

California Residential Electric Resistance Supplemental Heating Impacts and Mitigation Strategies

CalBEM Symposium 2026

Working Group 3: Advanced Capabilities

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RESOURCE REFOCUS

Agenda

- Introduction, Randall Higa (3 min)
- Study Background, Carrie Brown (12 min)
- Discussion
  - Heat pump performance (10 min)
  - Heat pump modeling (10 min)
  - Next steps (10 min)

Background

BACKGROUND & CHALLENGE

California's decarbonization goals call for installing six million heat pumps by 2030, yet many systems include inefficient supplemental electric resistance ("strip") heating that can substantially increase winter peak demand and energy use.

STUDY OBJECTIVE

This study examined the energy, emissions, peak demand, and grid impacts of strip heating in California single-family homes and identified strategies to mitigate its use.

Project Scope:

- Single-family California homes
- HVAC electrification
- Based on ResStock models with strip heat sized to full design load

Research Methodology

Three Core Tasks (Based on Single-Family ResStock Data)

TASK 1: ANNUAL ANALYSIS

Compared the impact of different heat pump types, efficiencies, and envelope retrofits on strip heating use and peak demand across California climate zones and home vintages.

TASK 2: TEMPERATURE THRESHOLDS

Compared the impact of heat pump and strip heating control strategies on demand profiles during extreme cold periods across CA climates.

TASK 3: COINCIDENT PEAK ANALYSIS

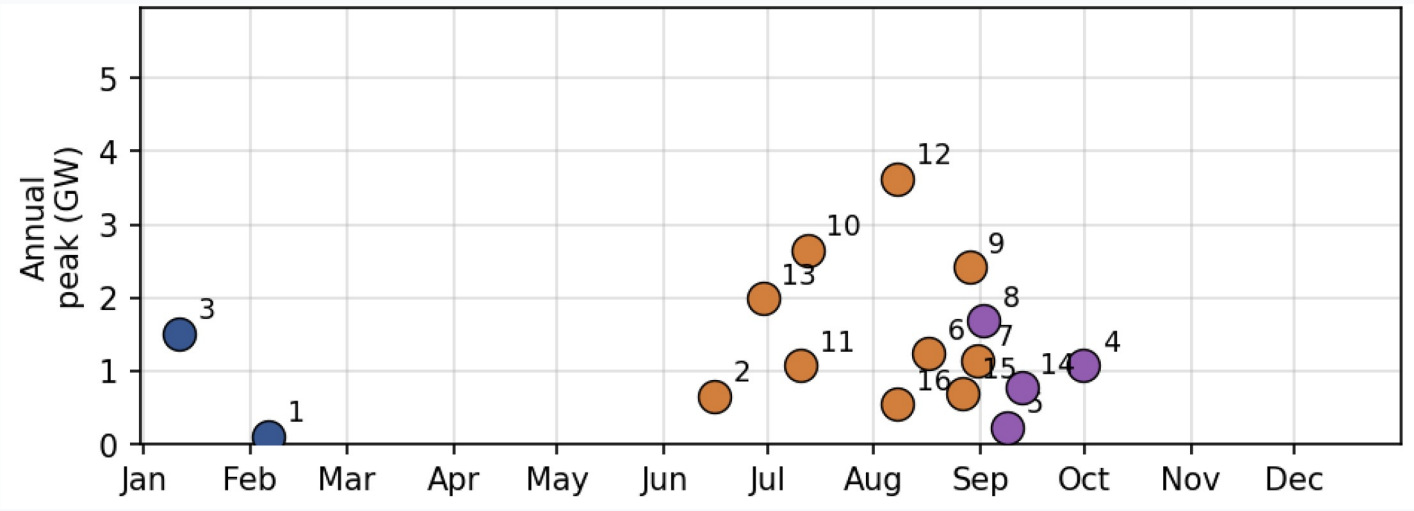
Assessed how single-family homes operate both individually and as an entire class of buildings, and how heat pump adoption may shift the timing of peak demand and coincidence factors across climates.

Strip Heating Impacts on Peak Demand

Peak Demand Shifts Under Std HP Adoption

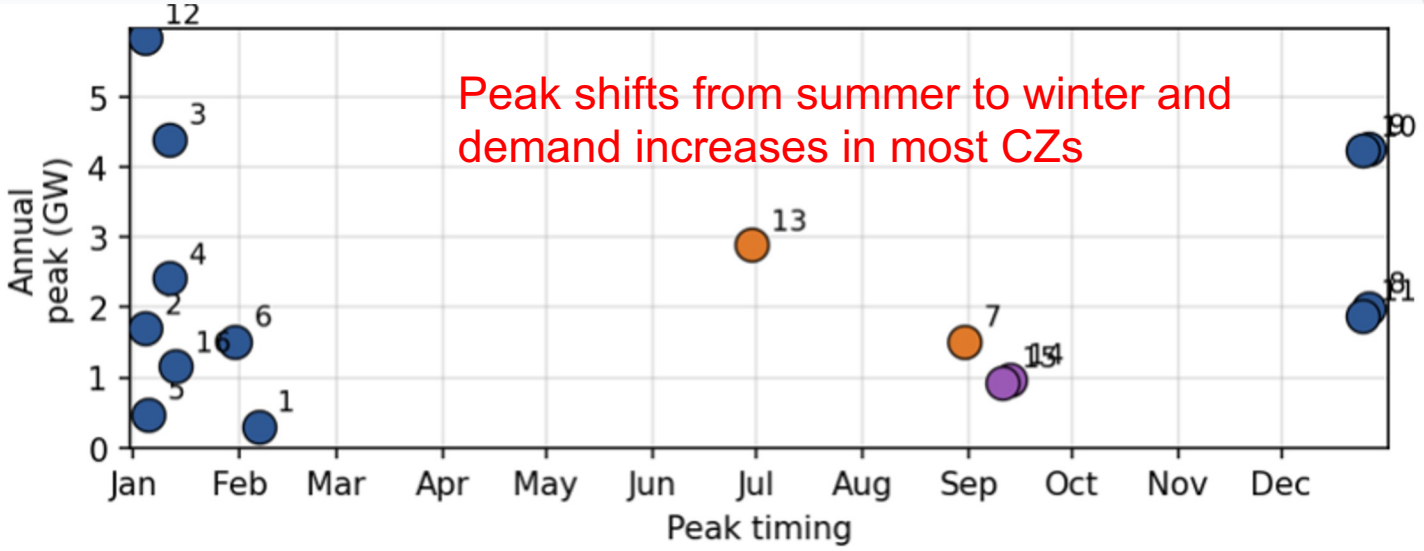
Aggregate Peak Demand — Baseline (Annual)

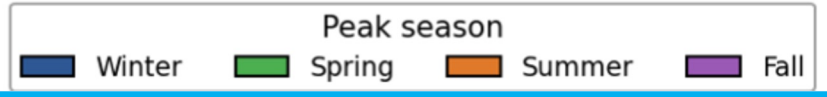
Pre-widespread residential heat pump adoption

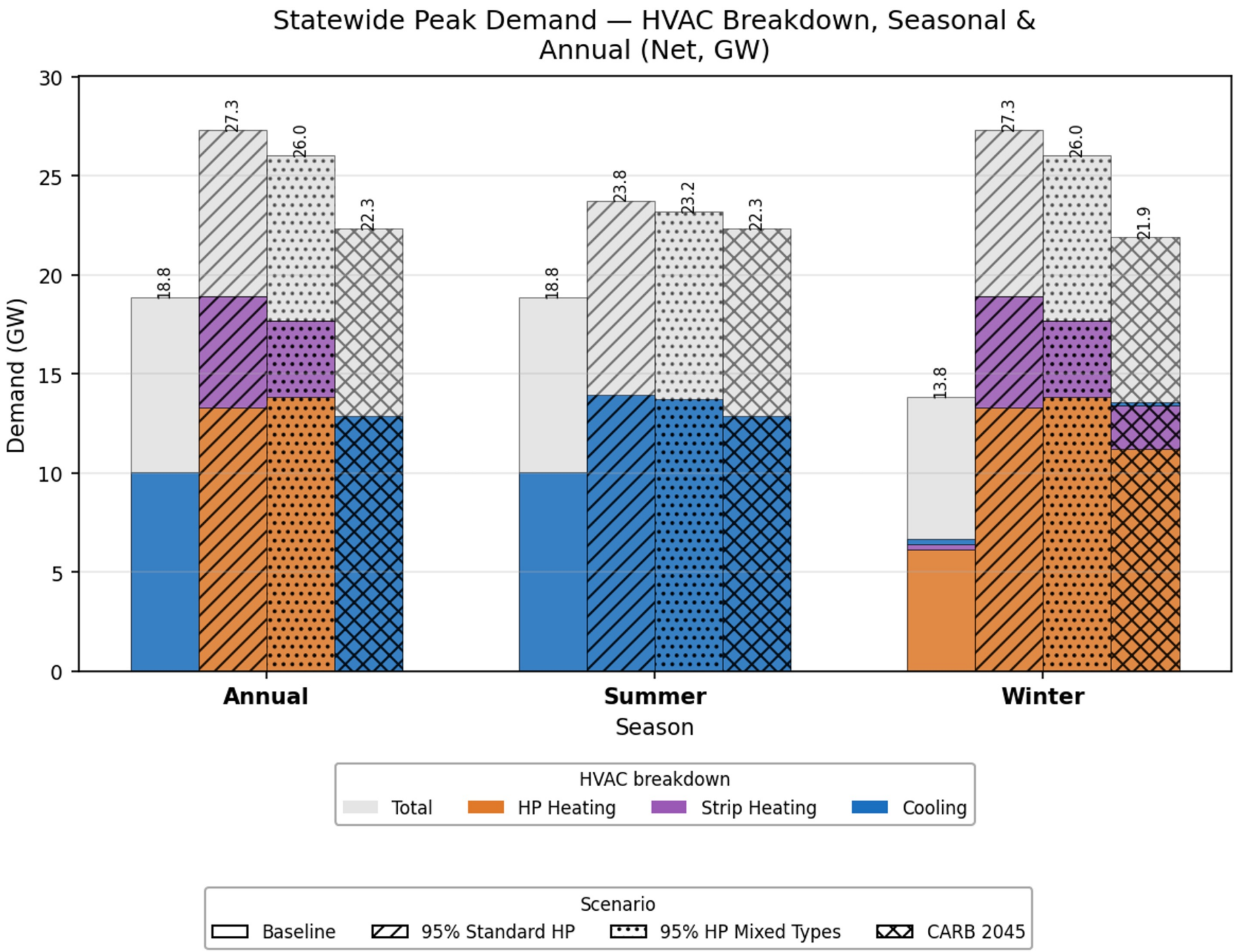


Aggregate Peak Demand — 95% Adoption of Standard HP

Bounding scenario for standard heat pump adoption







Heating demand:
Heat pump demand at the coincident winter peak roughly doubles across the future scenarios, from about 6 GW to between 11 and 14 GW

Strip heating demand grows from under <1 GW to between 2 and 5 GW

Peak magnitude:
In CZs where ccASHPs were modeled, coincident winter peak demand drops ~8% and strip heating's share of peak demand drops ~30%, compared to standard HP adoption.

Key Findings

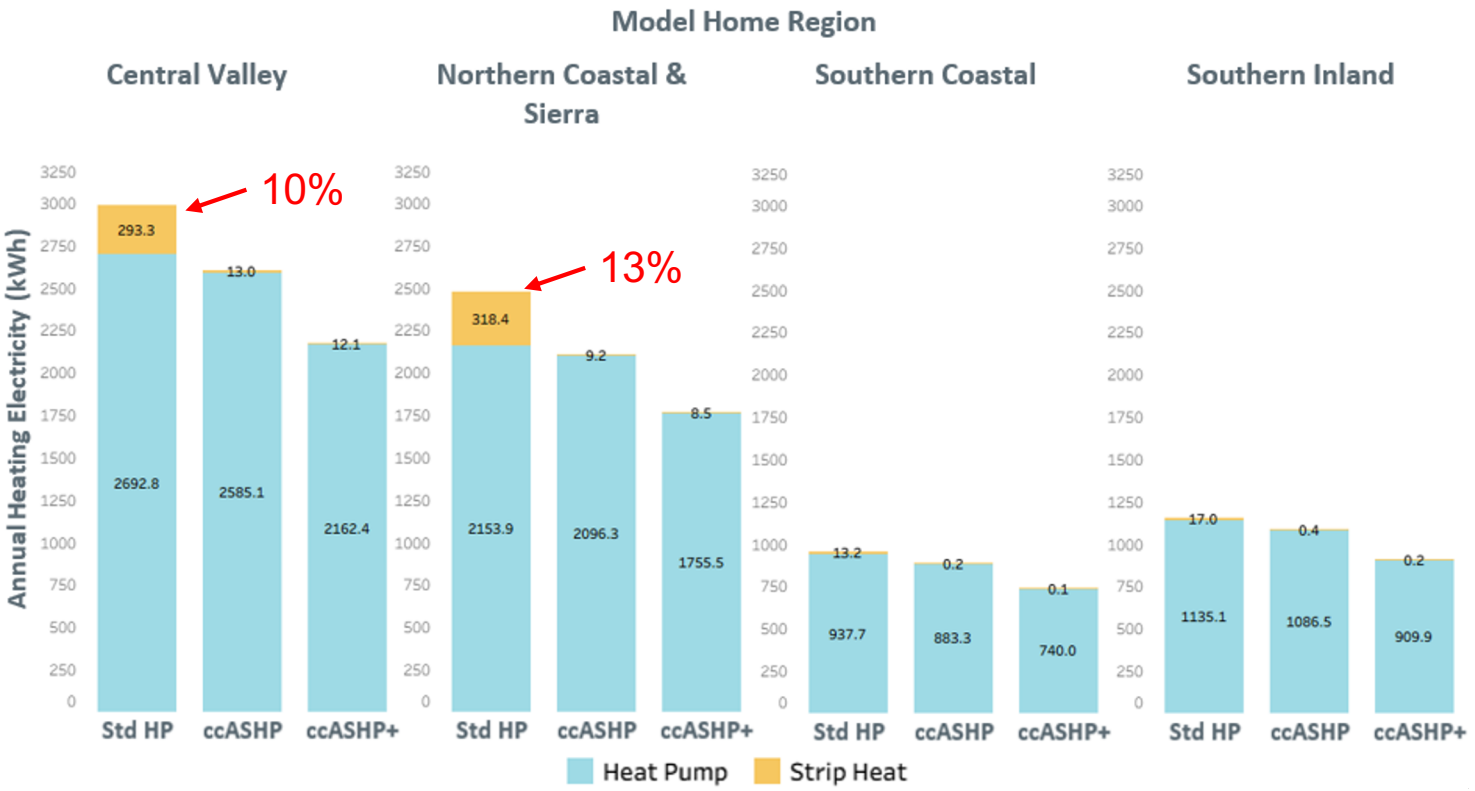
Statewide coincident peak. At a high heat pump adoption rate, the single-family annual peak shifts from summer evenings to winter mornings in most climate zones, while hotter inland and southern coastal zones continue to peak on summer evenings. Supplemental strip heating demand at the coincident winter peak could grow from under 1 GW today to up to 5 GW in 2045,[1] and heat pump demand could grow from about 6 GW to up to 14 GW. Total winter peak demand could increase by as much as 13 GW on the margin.

Supplemental strip heating represents a significant impact to the future electric grid. Choices around equipment, envelope retrofits, and control strategies require proactive consideration through energy codes, utility programs, and state policy.

1. 2025 CAISO peak was 44.5 GW. SCE's "Countdown to 2045" forecasted a CAISO peak of 70 GW under a 95% heat pump scenario without strip heating.

Mitigation Strategies

Strip Heating Energy By Climate and Vintage



Annual heating energy by HP type and region

Supplemental strip heating accounts for roughly 8% of statewide annual heating electricity under standard heat pump adoption, and 10–13% in the colder Central Valley and Northern Coastal and Sierra regions.

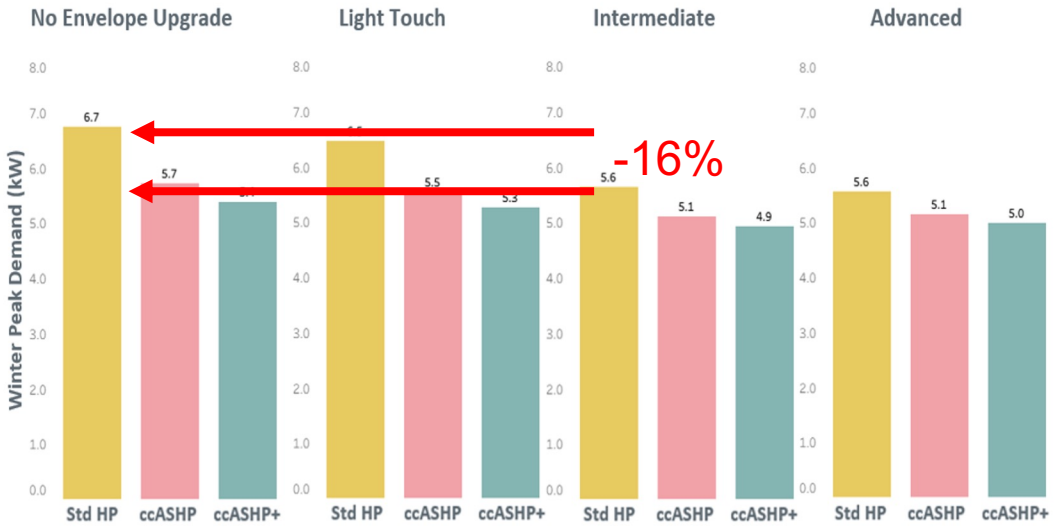
Supplemental strip heating use is also higher in older, less insulated homes.

→Mitigation efforts are most valuable where those conditions overlap.

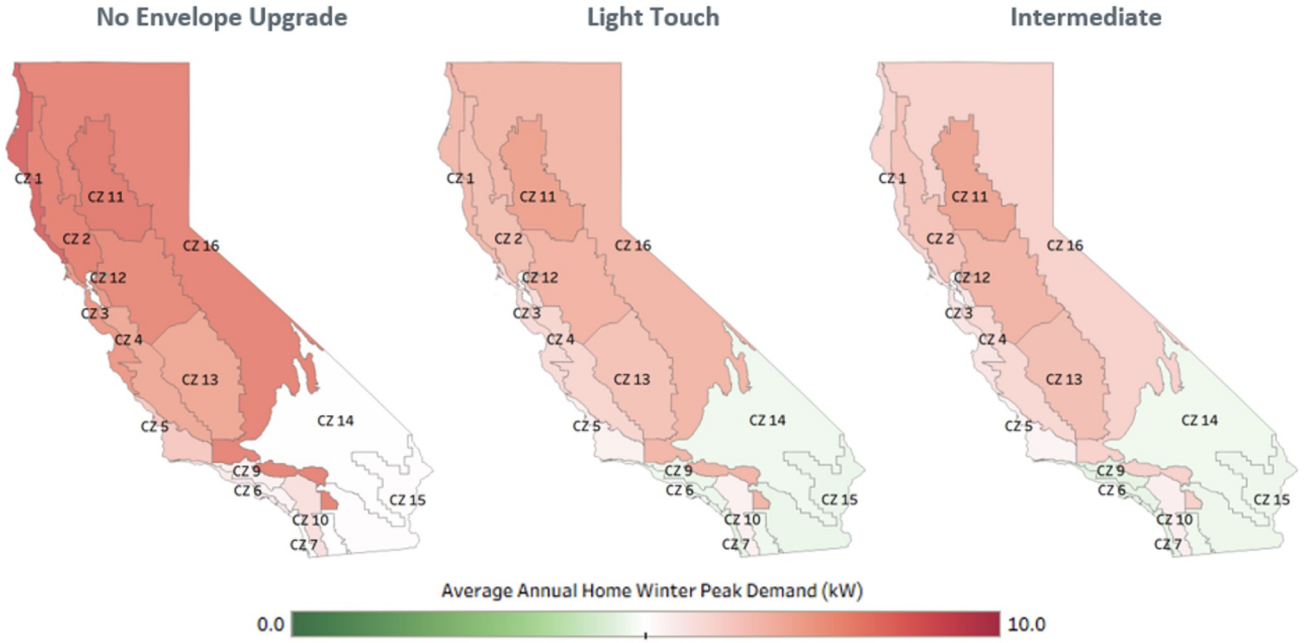
Envelope Retrofits

- "Intermediate Upgrade" retrofits reduce average winter peak demand by about 16% when paired with StdHP, and reduce peak demand in more climate zones than a ccASHP upgrade alone, including mild climates where ccASHPs offer less benefit.
- "Light Touch" envelope upgrades have minimal effect, and more advanced upgrades are prohibitively expensive to adopt at scale.

→ **Intermediate Upgrade retrofits are the most broadly applicable measure**, though cost may limit their use, and cost-effectiveness was not evaluated in this study.



Statewide average winter peak demand by HP type and envelope upgrade

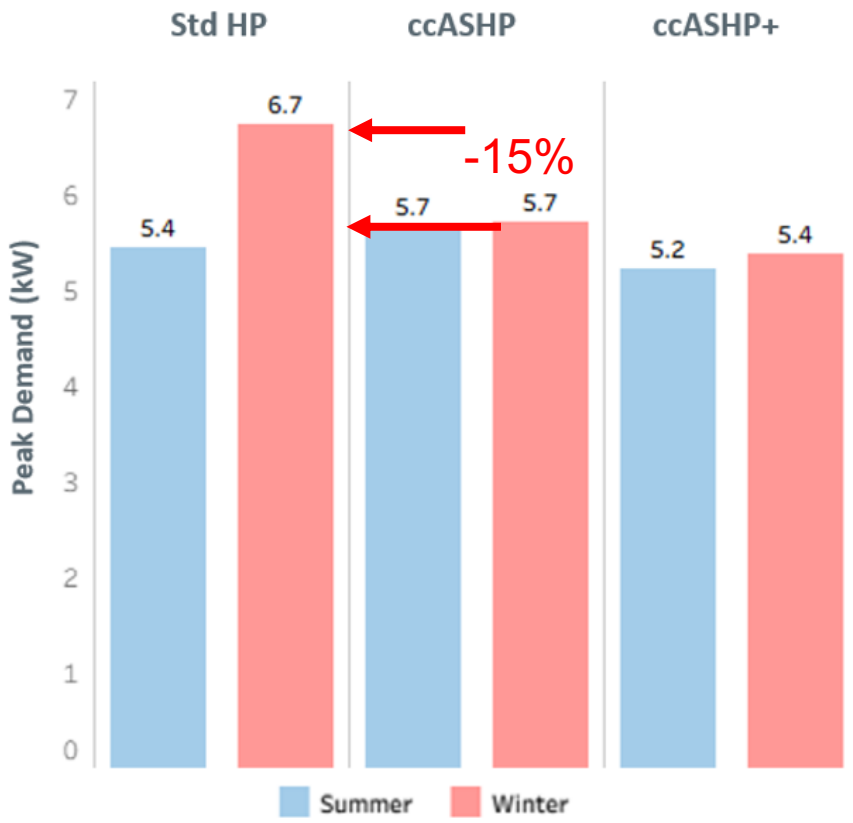


Winter peak demand by climate zone and envelope upgrade level (standard HP)

Heat Pump Type

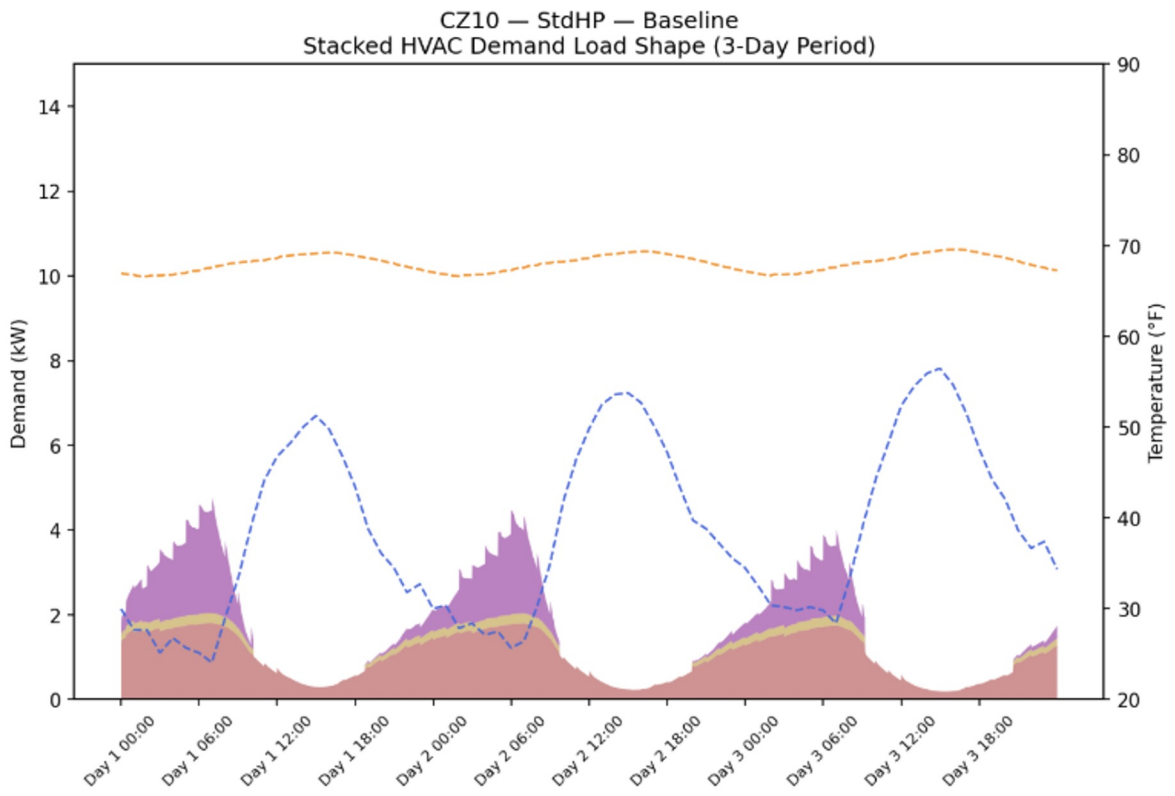
- ccASHPs nearly eliminate strip heating energy and reduce average winter peak demand by about 15% compared to standard heat pumps, with little winter peak benefit in mild southern climates.
- Targeting ccASHPs to the coldest climates reduces coincident winter peak demand by about 8% in those climate zones and 4% statewide, relative to uniform standard heat pump adoption.

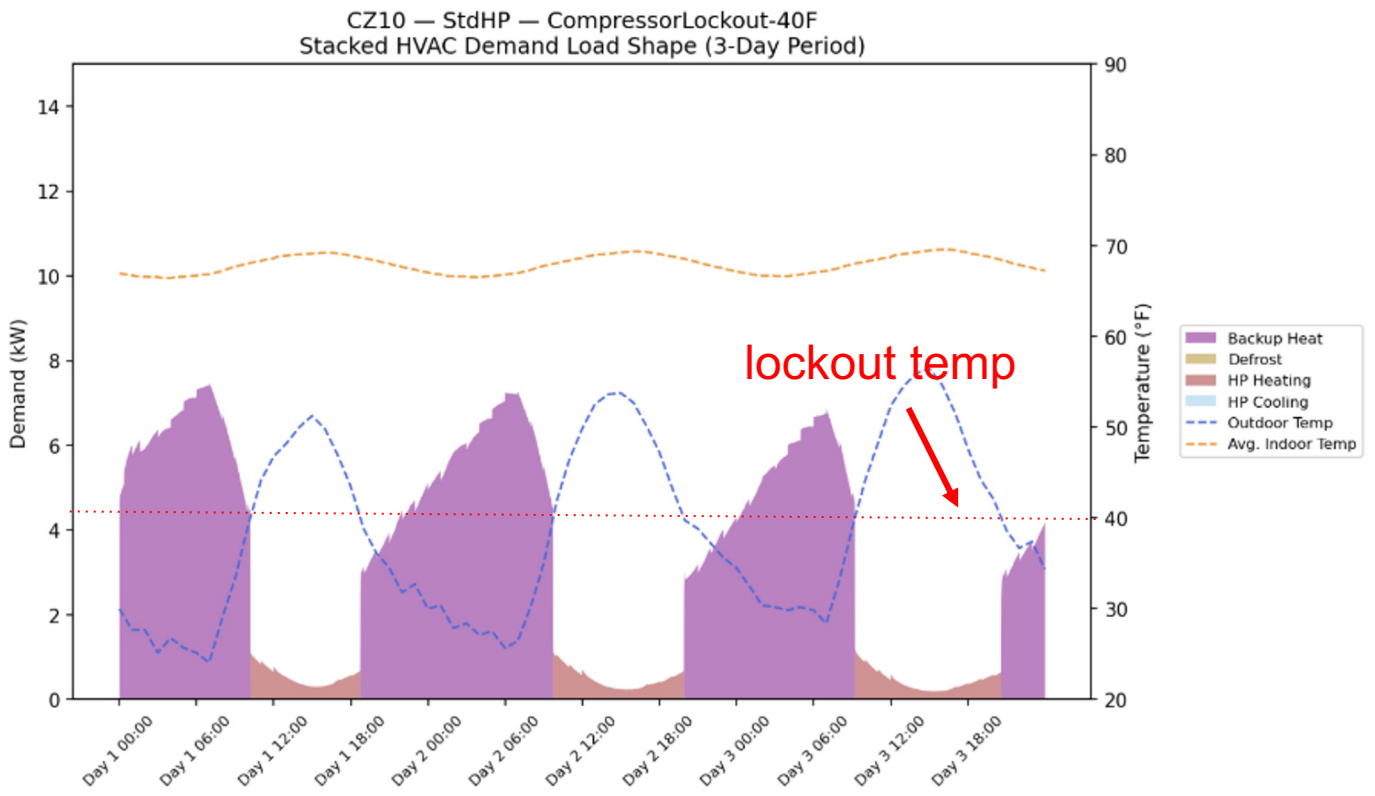
→ Prioritize ccASHP adoption in colder climate zones; uniform statewide adoption may not be necessary for winter peak reduction.



Statewide Average Total Building Peak Demand by HP and Season

Compressor Lockout

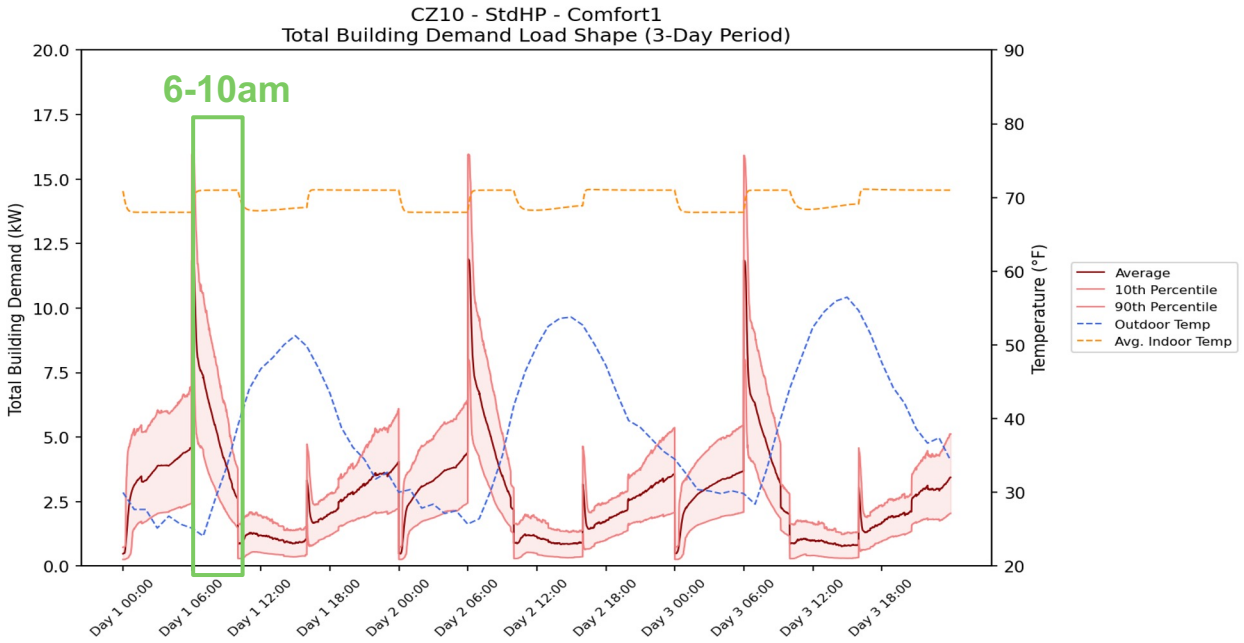




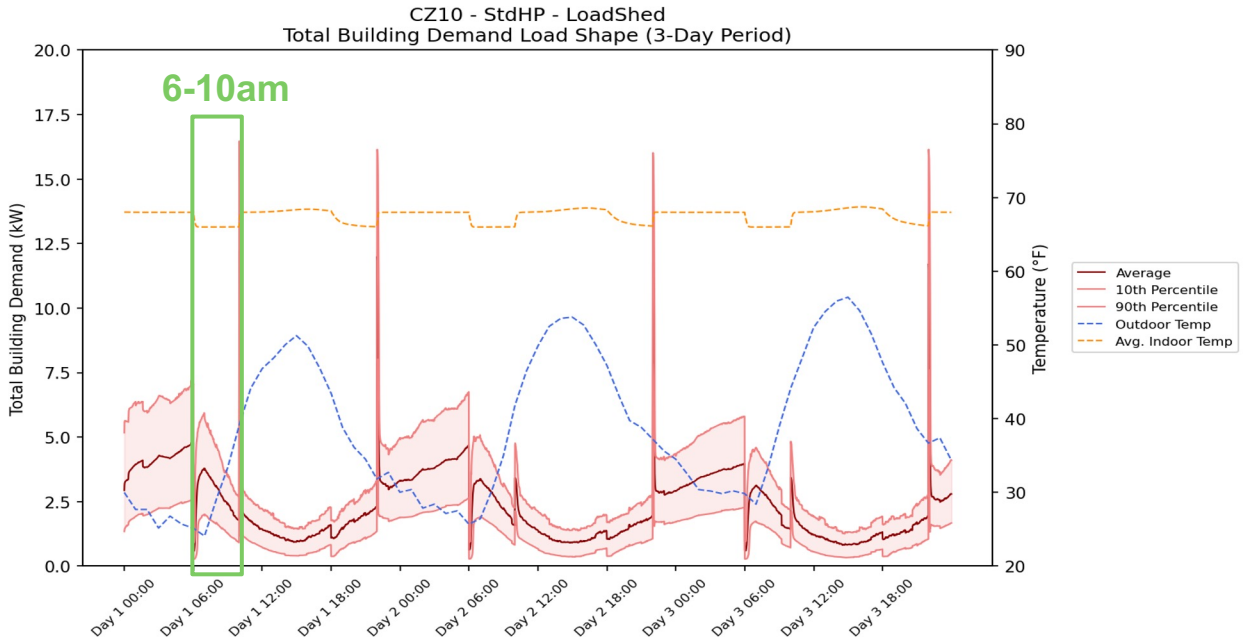
Elevated heat pump lockout temperatures produce large strip heating spikes with no reduction in unmet hours.

→Avoid elevated temperature heat pump lockout settings.

Setpoint Temperature Schedules



CZ10 standard HP — comfort-focused schedule (setpoint raised at 6am)



CZ10 standard HP — load shed schedule (setpoint lowered 6–10am)

The timing of the morning heating setpoint temperature increase affects peak intensity more than the setpoint level itself, and delaying the increase until after the coldest hours reduces both peak duration and magnitude.

→ Setpoint temperature recovery timing is a promising lever for peak reduction.

Research and Data Needs

EMPIRICAL DATA

Better data on real-world strip heating sizing and control practices to inform code and program requirements.

MANUFACTURER SUPPORT

Manufacturer support for staged or variable strip heating capacity and smarter heat pump ramp-up controls to reduce peak demand impacts and improve grid compatibility.

MODELING TOOLS

Modeling tools that can represent smart heat pump controls and on/off strip heating behavior more accurately to better support utility planning and code development.

STRIP CAPACITY AND FULL ELECTRIFICATION

Modeling of smaller supplemental strip heating capacities, accounting for nominal sizes available in practice, and of full electrification including water heating, to establish how much of the projected winter peak strip heating actually drives.

Appendix

Task 1

Key Limitation: Strip heat sized to full design load; modeled as modulating — likely understates real-world peak spikes.

Task 1 ANNUAL ANALYSIS

Compared the impact of different heat pump types, efficiencies, and envelope retrofits on strip heating use and peak demand across California climate zones and home vintages.

Heat Pump Types

Three residential heat pump configurations evaluated:

- **Standard ASHP**
- **ccASHP** (Cold Climate)
- **ccASHP+** (High Efficiency)

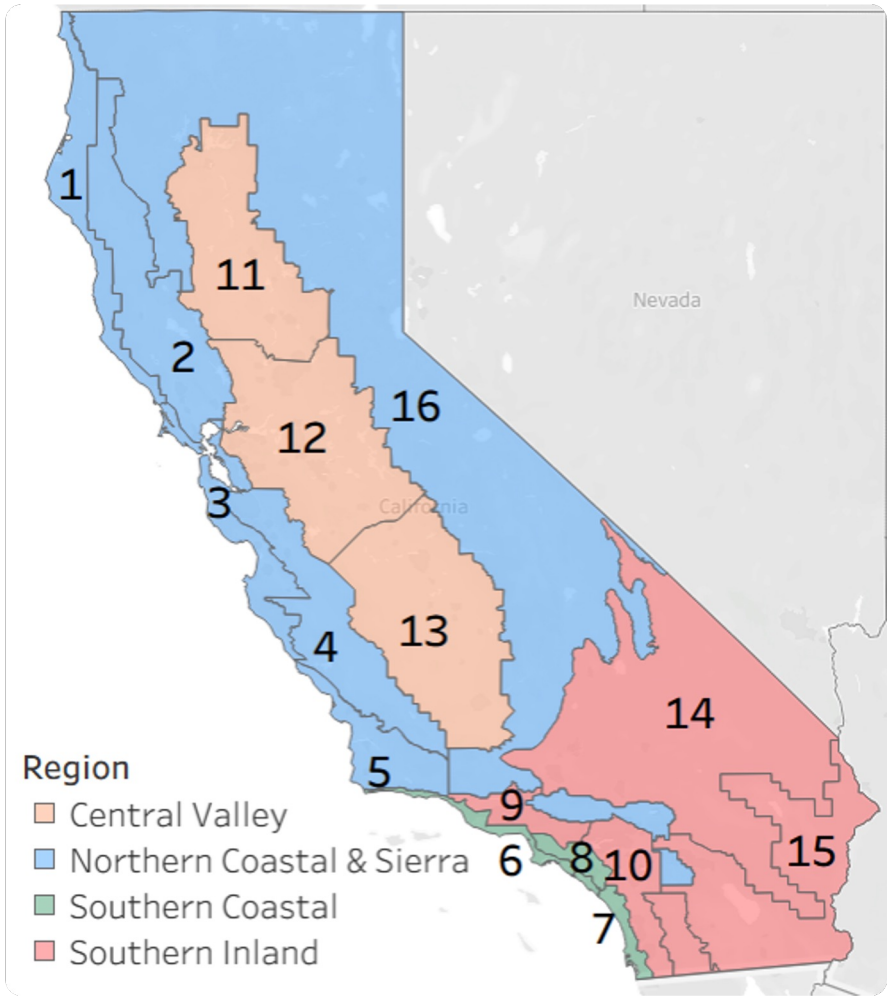
Envelope Upgrades

Three upgrade tiers tested against baseline performance:

Light Touch:
Attic insulation, basic air sealing.

Intermediate:
Duct sealing, drill-and-fill wall, foundation wall and rim joist insulation.

Advanced:
ENERGY STAR windows, continuous wall.



ResStock Heat Pumps

Heat Pump Retrofit Name	Existing Heat Transfer System	Heat Pump Type	Single Stage or Variable Speed	HP Sizing Method[4]	Strip Heat Sizing Method	SEER1	HSPF1	Capacity Retention at 5°F
ENERGY STAR Air-to-Air Heat Pump ("StdHP")	Ducted	Central ASHP	Single	ACCA Manual S/J	ACCA Manual S/J	16	9.2	50%
	Ductless	Minisplit	Variable	Sized to max load (cooling or heating)				
High Efficiency Cold-Climate Air-to-Air Heat Pump ("ccASHP")	Ducted	Central ASHP				20	11	90%
	Ductless	Minisplit						
Ultra-High Efficiency Air-to-Air Heat Pump ("ccASHP+")	Ducted	Central ASHP				24	13	
	Ductless	Minisplit						

From the 2024.1 documentation, "The size of the heat pump is calculated using either ACCA Manuals J and S, or the maximum load between the design cooling and heating load of the dwelling unit (i.e., "Max Load"). ACCA Manual S primarily sizes heat pumps using the cooling load, with allowed oversizing factors. For higher heating loads, a 15% oversizing allowance applies when the heat pump is single-stage (e.g., the ENERGY STAR Ducted ASHP with electric or existing fuel-fired backup). A +1 ton allowance applies if in a cold, dry climate. A 30% oversizing allowance applies to variable speed heat pumps (e.g., the ENERGY STAR cc Ducted ASHP with existing fuel-fired backup modeled for this dataset)."

ResStock Envelope Upgrades

Table 2. Envelope Retrofit Types

Envelope Upgrade	Ducts/Ventilation	Insulation	Windows	Air Leakage
Light Touch	—	Attic floor insulation	—	Basic air sealing
Intermediate Upgrade	Duct sealing	Attic floor insulation, drill-and-fill wall insulation, foundation wall and rim joist insulation	—	Basic air sealing
Advanced Upgrade	Duct sealing, improved ventilation	Attic floor insulation, drill-and-fill wall insulation, foundation wall and rim joist insulation, exterior continuous wall insulation	ENERGY STAR windows	IECC 2021-level air sealing

Task 2

Key Limitation: EnergyPlus activates strip heating more aggressively than most real thermostats. Results are bounding cases, not precise predictions.

Task 2 THRESHOLD ANALYSIS

Compared the impact of heat pump and strip heating control strategies on demand profiles during extreme cold periods across CA climates.

- Evaluated standard HP and ccASHP performance during the coldest 3-day period.

Vintages & Regions

Newer (post-1980): CZ10 (Inland Empire), CZ12 (San Joaquin Valley), CZ14 (Mojave Desert)

Older (pre-1980): CZ3 (Bay Area), CZ16 (Sierra Nevada)

Key Modeling Control Variables

01
Setpoint Schedules
Comfort-based, gradual start, and winter morning load shift schedules.

02
Compressor Lockout
Minimum lockout temp. Default is 0°F; evaluated 20°F and 40°F.

03
Strip Lockout
Maximum lockout temp. Default is 40°F; evaluated 30°F and 50°F.

04
Defrost Control
Resistive vs. reverse cycle, and timed vs. on-demand defrost combinations.

Task 3

Key Limitation: Typical meteorological year (TMY) weather — typical conditions, not extreme events; no battery storage modeled.

Task 3 COINCIDENT PEAK ANALYSIS

Assessed how single-family homes operate both individually and as an entire class of buildings, and how heat pump adoption may shift the timing of peak demand and coincidence factors across climates

Four scenarios:

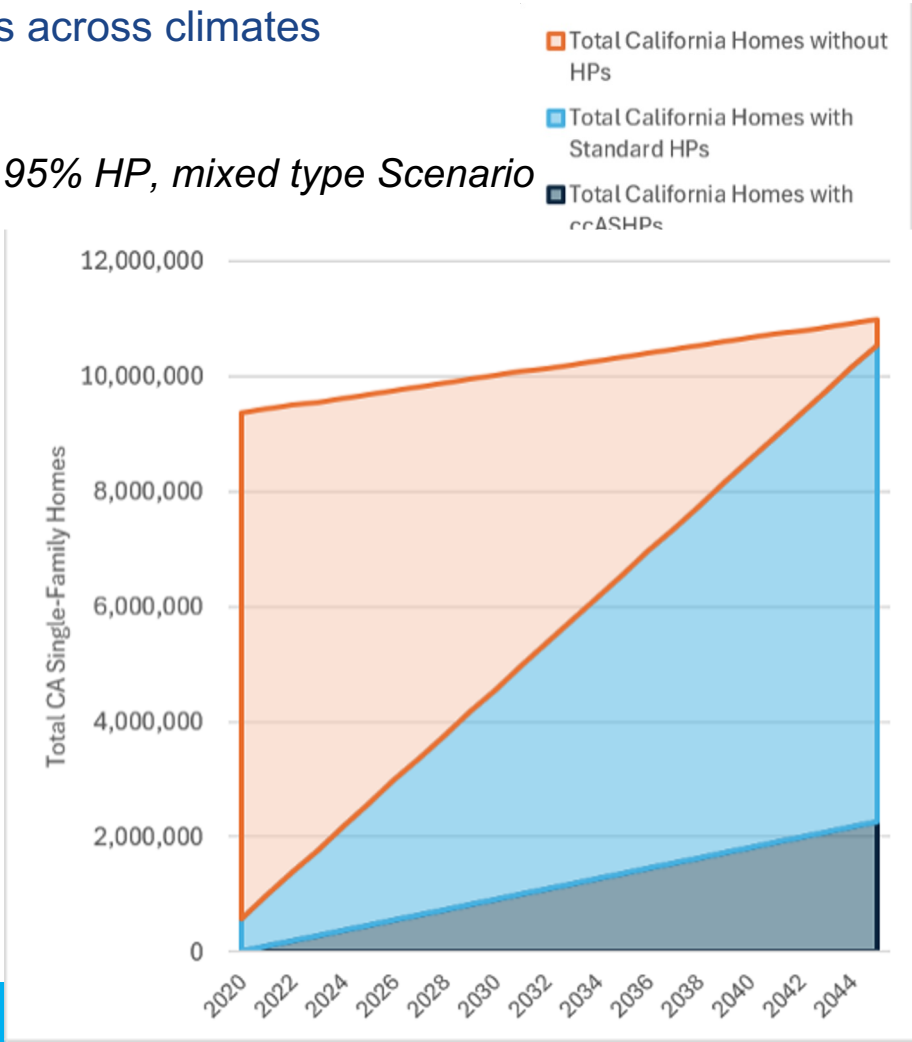
Baseline: current California single-family building stock (~6% with heat pumps)

95% Adoption of standard HPs: all homes receive standard HPs regardless of climate or vintage (worst-case bounding scenario)

95% Adoption of mixed types HPs: same adoption level; ccASHPs in coldest climates and older homes in cold climates

CARB 2045: ~60% HP adoption based on California Air Resources Board emissive equipment sales limits

95% HP, mixed type Scenario



Background – CSE/CBECC Preliminary Model Result

Table 3. Comparison of CSE results modeling a VCHP using the standard and detailed models.

Title 24 Climate Zone (CZ) 12	**Standard Model**	**Detailed Model**	**Detail vs Std % Difference**
Primary Heating, Site Energy (kWh)	830.4	843.9	1.63%
Auxiliary Strip Heating, Site Energy (kWh)	166.9	1.5	-99.10%
Total Heating Energy (kWh)	**997.3**	**845.4**	**-15.23%**
Cooling, Site Energy (kWh)	237.4	226.6	-4.55%
Annual Heating and Cooling Energy (kWh)	**1234.7**	**1072**	**-13.18%**

Table 4. Comparison of CSE results modeling a VCHP using the standard and detailed models.

Title 24 Climate Zone (CZ) 16	**Standard Model**	**Detailed Model**	**Detail vs Std % Difference**
Primary Heating, Site Energy (kWh)	2673	2754.2	3.04%
Auxiliary Strip Heating, Site Energy (kWh)	653.9	14.4	-97.80%
Total Heating Energy (kWh)	**3,326.9**	**2,768.6**	**-16.78%**
Cooling, Site Energy (kWh)	5.7	1.9	-66.67%
Annual Heating and Cooling Energy (kWh)	**3,332.6**	**2,770.5**	**-16.87%**



Discussion Topics

Agenda

- Introduction, Randall Higa (3 min)
- Study Background, Carrie Brown (12 min)
- Discussion
  - Heat pump performance (10 min)
  - Heat pump modeling (10 min)
  - Next Steps (10 min)

Heat Pump Performance

How are heat pumps supposed to perform?

- Real-world sizing and control practices
- Performance curves
- Related efforts
  - ASHRAE Standard 205, Representation of Performance Data for HVAC&R and Other Facility Equipment
  - NEEP Guides and Product List
  - Title 24 JA2 Climatic Data Update

Technology improvements

- Staged or variable strip heating capacity
- Smarter heat pump ramp-up controls, to directly reduce peak demand impacts and improve grid compatibility as adoption scales

Heat Pump and Strip Heat Modeling

What are the current limitations for energy modeling tools?

- Continuously modulating (rather than cycling on/off)
  - Understates demand spikes, overstates runtime duration
- Timestep resolution
  - Half capacity over a full interval is indistinguishable from full capacity over half of it
- Setpoint recovery and compressor ramp
- Defrost behavior

Next Steps

Research and data needs

- Do we have enough information to determine next steps and action items?
- Improvements energy simulation in general, including compliance modeling in CBECC and other applications like design, panel sizing, grid planning, etc.

Thank you!

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