZ10	75.25	CZ14	75.5
CZ03	74.0	CZ07	75.0	CZ11	75.5	CZ15	75.5
CZ04	75.5	CZ08	75.0	CZ12	75.5	CZ16	75.75

Source: California Energy Commission

127 Staff calculated PMV using the algorithm provided in ASHRAE Standard 55-2023. Staff set metabolic rate to 1.5 Met as consumers at home engage in various activities such as cooking, cleaning, and sitting. In the summer, occupants in climate zones without much cooling load (CZ01, CZ02, CZ03, CZ05) were given clothing with 0.67 Clo, while the remaining occupants were given clothing with 0.57 Clo. All occupants were given 1.0 Clo in the winter. Mean radiant temperature and relative humidity for each climate zone were obtained from CBECC. Staff assumed an indoor air velocity of 0.1 m/s.

128 Energy and Environmental Economics, Inc. Residential Building Electrification in California. 2019. Available at https://www.ethree.com/wp-content/uploads/2019/04/E3_Residential_Building_Electrification_in_California_April_2019.pdf

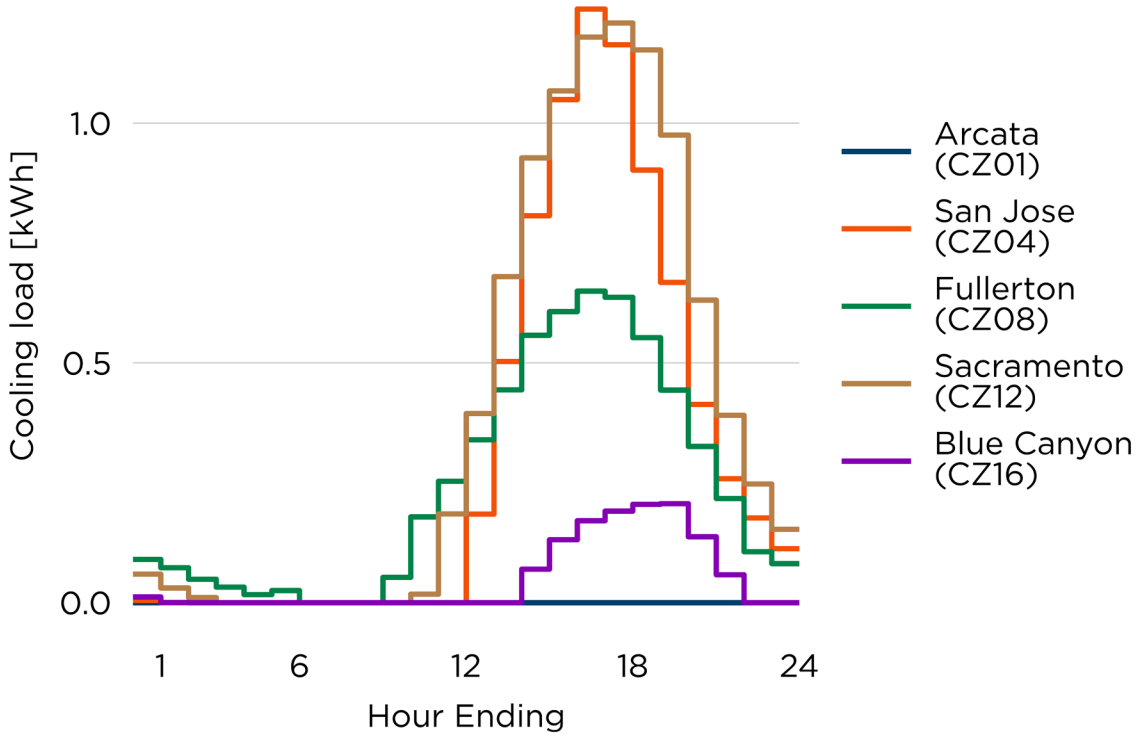
Table D-5: Ideal Thermostat Temperature Set points by Climate Zone, Heating

Climate Zone	Ideal Set point (°F)	Climate Zone	Ideal Set point (°F)	Climate Zone	Ideal Set point (°F)	Climate Zone	Ideal Set point (°F)
CZ01	69.0	CZ05	69.0	CZ09	69.5	CZ13	69.25
CZ02	69.0	CZ06	69.0	CZ10	69.75	CZ14	69.75
CZ03	68.75	CZ07	69.0	CZ11	69.5	CZ15	70.0
CZ04	69.25	CZ08	68.5	CZ12	69.0	CZ16	70.0

Source: California Energy Commission

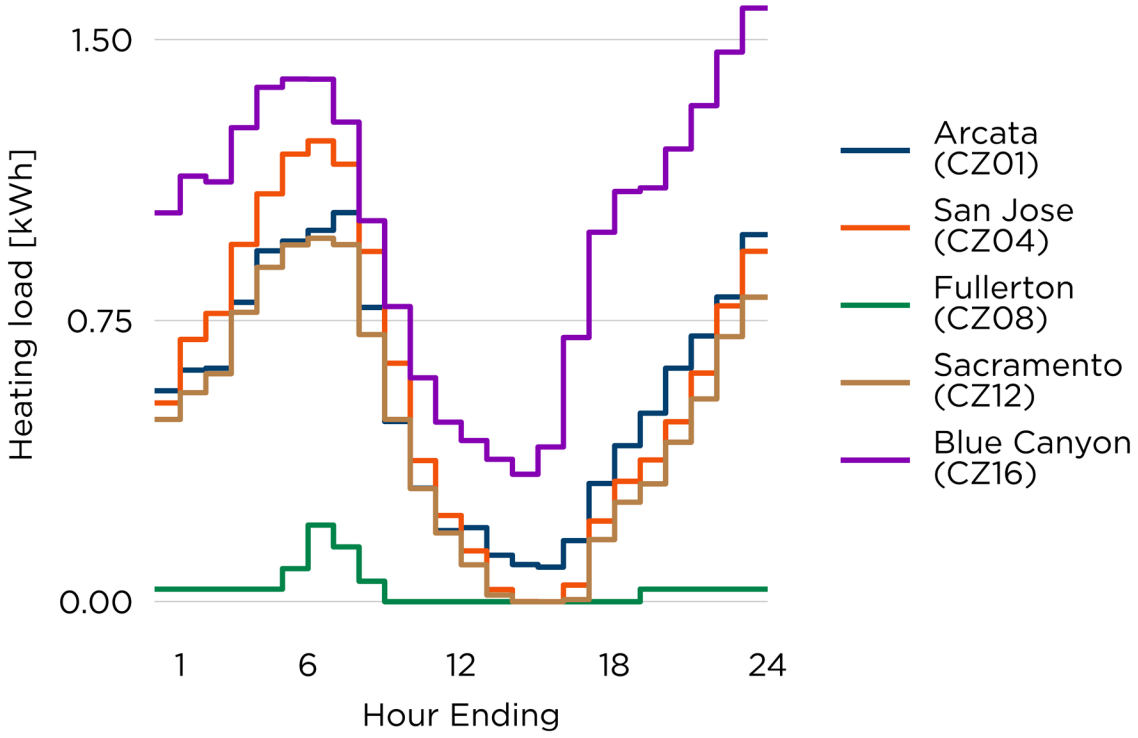
Figure D-3 shows example cooling loads while **Figure D-4** shows example heating loads generated by CBECC for the modern, SF1250 prototype using the baseline temperature set points.

Figure D-3 Example Cooling Load Shapes on August 1st



Source: California Energy Commission

Figure D-4 Example Heating Load Shapes on December 1st

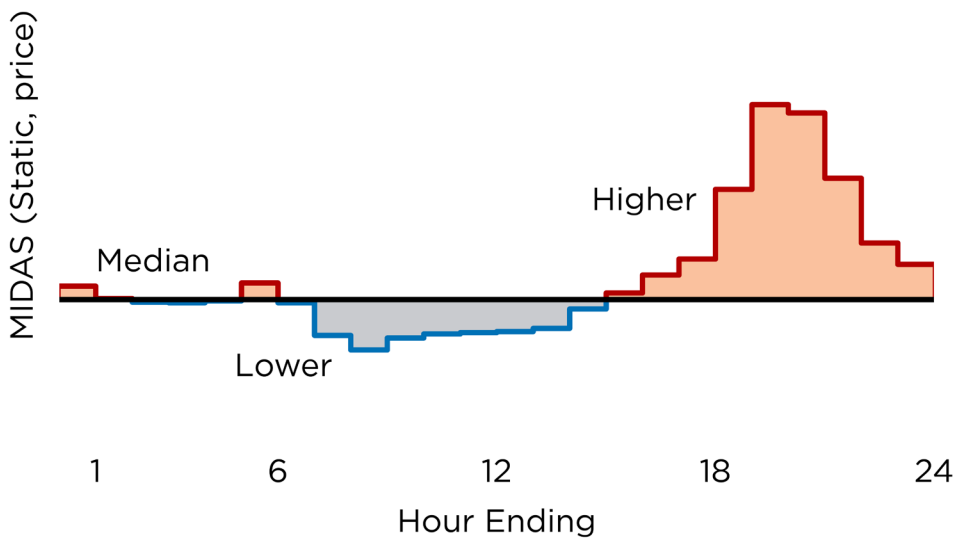


Source: California Energy Commission

Impact of Staff Proposal on Consumer Comfort

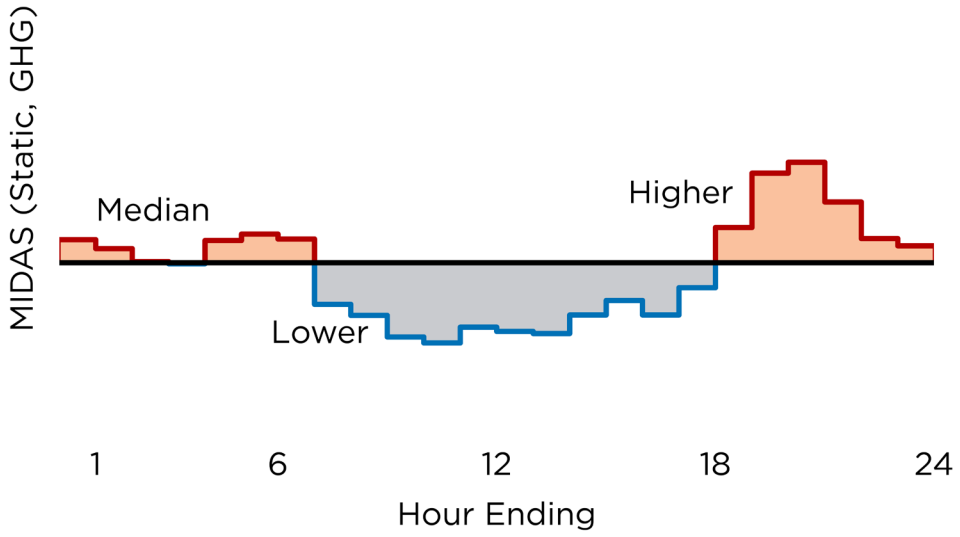
In the proposed standards, the default signals thermostats used to create operating schedules are in the MIDAS static dataset pre-loaded onto the device by the manufacturer. These signals can be updated through over-the-air updates. The end consumer can instead elect to use a MIDAS dataset associated with their RIN that provides more localized information. The rudimentary implementation of the staff proposal creates set point schedules by categorizing signals below ("shed") and above ("load") the day's median value. Preconditioning occurs during times when the signal is below the median, and setback occurs when the signal is above the median. **Figure D-5** shows an example price signal in the summer grouped lower than and higher than the median value. **Figure D-6** shows the greenhouse gas (GHG) signals for the same day. The signals are unitless.

Figure D-5: MIDAS Static Price Signal vs. Day's Median, July 1st, 2024



Source: California Energy Commission

Figure D-6: MIDAS Static GHG Signal vs. Day's Median, July 1st, 2024

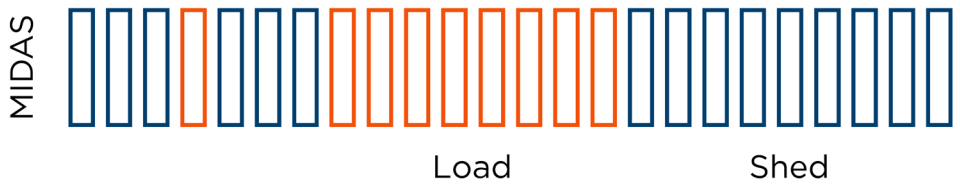


Source: California Energy Commission

Each day, the above procedure is applied to both price and GHG signals, yielding two sets of categorized 24-hour signals. The staff proposal merges the two sets: at each hour, if the category is the same between the two sets, the final signal at the hour takes that category; if the categories are different, the final signal at the hour takes the "shed" category. The resulting final signal has at least 12 "shed" hours and at most 12 "load" hours. **Figure D-7**

shows the procedure applied to the signals for July 1, 2024. The set points input into CBECC are the ideal temperature set points from **Table D-4** & **Table D-5,** raised or lowered by a temperature offset: 2 °F by default or according to the consumer's preferences. For cooling, the set points are lowered by the offset during the "load" hours and increased by the offset during the "shed" hours. For heating, the set points are raised during the "load" hours and increased during the "shed" hours. The process is also described in **Appendix A**.

Figure D-7: MIDAS Combined Signal, July 1, 2024



Source: California Energy Commission

Staff analyzed the effect of different offset temperatures on load shift, indoor temperatures, and consumer comfort. For each LSE, staff analyzed the climate zone with the most cooling demand within its service territory. **Table D-6** shows the climate zones analyzed and the dates corresponding to average summer days and max cooling summer days. Average summer days had average daily temperatures close to the average temperature for the whole summer (June, July, and August) for that climate zone. Data associated with CBECC do not correspond to a specific year since the simulations use weather data for typical meteorological years. Staff simulated the effect of using the staff proposal for these individual days. The thermostat set points for the rest of the year were kept at the ideal set points discussed above.

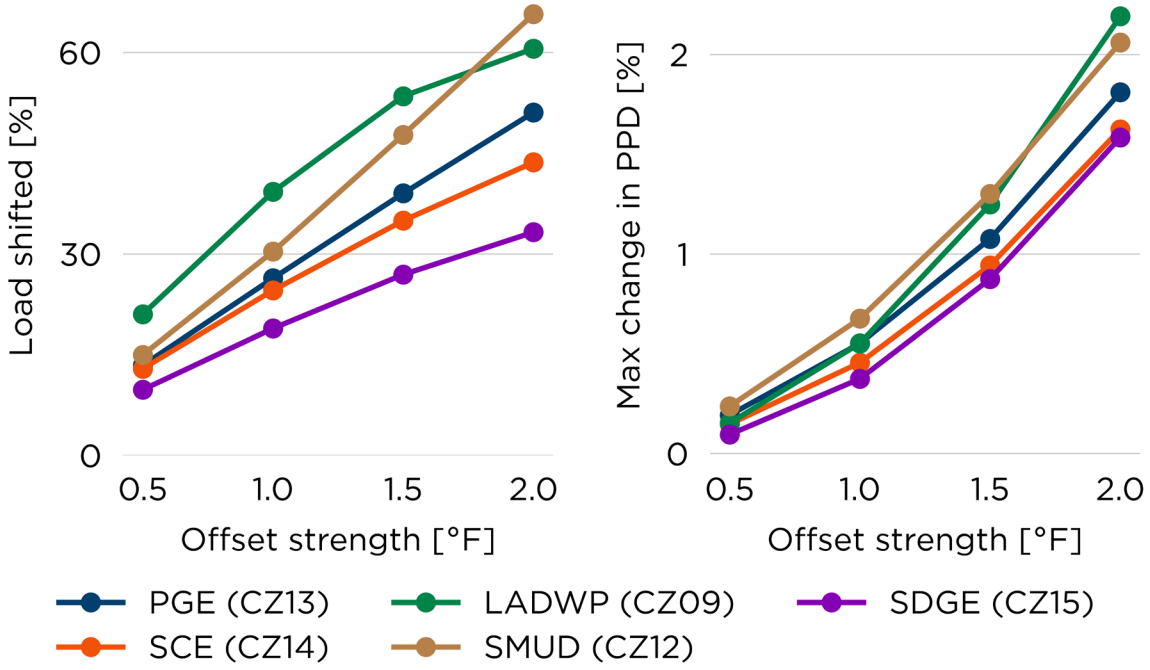
Table D-6: Average and Max Cooling Summer Days per LSE

Climate Zone	Average summer day (average temperature)	Max cooling summer day (average temperature)
PGE: Fresno, CZ13	06/25 (82.7 °F)	07/06 (93.6 °F)
SCE: Palmdale, CZ14	07/05 (94.2 °F)	07/13 (82.5 °F)
LADWP: Burbank, CZ09	07/06 (73.8 °F)	06/20 (93.6 °F)
SMUD: Sacramento, CZ12	07/28 (73.6 °F)	07/05 (86.0 °F)
SDGE: Palm Springs, CZ15	06/18 (93.1 °F)	06/20 (105.6 °F)

Source: California Energy Commission

Figure D-8 shows the degree of load shifted and the maximum hourly change in PPD compared to the baseline conditions for average summer days.

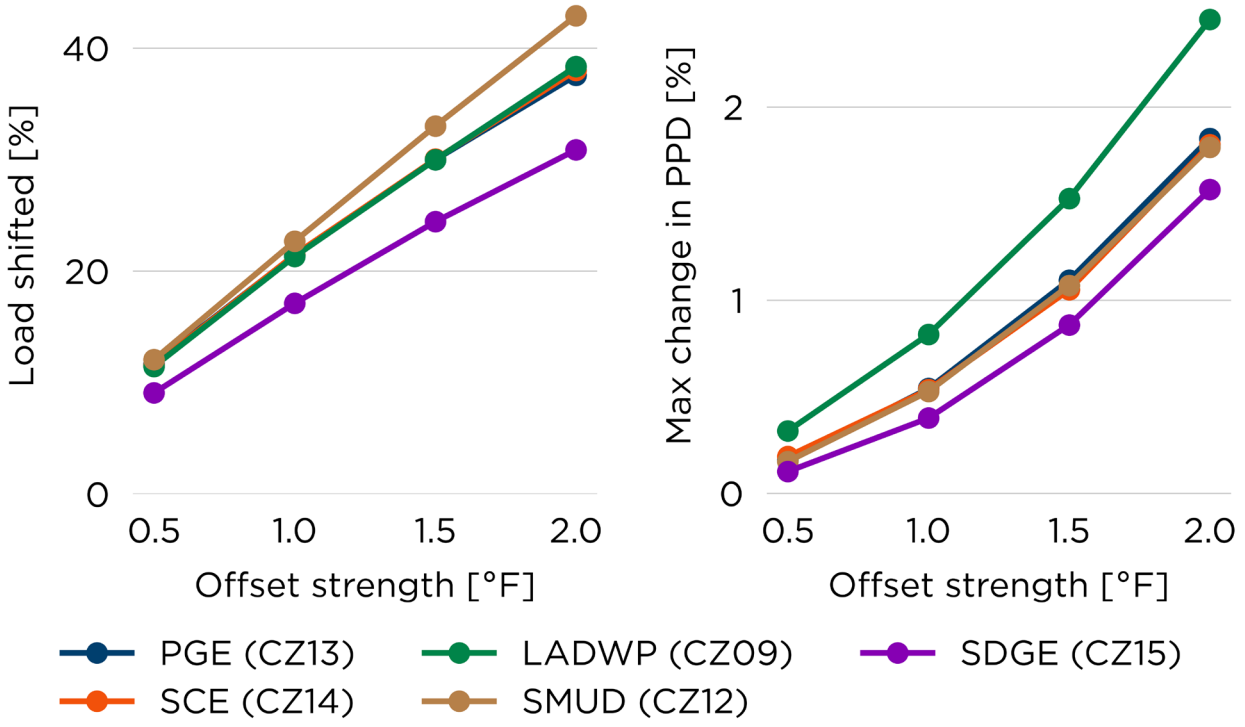
Figure D-8: Impact of Temperature Offsets, Average summer days



Source: California Energy Commission

Figure D-9 shows those for max cooling days. The signals used to generate the set point schedules were August 7, 2024, for the max cooling day and July 18, 2024, for the average summer day, corresponding to max and average statewide cooling loads from HELM. The building prototypes used by staff for this analysis were the SF1250 prototype built before the building energy codes. Thus, the impacts should correspond to those for the worst-case scenarios for the implementation of the staff proposal.

Figure D-9: Impact of Temperature Offsets, Max cooling days



Source: California Energy Commission

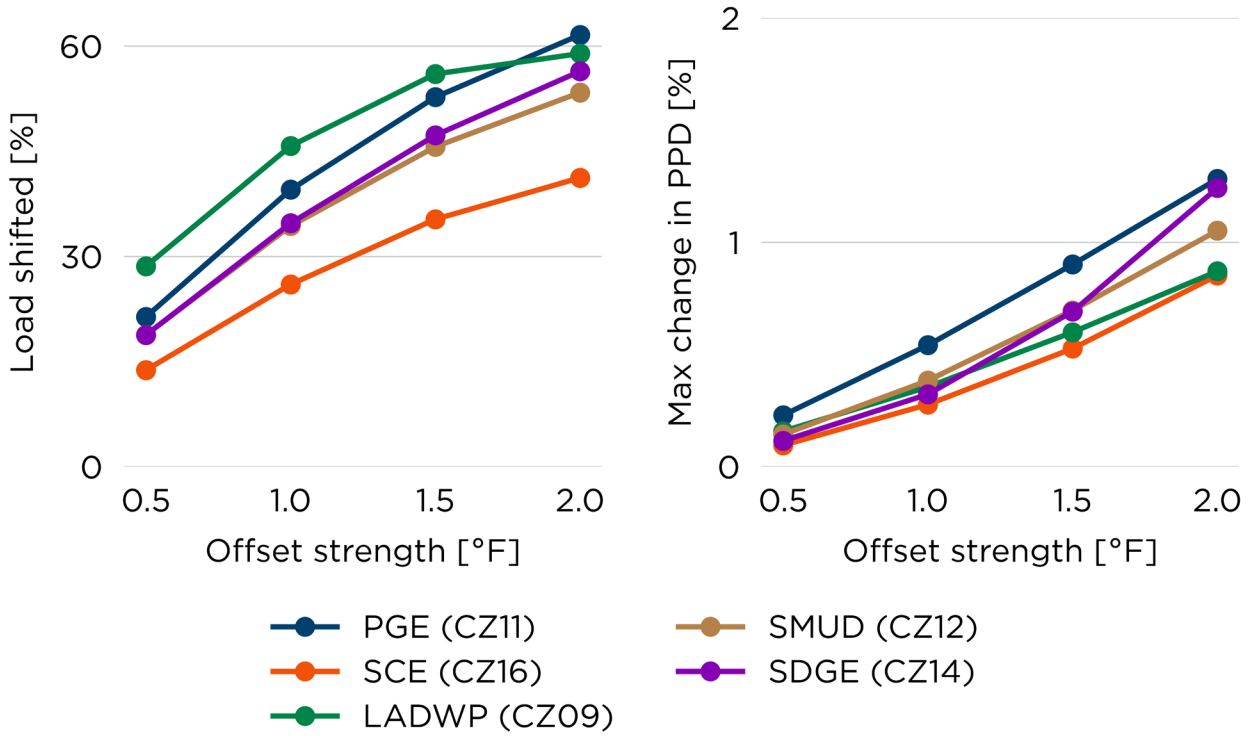
Staff performed the same analysis for the heating season. **Table D-7** shows the average winter days and max heating days for the coldest climate zones in each LSE's service territory. **Figure D-10** and **Figure D-11** show the impact of varying offset temperatures on load and daily change in PPD, respectively. For the average winter day, the MIDAS signals from February 3, 2024, were used. The MIDAS signals from January 26, 2024 were used for the max heating day.

Table D-7: Average and Max Heating Winter Days per LSE

Climate Zone	Average winter day (average temperature)	Max heating winter day (average temperature)
PGE: Red Bluff, CZ11	12/01 (47.6 °F)	12/25 (34.3 °F)
SCE: Blue Canyon, CZ16	01/13 (41.2 °F)	02/04 (24.8 °F)
LADWP: Burbank, CZ09	12/09 (55.1 °F)	01/02 (44.4 °F)
SMUD: Sacramento, CZ12	01/30 (46.7 °F)	12/15 (36.4 °F)
SDGE: Palmdale, CZ14	12/15 (45.0 °F)	01/02 (32.8 °F)

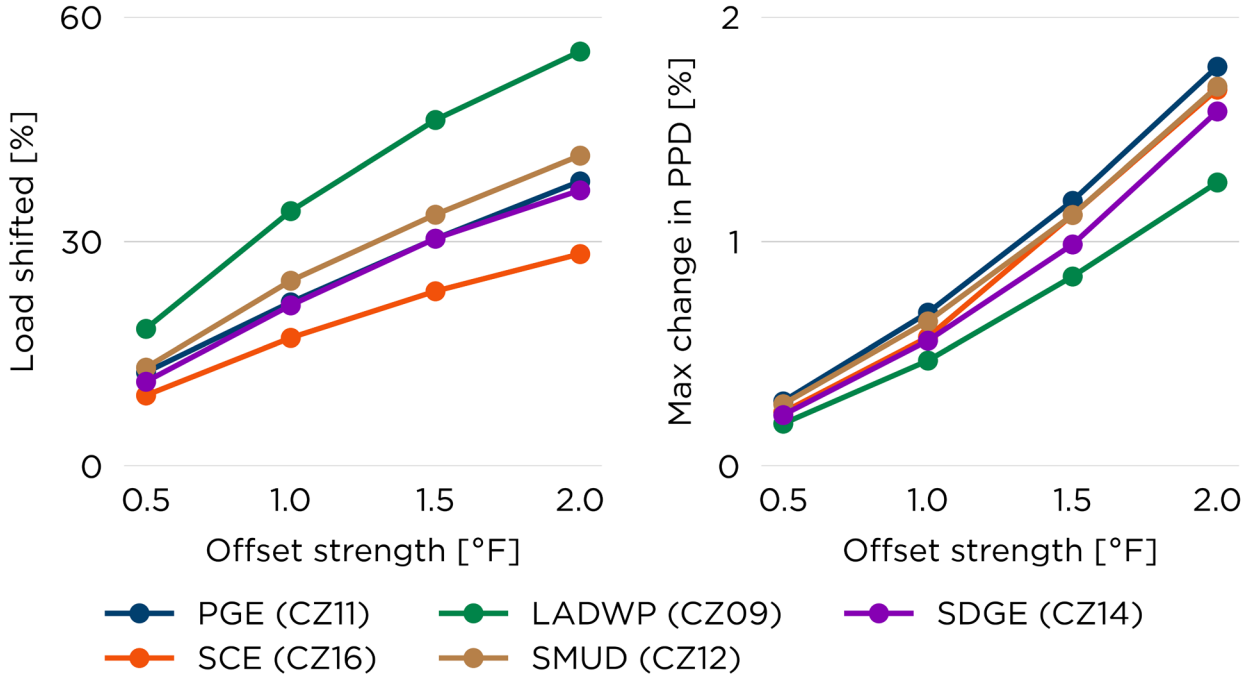
Source: California Energy Commission

Figure D-10: Impact of Temperature Offsets, Average winter days



Source: California Energy Commission

Figure D-11: Impact of Temperature Offsets, Max heating days



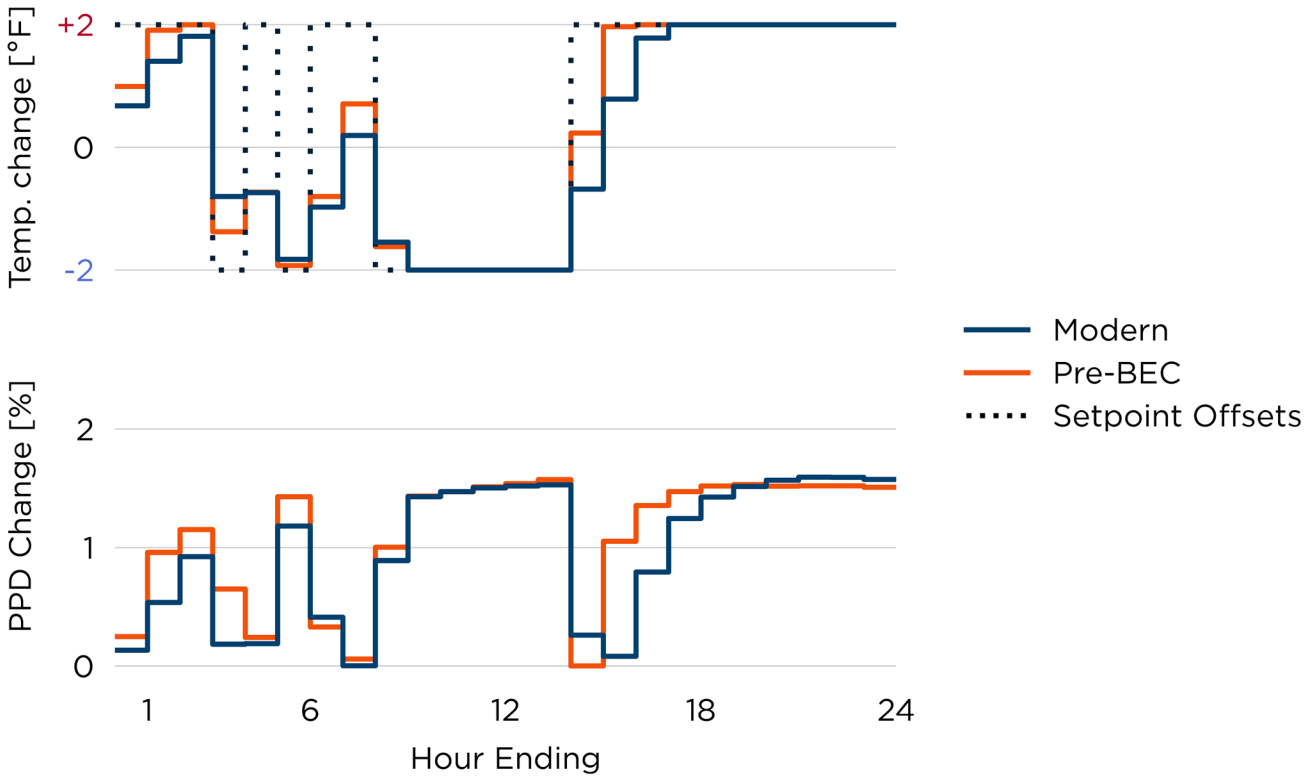
Source: California Energy Commission

The staff proposal provides the capability for compliant thermostats to shift space-conditioning load. The default offset of 2 °F allows for significant load shifts while keeping the change in PPD small. Staff determined any changes in PPD higher than 2.5% to be unacceptable. For reference, conditions corresponding to the "comfort zone" described in ASHRAE 55-2023 provide changes in PPD smaller than 5% from optimal conditions. Criticism of PPD is discussed in the main body of the staff report. Consumers can increase or decrease their offset temperatures according to their preferences.

Staff modelled and analyzed the impact of the proposed standards on prototypes representative of the current stock of single-family homes in California. **Figures D-12** through **Figure D-15** compare the impact of the standards on various newly constructed and pre-Building Energy Code (pre-BEC) single family homes for the SF1250, SF1750, SF2250, and SF2750 prototypes. Staff analyzed homes in Palm Springs (CZ15), the hottest climate zone, on the hottest day, Jun 20th. The set point schedules for this max cooling day were created using the combined HDP+GHG static MIDAS signal for August 7, 2024. The dashed lines in the figures for SF2250 and SF2750 are for the second (top) floor, whereas the solid lines are for the first (bottom) floor.

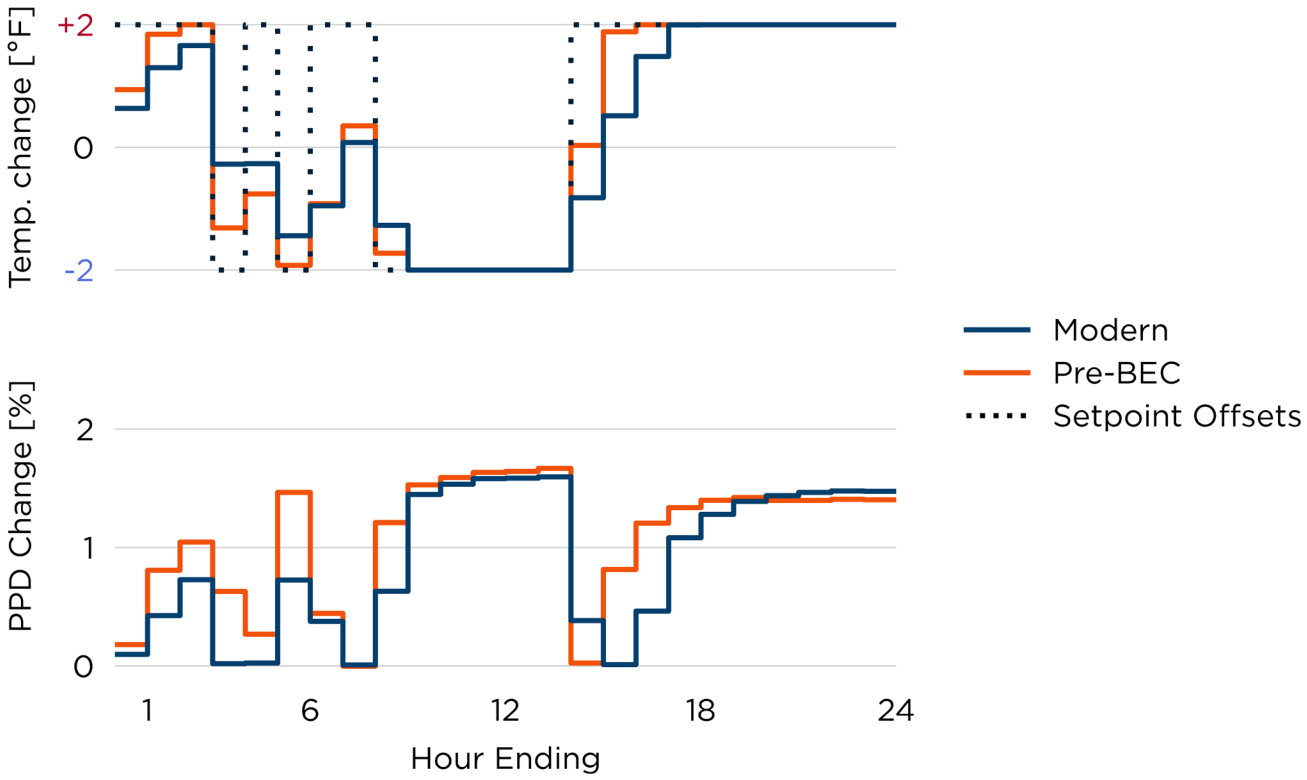
For all four prototypes of both vintages, the set point schedules effectively shifted space-conditioning load from the evening period to the day period. The load shifts also kept changes in PPD under 2%. Among the prototypes with two floors (SF2250 and SF1750), the temperatures in the zones on the top floors were generally higher than those on the bottom floors. Overall, modern homes kept pre-cooled temperatures for ~2 hours longer than the pre-BEC homes across all the prototypes.

Figure D-12: Impact of Proposed Standards, SF1250 Prototype on the Hottest Day in Palm Springs (CZ15)



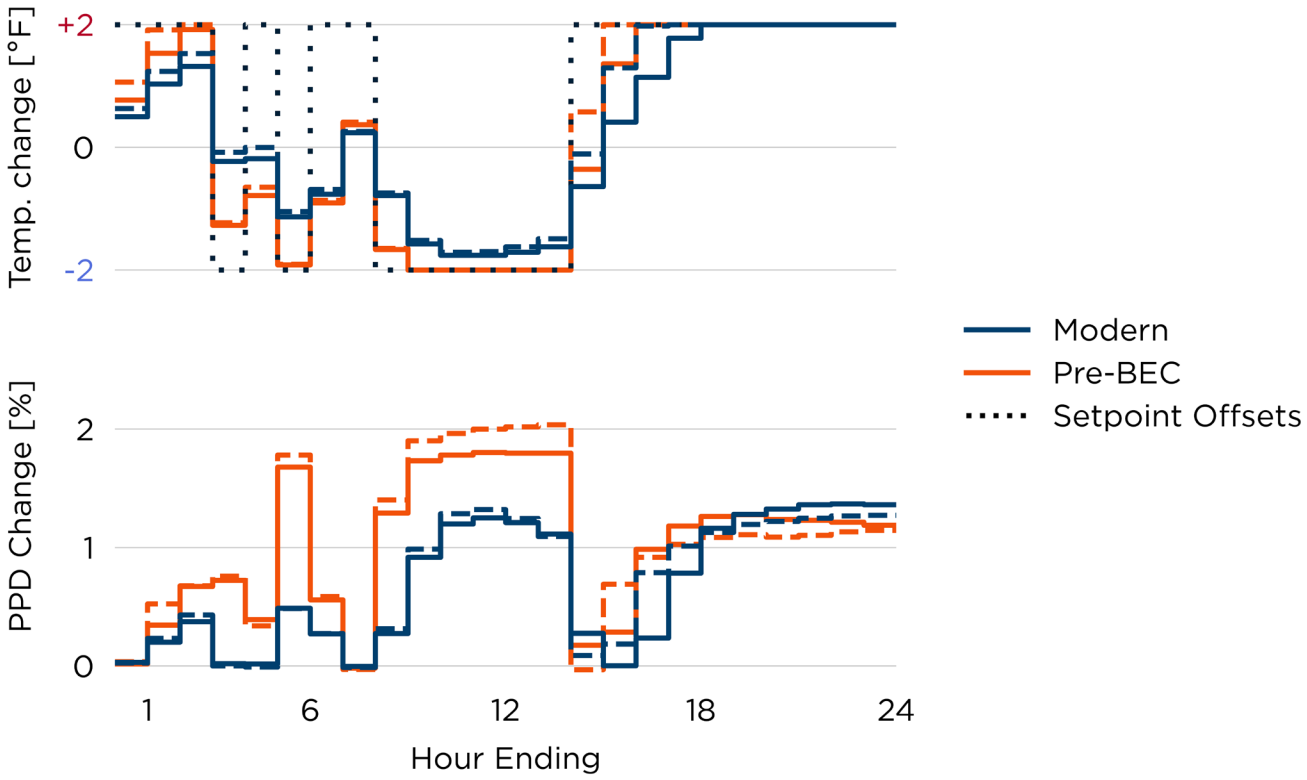
Source: California Energy Commission

Figure D-13: Impact of Proposed Standards, SF1750 Prototype on the Hottest Day in Palm Springs (CZ15)



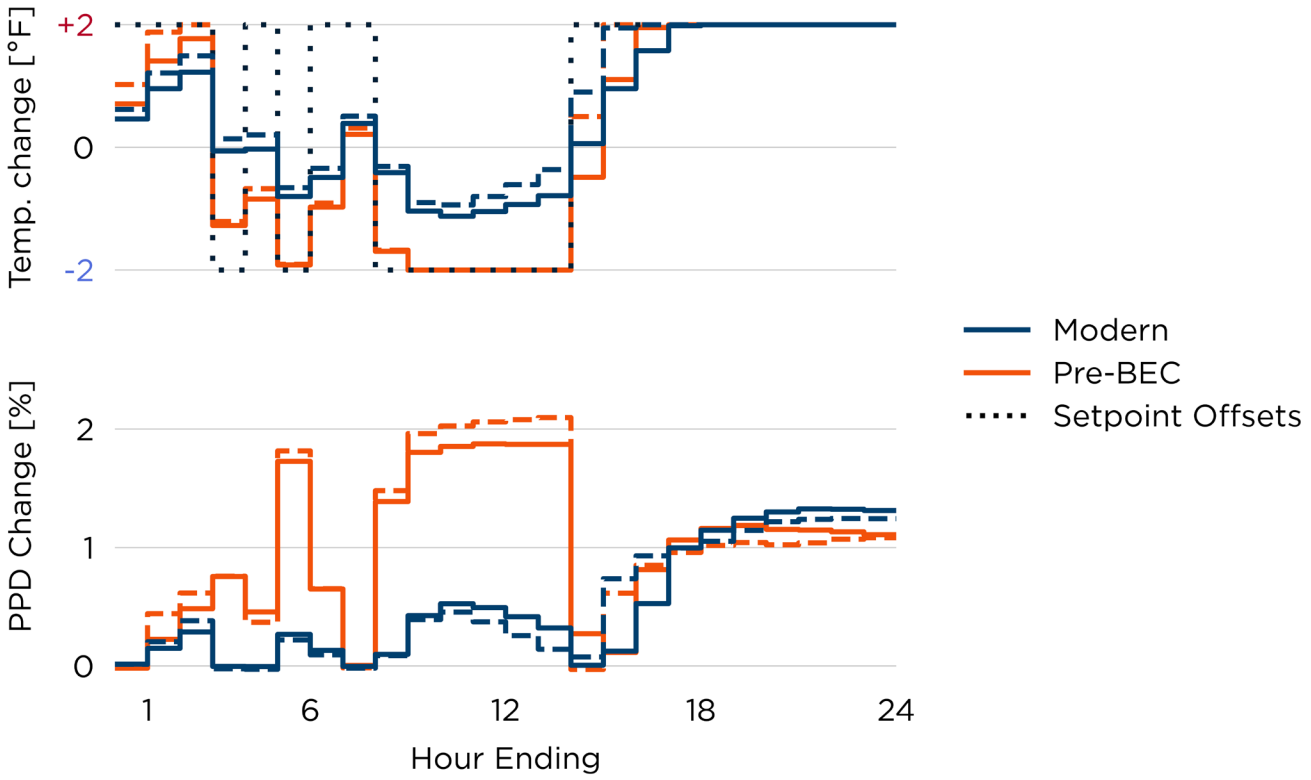
Source: California Energy Commission

Figure D-14: Impact of Proposed Standards, SF2250 Prototype on the Hottest Day in Palm Springs (CZ15)



Source: California Energy Commission

Figure D-15: Impact of Proposed Standards, SF2750 Prototype on the Hottest Day in Palm Springs (CZ15)

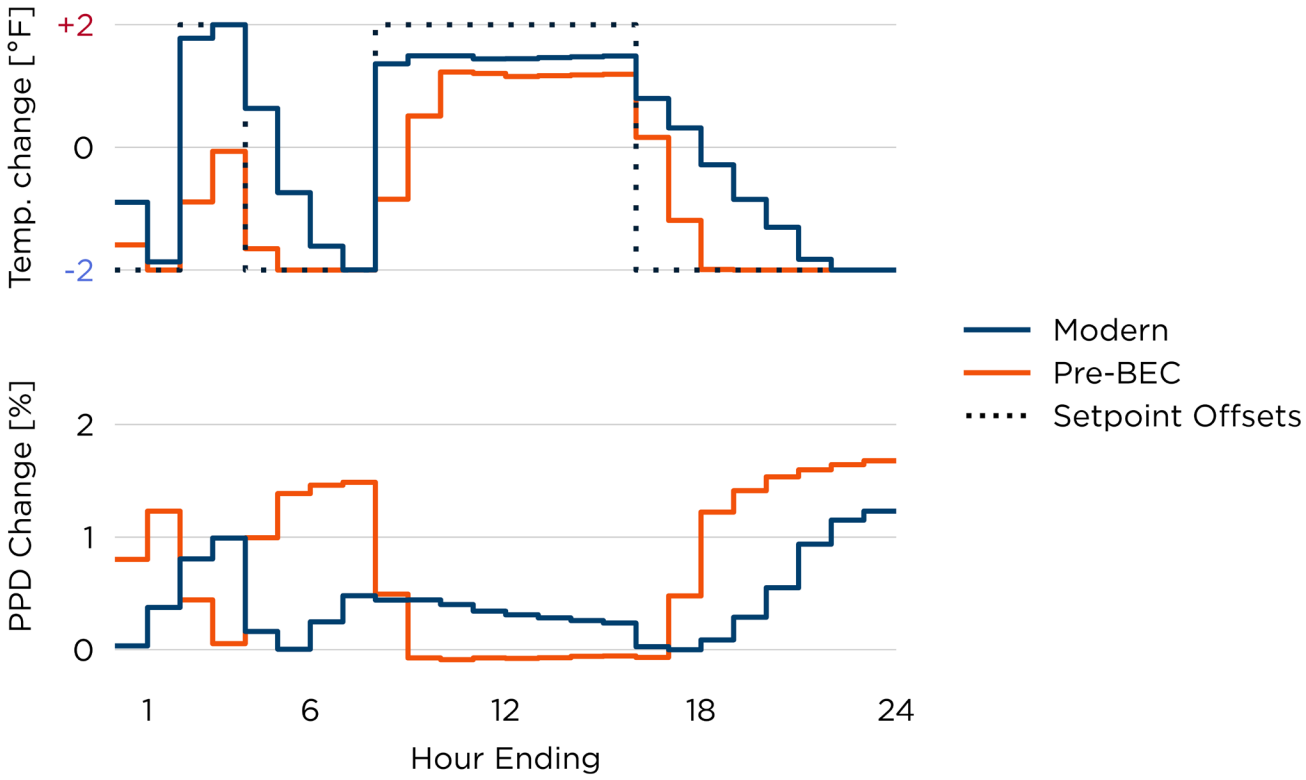


Source: California Energy Commission

Staff also compared the impact of different housing prototypes during the heating season. **Figures D-16** through **Figure D-19** show the results for SF1250, SF1750, SF2250, and SF2750 prototypes in the coldest climate zone, Blue Canyon (CZ16), on the coldest day of the year, Feb 4th. The set point schedules for this max heating day were created using the combined HDP+GHG static MIDAS signal for January 26, 2024. The dashed lines in the figures for SF2250 and SF2750 are for the second (top) floor, whereas the solid lines are for the first (bottom) floor.

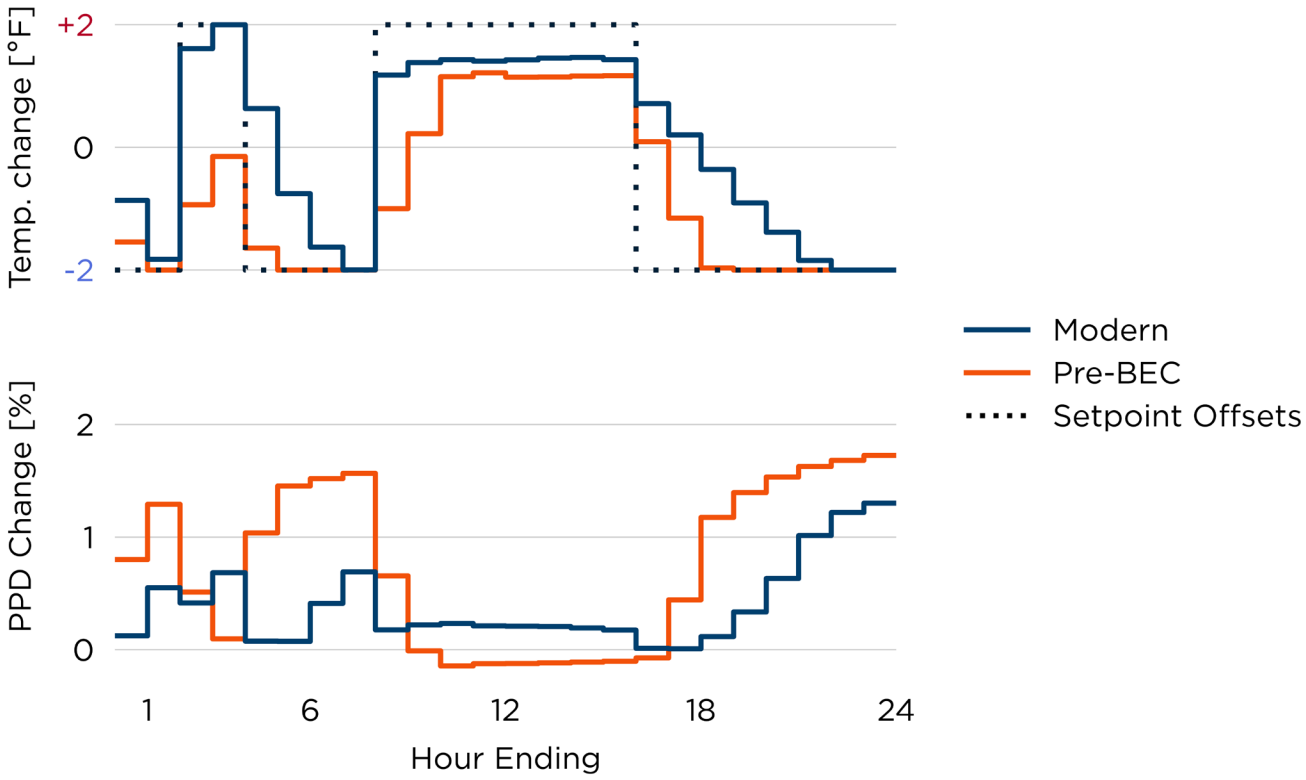
Results for heating are similar to those for cooling. The MIDAS signal effectively shifted space-conditioning to the daytime for all prototypes and vintages while keeping the change in PPD within 2%. One key difference from the results on cooling is the electric resistance heating in the pre-BEC home could not effectively preheat the homes. Preheating was accomplished in the modern home through a combination of heat pump and backup electric resistance heating. While the resulting change in PPD did not reach significant levels, pre-BEC homes experienced maximum offset (-2 °F) conditions for longer periods.

Figure D-16: Impact of Proposed Standards, SF1250 Prototype on the Coldest Day in Blue Canyon (CZ16)



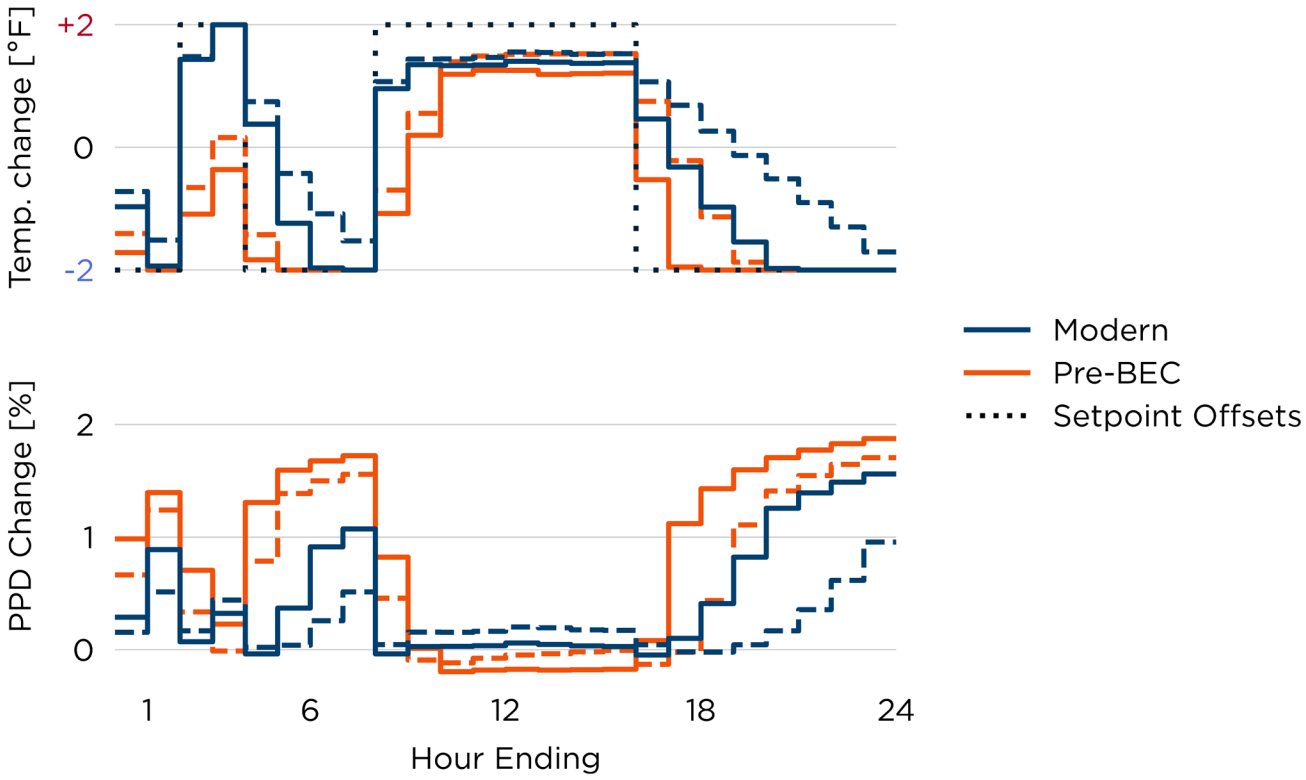
Source: California Energy Commission

Figure D-17: Impact of Proposed Standards, SF1750 Prototype on the Coldest Day in Blue Canyon (CZ16)



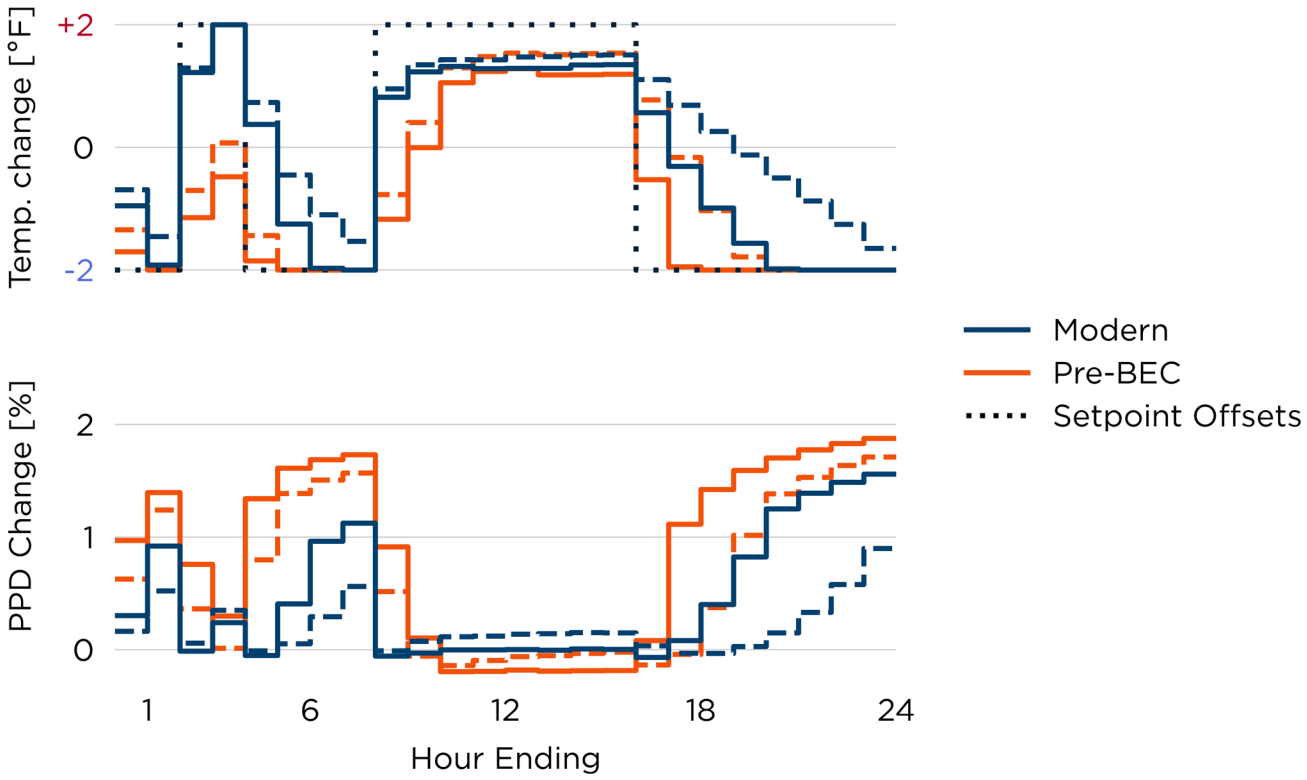
Source: California Energy Commission

Figure D-18: Impact of Proposed Standards, SF2250 Prototype on the Coldest Day in Blue Canyon (CZ16)



Source: California Energy Commission

Figure D-19: Impact of Proposed Standards, SF2750 Prototype on the Coldest Day in Blue Canyon (CZ16)



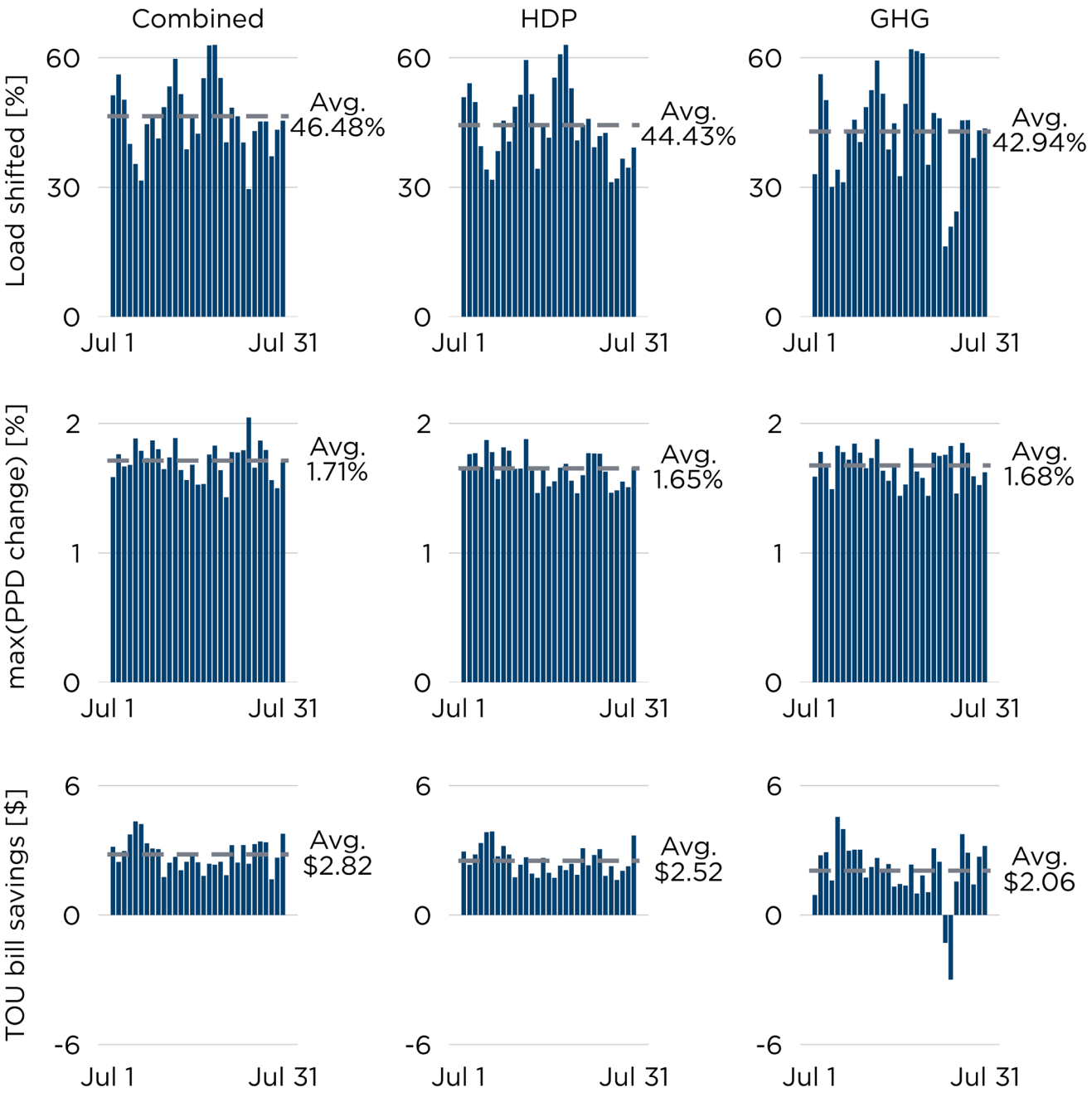
Source: California Energy Commission

To compare the long-term effects of daily space-conditioning shifts between the staff proposal (combined signal) and the alternatives, staff simulated a month's worth of thermostat set point schedules generated by the highly dynamic price (HDP), greenhouse gas (GHG), and combined static MIDAS signals. **Figure D-20** through **Figure D-24** compare the effect of the algorithms on each simulated day in the month of July for the hottest climate zones in each LSE service territory. **Figure D-25** through **Figure D-29** compare those in the month of December for the coldest climate zones in each LSE service territory. This time, the same dates were used for both the MIDAS signals and the CBECC simulations. Staff used the default 2 °F temperature offset for both preconditioning and setback. Staff used the pre-BEC SF1250 prototypes.

Since all three signals come from MIDAS, thermostat schedules generated using HDP, GHG, and combined strategies generally shifted load from peak periods to off-peak periods. The first rows of the figures show the percentages of baseline (unshifted) loads shifted by the load-shift strategies. Weather played a large role in the degree of load shift, from a July-long average of 31% in SDGE (CZ15) to 70% in SMUD (CZ12) when using the combined signal. Throughout December, the load shifts varied from 57% (PGE, CZ11) to 48% (SCE, CZ16) Using only the GHG signal consistently yielded the lowest load shift and using the combined signal consistently yielded the highest load shift. Because the staff proposal keeps temperature within a certain range (+/- 2 °F from the baseline set point), the change in PPD remained near

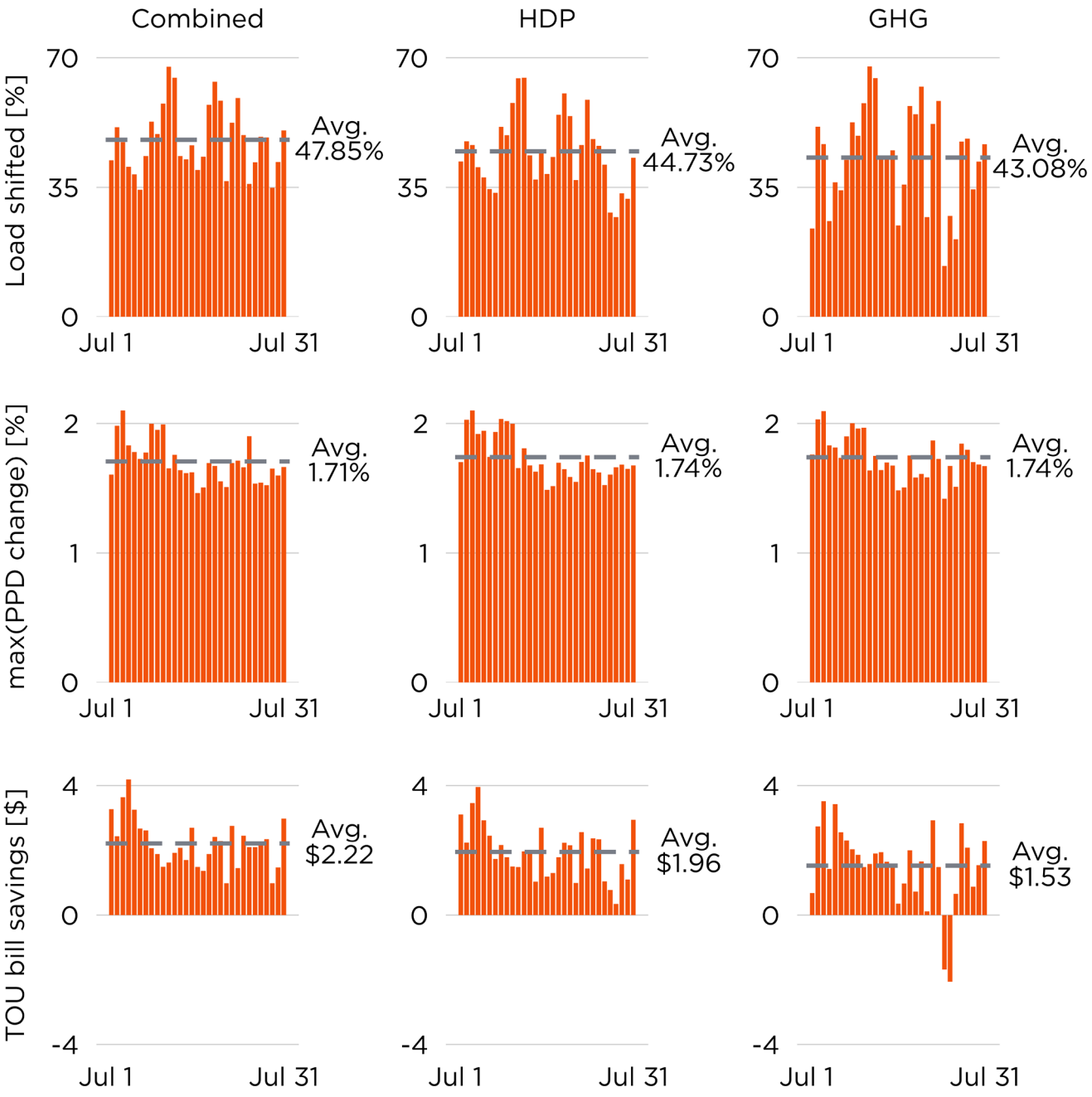
or under 2.5% for all days in most climate zones. Days that resulted in higher changes in PPD resulted from conditions that were colder than the baseline. For LADWP and SMUD, the higher changes in PPD during July were caused by cool mornings, further cooling a precooled home. In December, higher changes in PPD were caused by long periods of "shed" signals. The high degrees of load shift led to high daily bill savings, assuming consumers are using TOU rate structures. Compared to set point schedules created using the HDP and GHG signals, schedules generated by the combined signals consistently provide the most bill savings. Because increases in GHG signals did not always correlate with increases in hourly TOU rates, sometimes the GHG signal caused an increase in electricity bill (negative savings) for both cooling and heating modes.

Figure D-20: Effect of Combined, HDP, and GHG MIDAS Signals, July in PGE



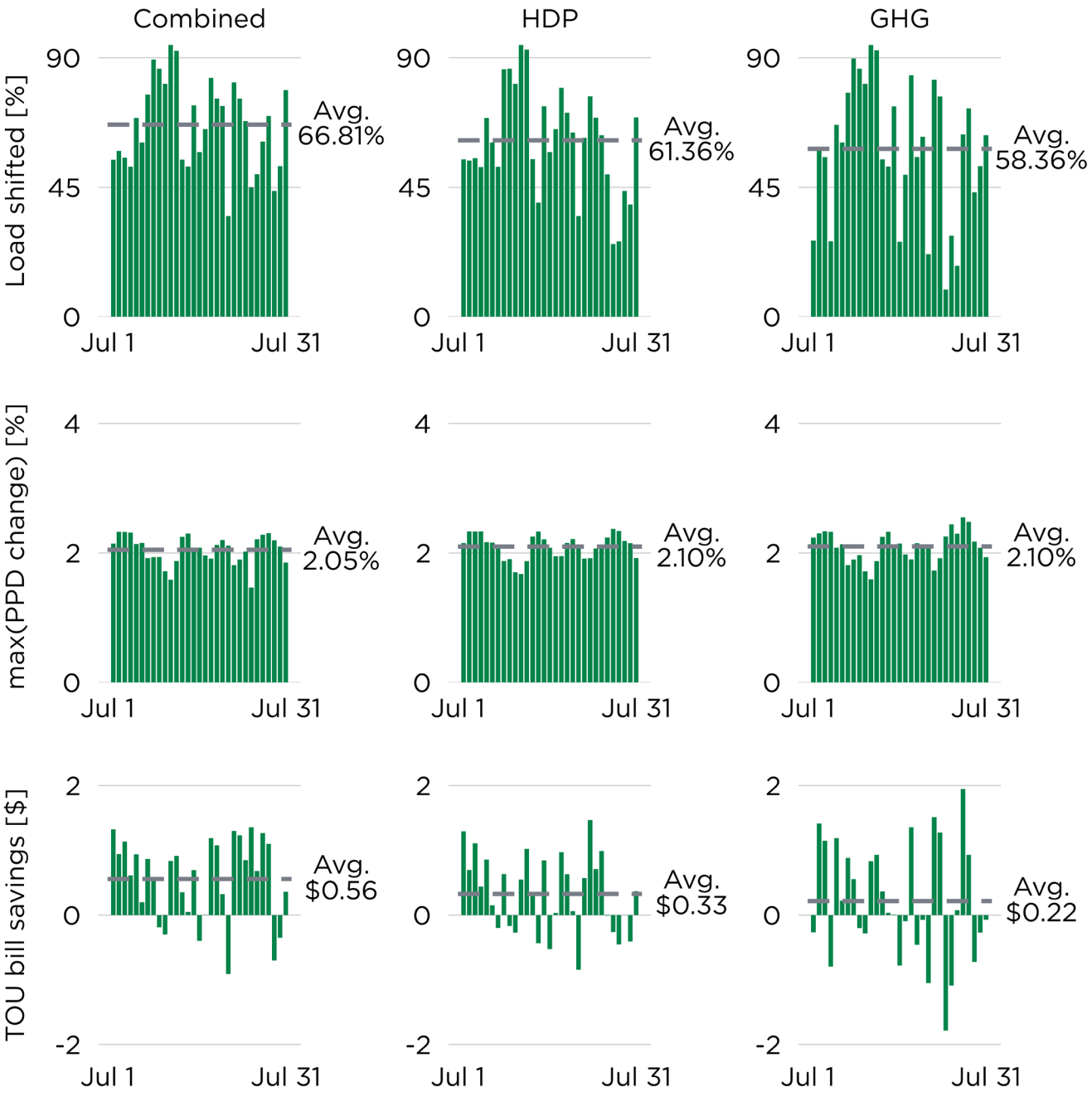
Source: California Energy Commission

Figure D-21: Effect of Combined, HDP, and GHG MIDAS Signals, July in SCE



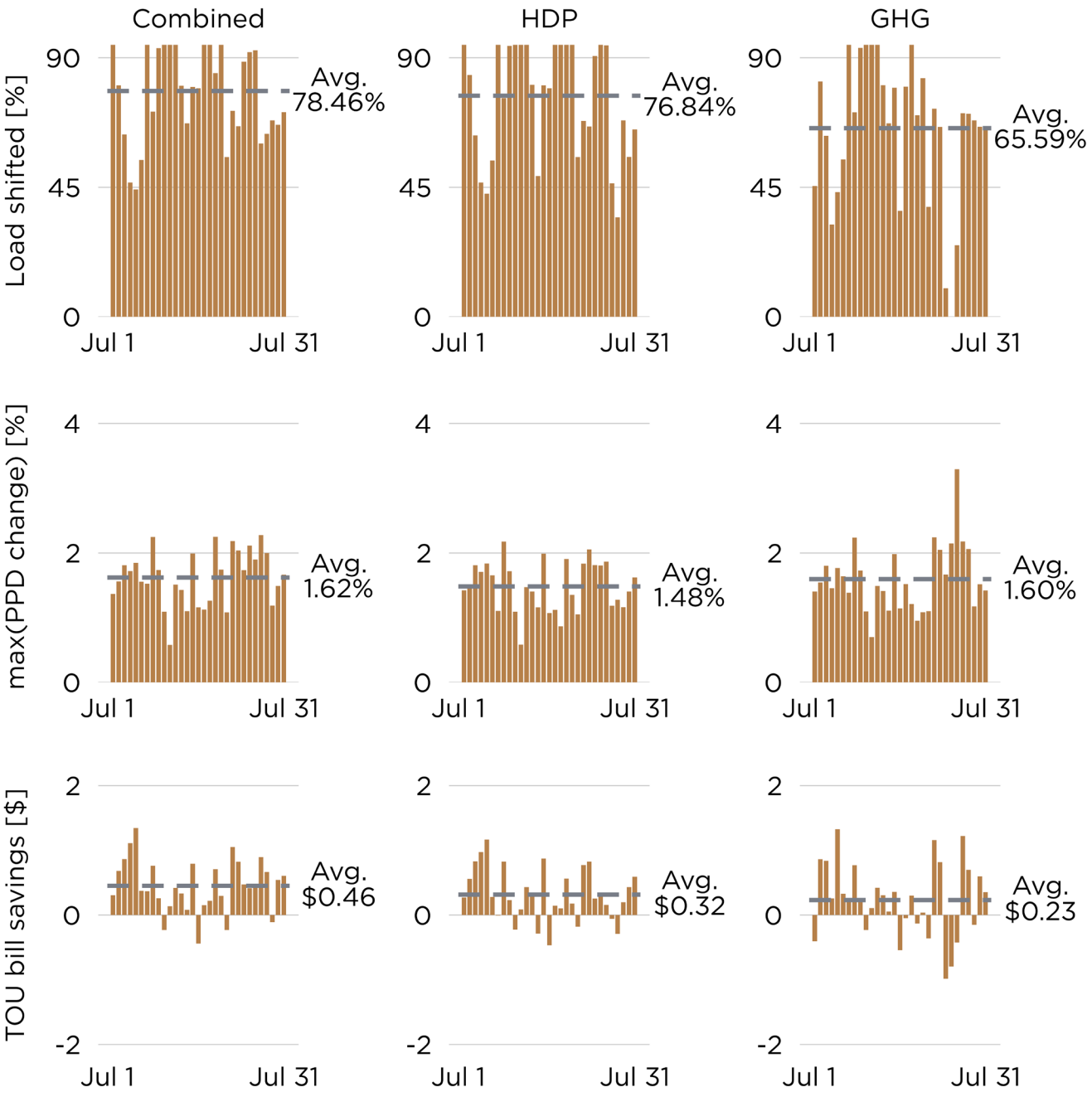
Source: California Energy Commission

Figure D-22: Effect of Combined, HDP, and GHG MIDAS Signals, July in LADWP



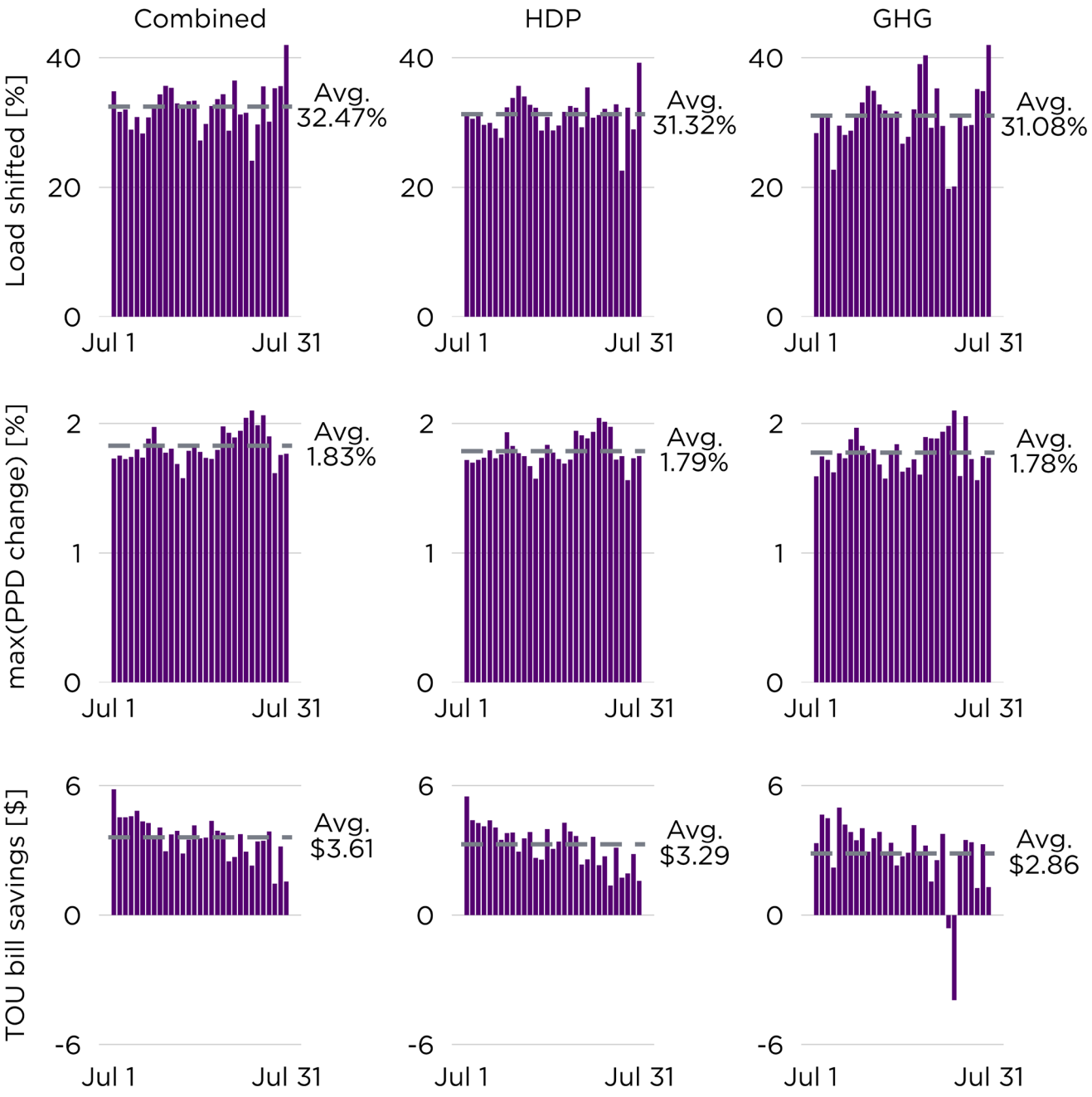
Source: California Energy Commission

Figure D-23: Effect of Combined, HDP, and GHG MIDAS Signals, July in SMUD



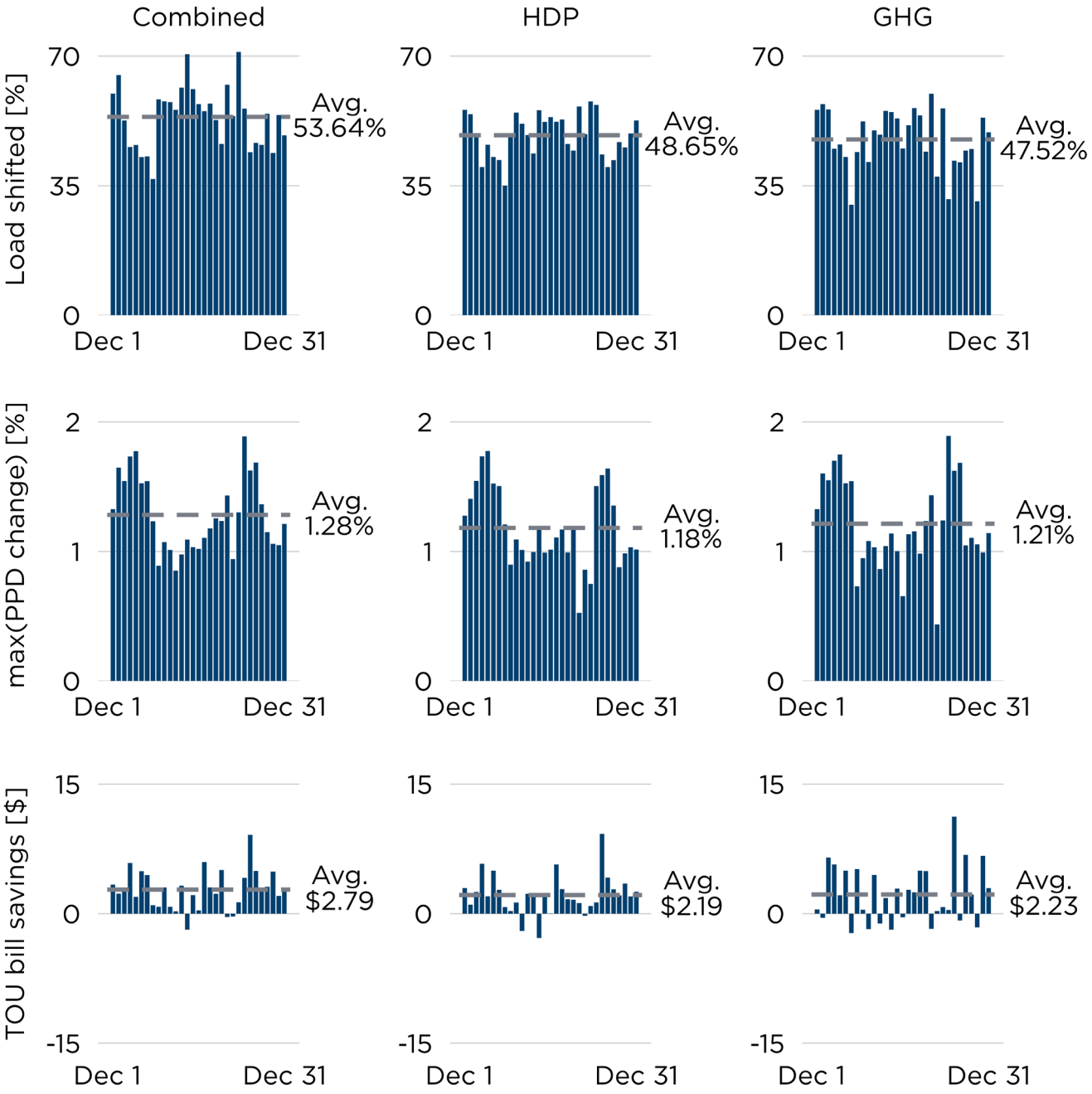
Source: California Energy Commission

Figure D-24: Effect of Combined, HDP, and GHG MIDAS Signals, July in SDGE



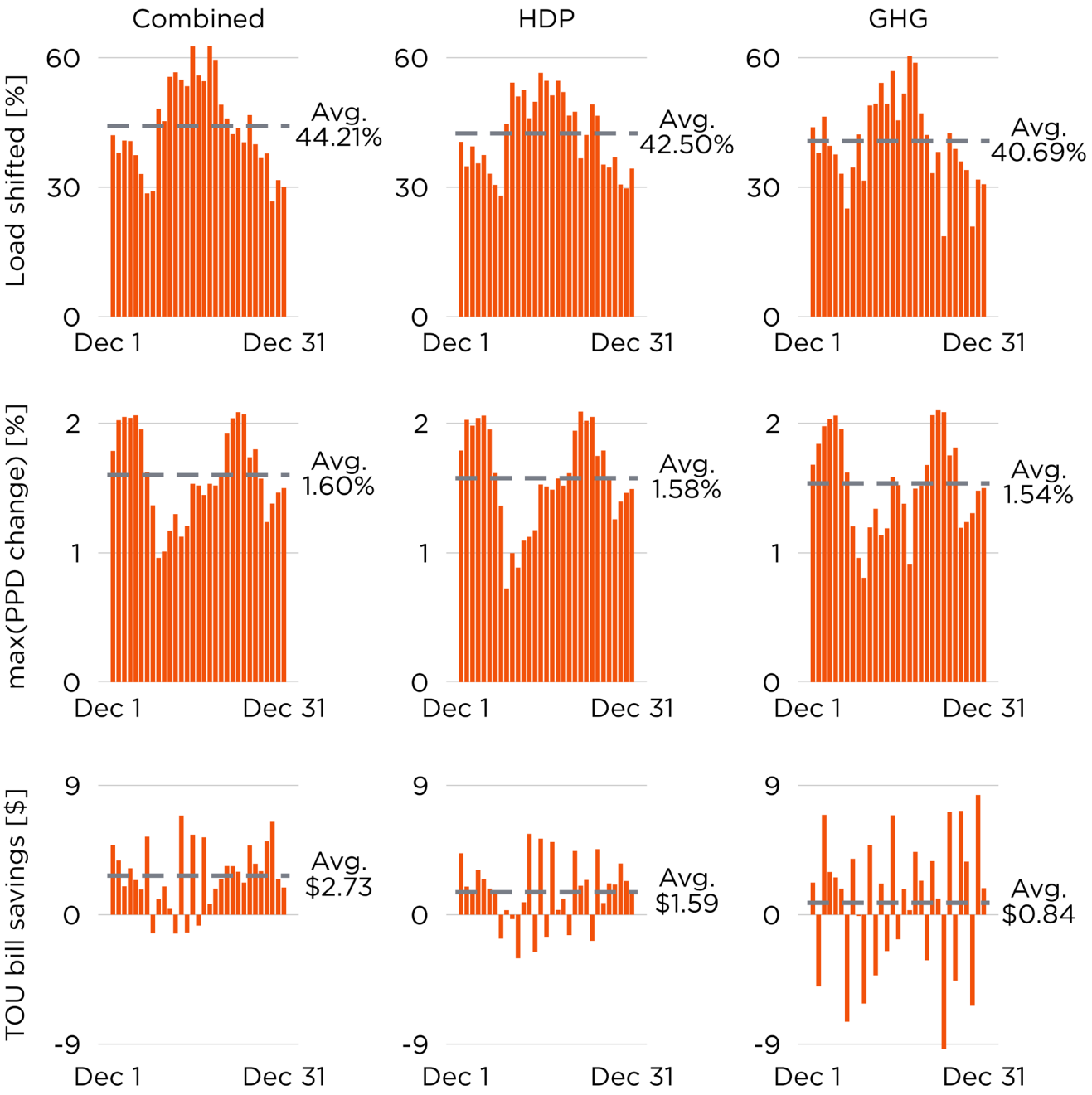
Source: California Energy Commission

Figure D-25: Effect of Combined, HDP, and GHG MIDAS Signals, December in PGE



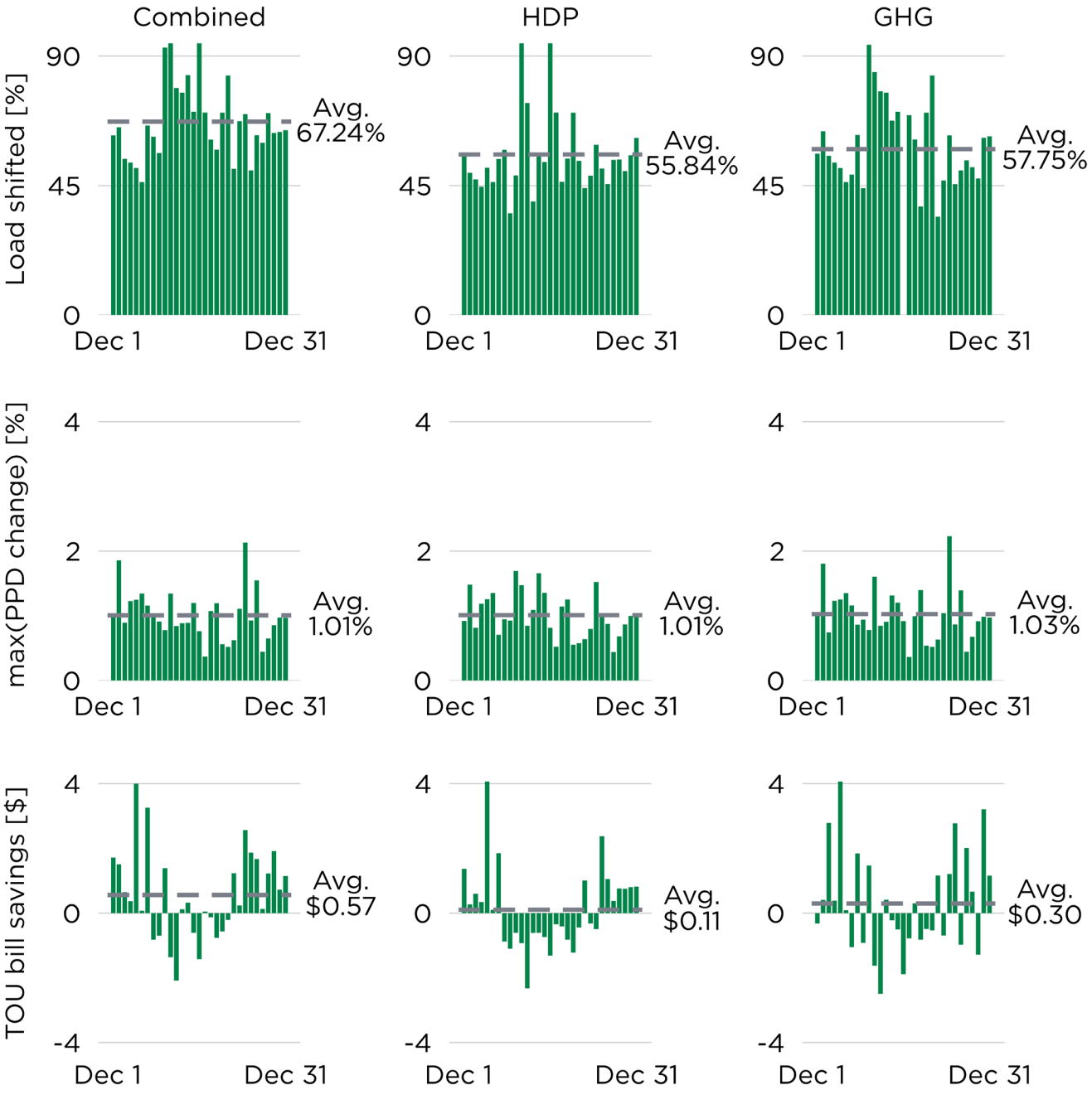
Source: California Energy Commission

Figure D-26: Effect of Combined, HDP, and GHG MIDAS Signals, December in SCE



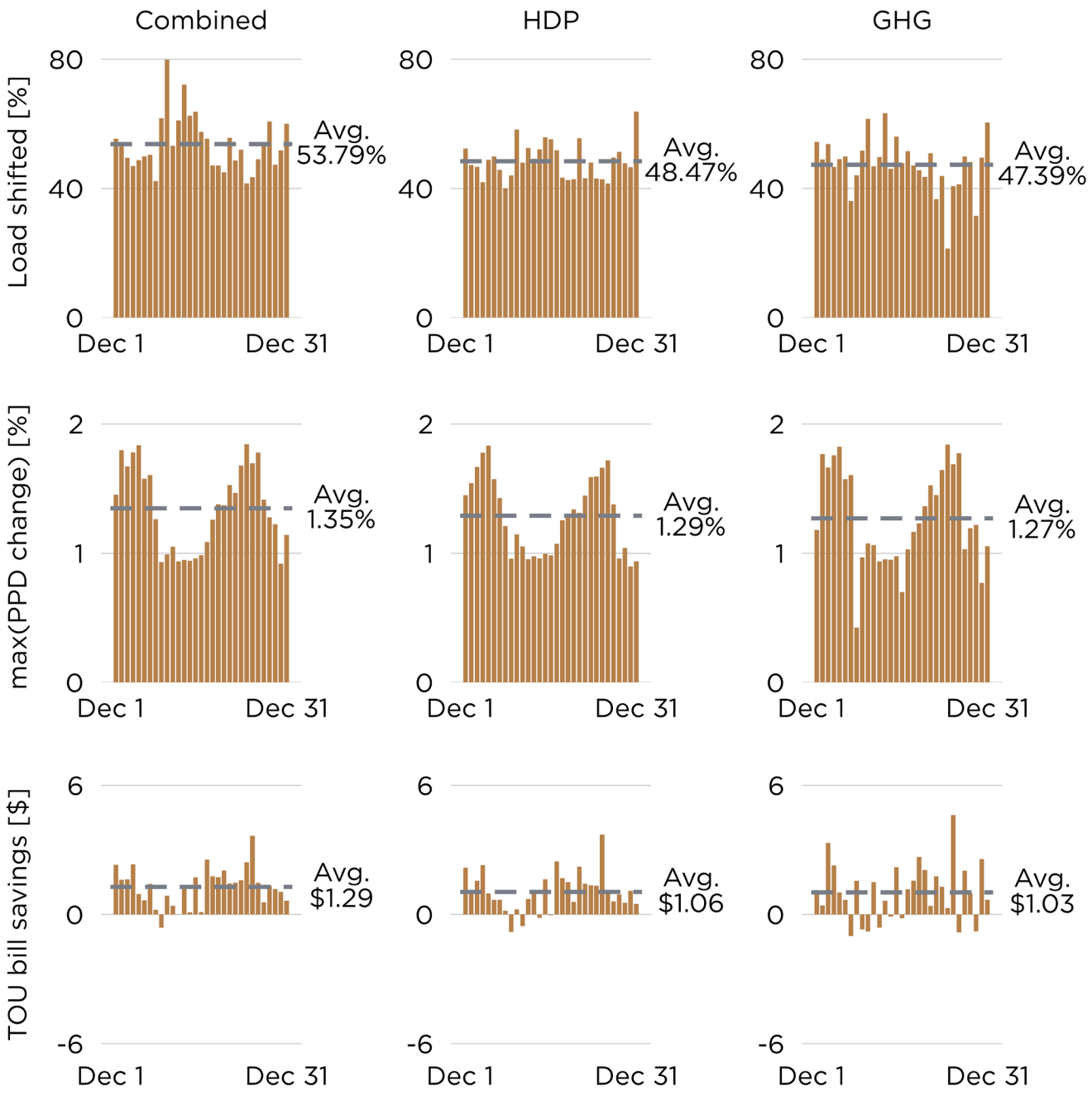
Source: California Energy Commission

Figure D-27: Effect of Combined, HDP, and GHG MIDAS Signals, December in LADWP



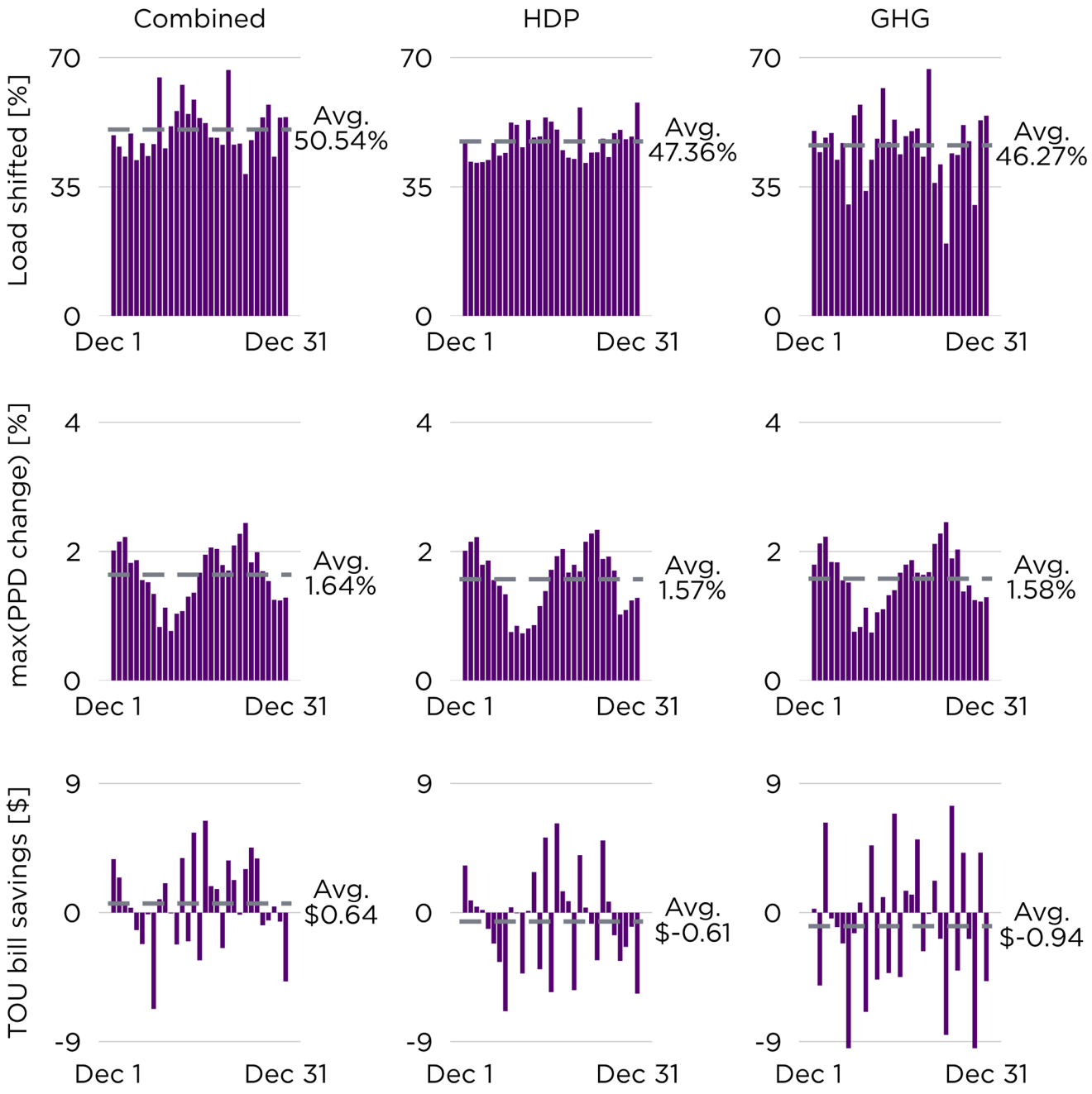
Source: California Energy Commission

Figure D-28: Effect of Combined, HDP, and GHG MIDAS Signals, December in SMUD



Source: California Energy Commission

Figure D-29: Effect of Combined, HDP, and GHG MIDAS Signals, December in SDGE



Source: California Energy Commission

APPENDIX E:
STAFF PROPOSED REGULATIONS

Refer to the Express Terms document for the Proposed Regulatory Language.