Take a Load Off Showering

How Much Might Heat Pump Water Heaters Help?

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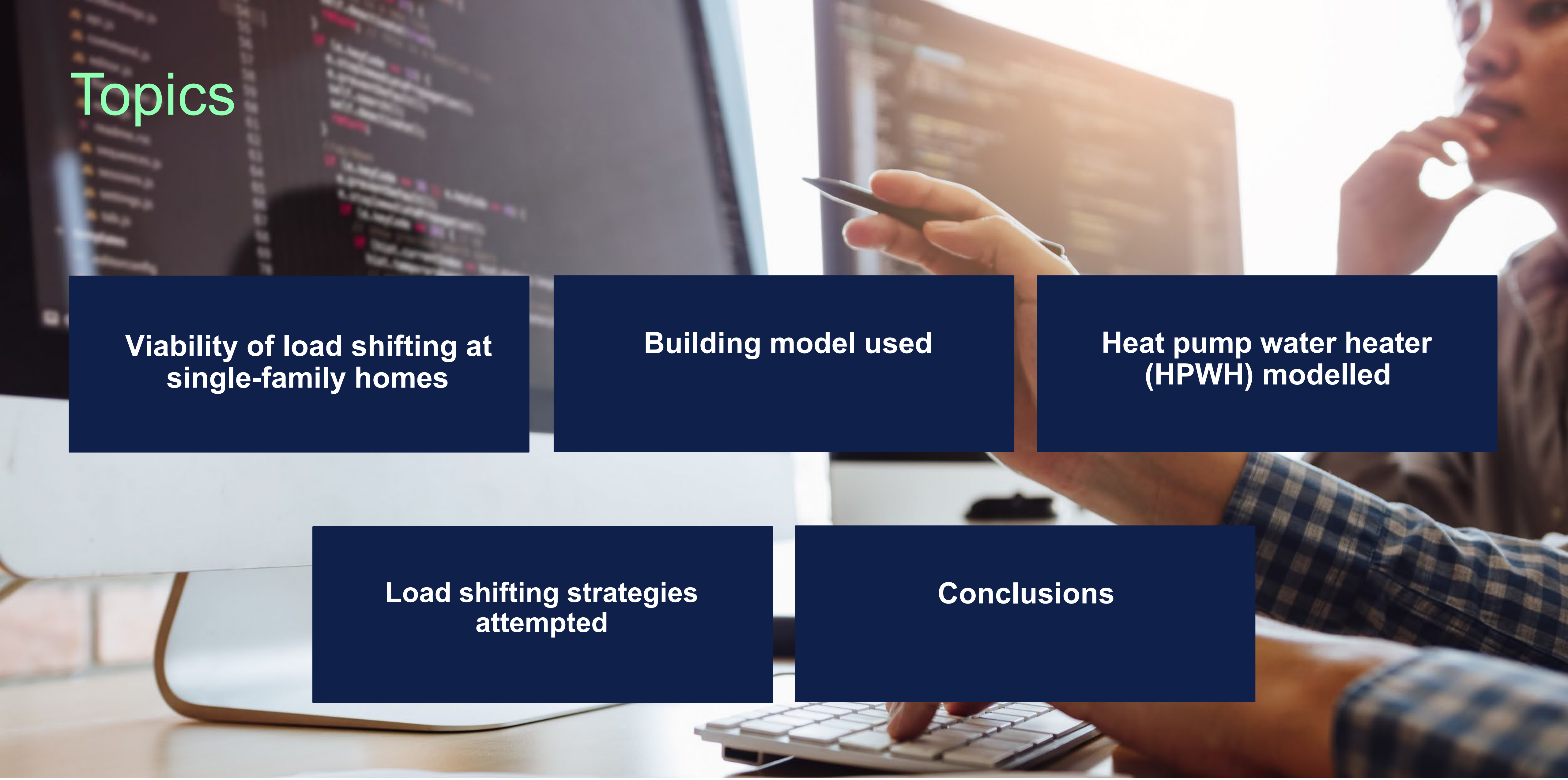
04 November 2022



Topics

Viability of load shifting at single-family homes

Building model used

Heat pump water heater (HPWH) modelled

Load shifting strategies attempted

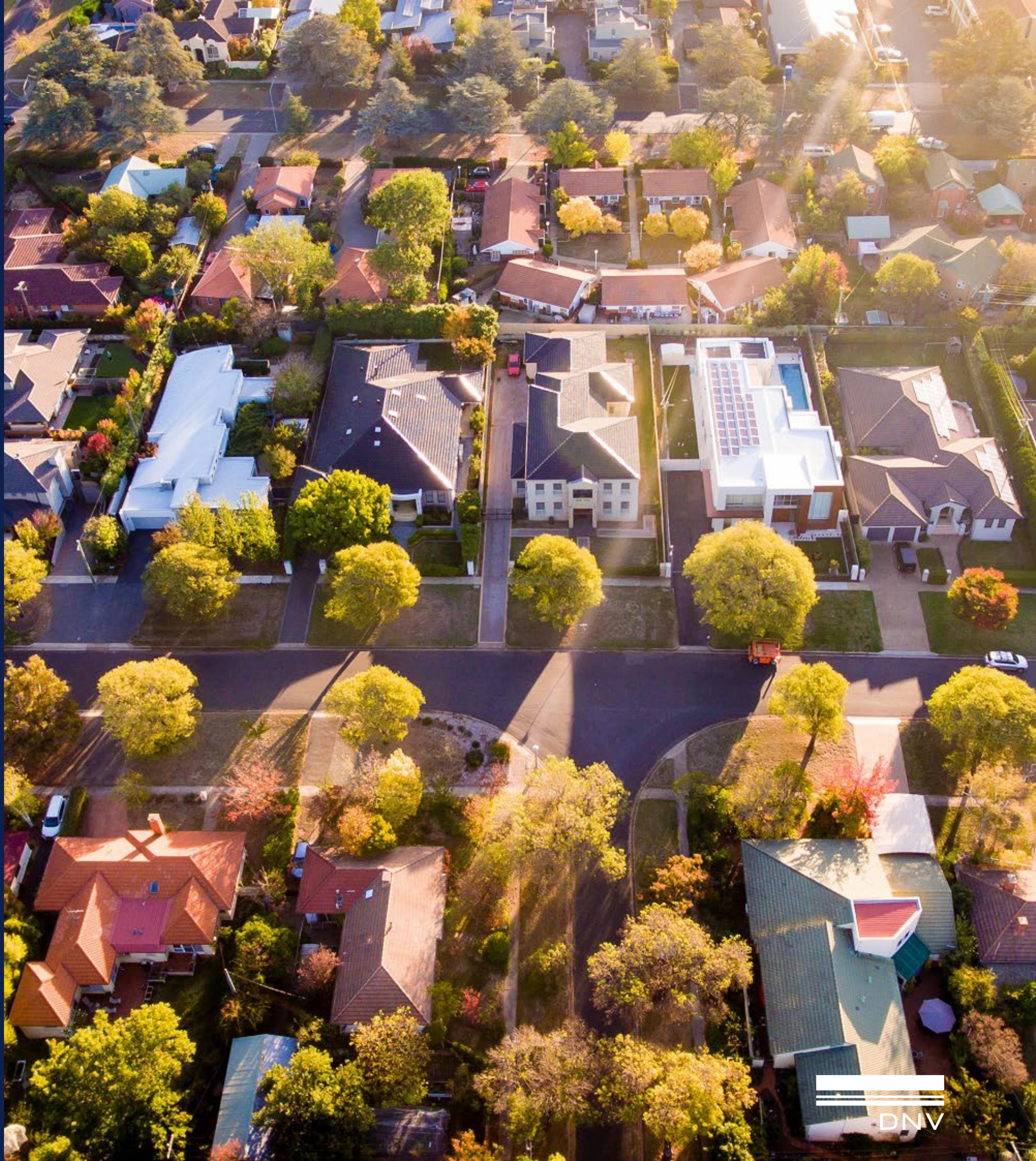
Conclusions

Heat pump water heater (HPWH) load shifting

Benefits to resource-constrained regions include:

- reducing peak energy demand
- improving grid reliability
- shifting the energy usage to periods when power generation produces fewer GHG emissions

WiFi-enabled HPWH technology* has made it possible to remotely shift DHW loads from periods of high electric energy demand to those with lower demand.



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Who, when, where and how?

Who?

Single family homes

When?

- On hot afternoons, when high hot water and HVAC cooling loads coincide, between the hours of 4 and 9 PM
- On cold morning, when high hot water and HVAC heating loads coincide, between the hours of 5 and 8 AM

Where?

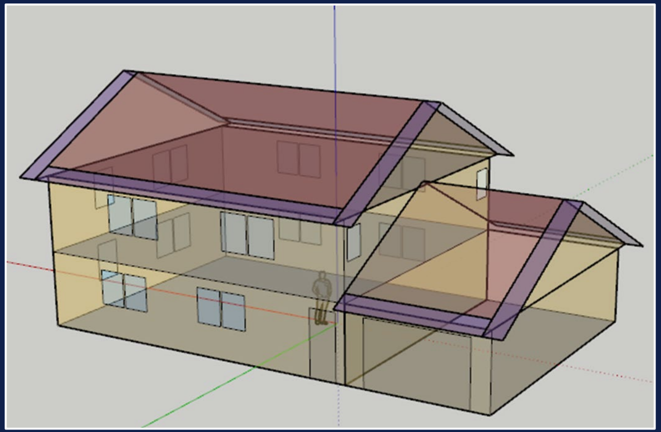
Sacramento, CEC Climate Zone 12

How?

EnergyPlus™ models

California Building Energy Code Compliance Software CBECC-Res 2022.0.5 (Research Version)

- 2,100 sq. ft.
- 3 bedrooms
- 2 bathrooms
- 2.64 occupants



SketchUp™ software was used to produce image.

Using the following prototype: 2022_CZ12_2100ft2_std_HP – Std.rbd22i

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DNV

Migration from CBECC-Res to EnergyPlus

CBECC-Res

v. 2022.0.5 RV

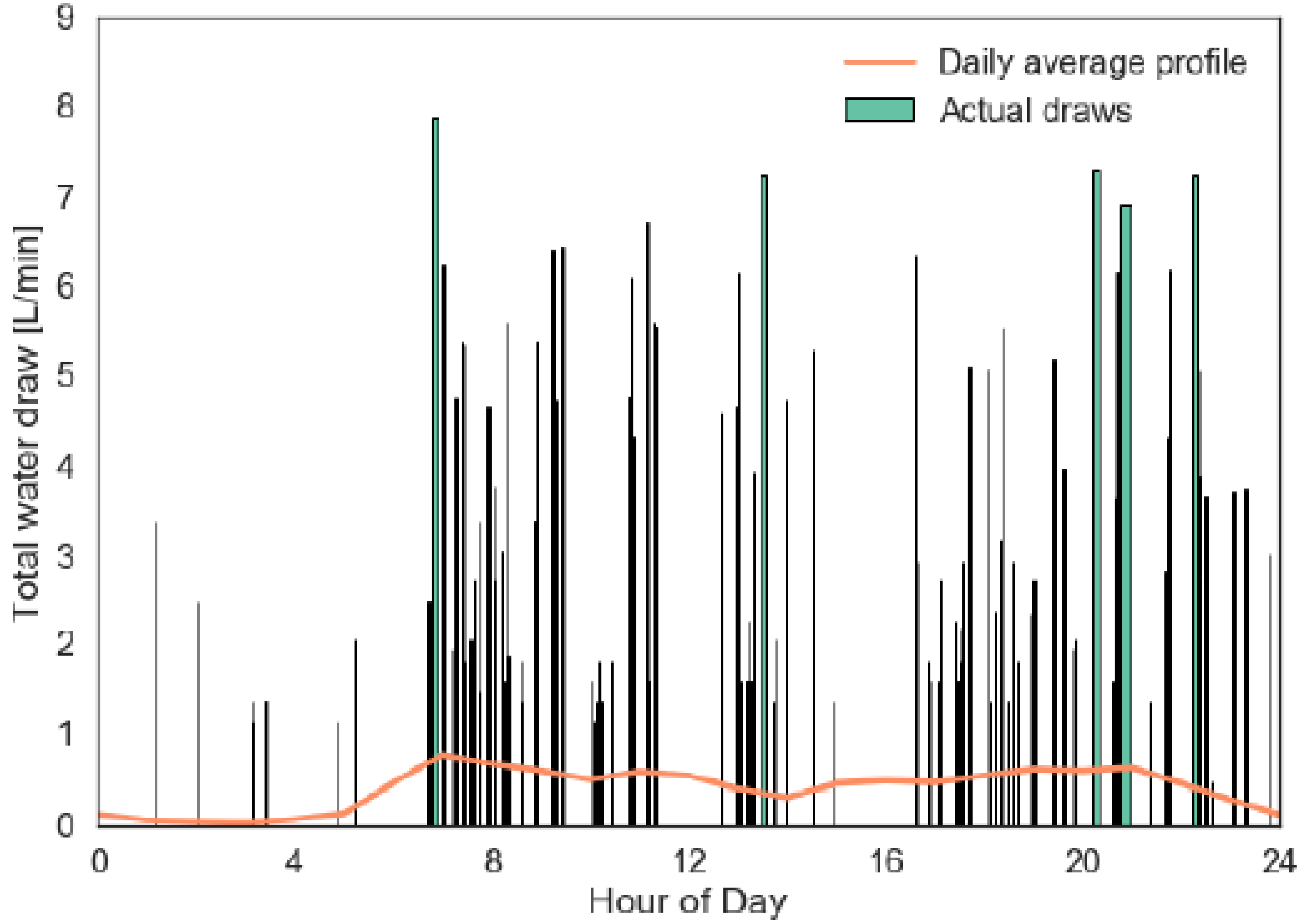
BEopt
Building Energy Optimization
with Hour-by-Hour Simulations
NREL
National Renewable Energy Laboratory
15013 Denver West Parkway
Golden, CO 80401
www.nrel.gov

v. 2.8.0

EnergyPlus

v. 9.5.0

Hot water draws in 1-minute intervals

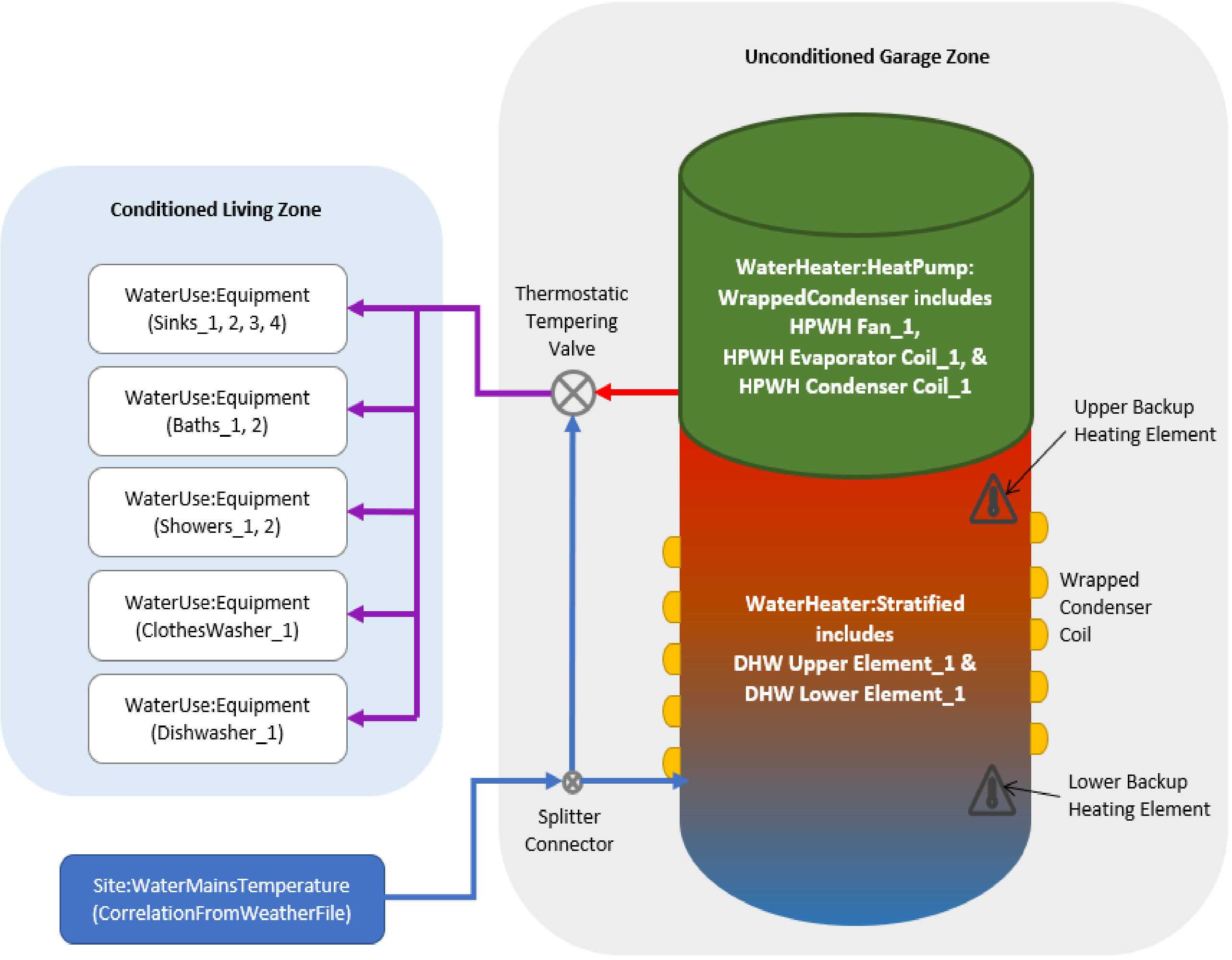


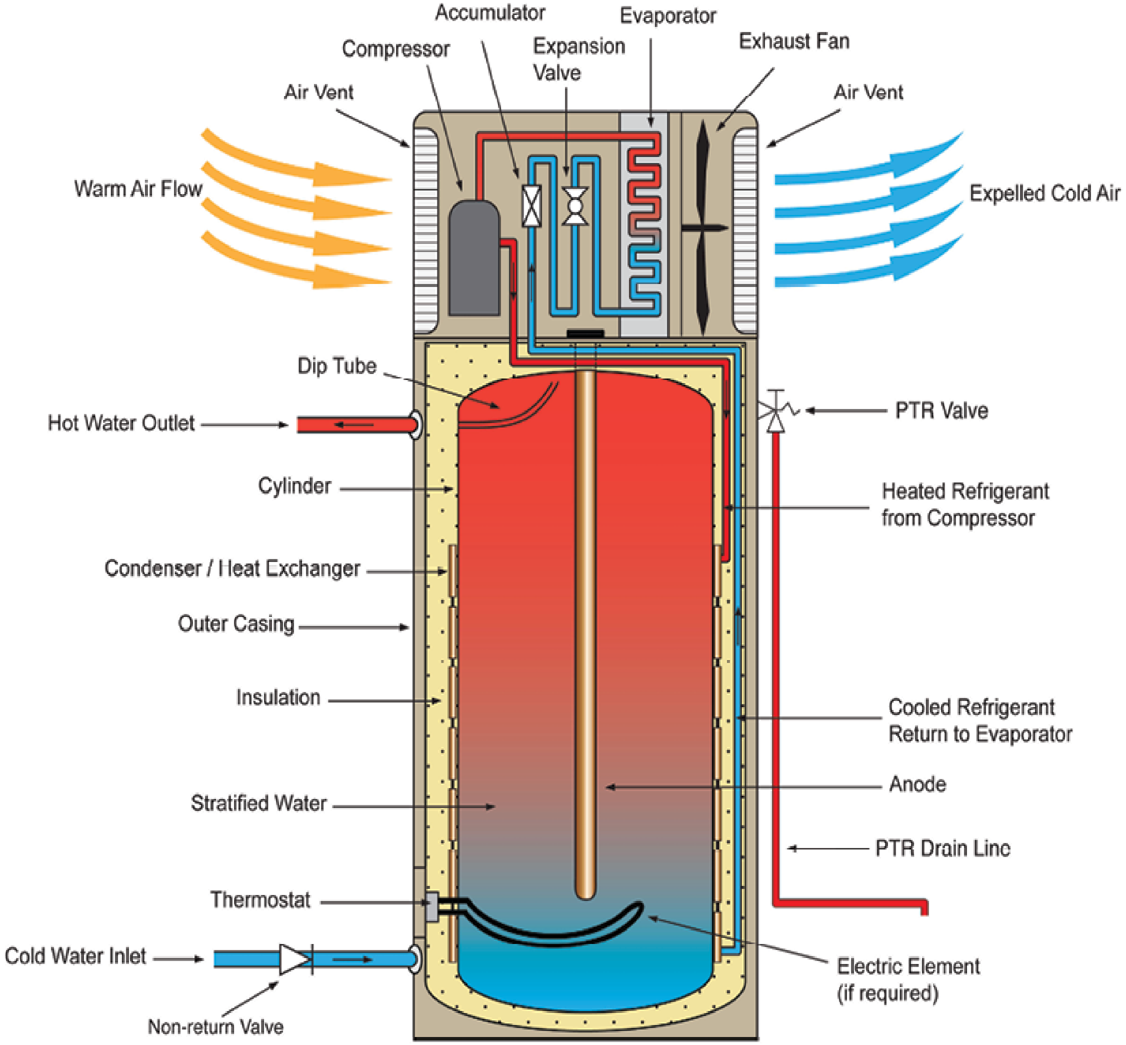
Kruis, N., B. Wilcox, J. Lutz, and C. Barnaby. 2019. *Development of Realistic Water Draw Profiles for California Residential Water Heating Energy Estimation—Revised (March 2019).*

Provided with CBECC-Res in a .csv file

Modified by replacing vacation days with days containing ~average gallons of daily DHW

Plant loop diagram



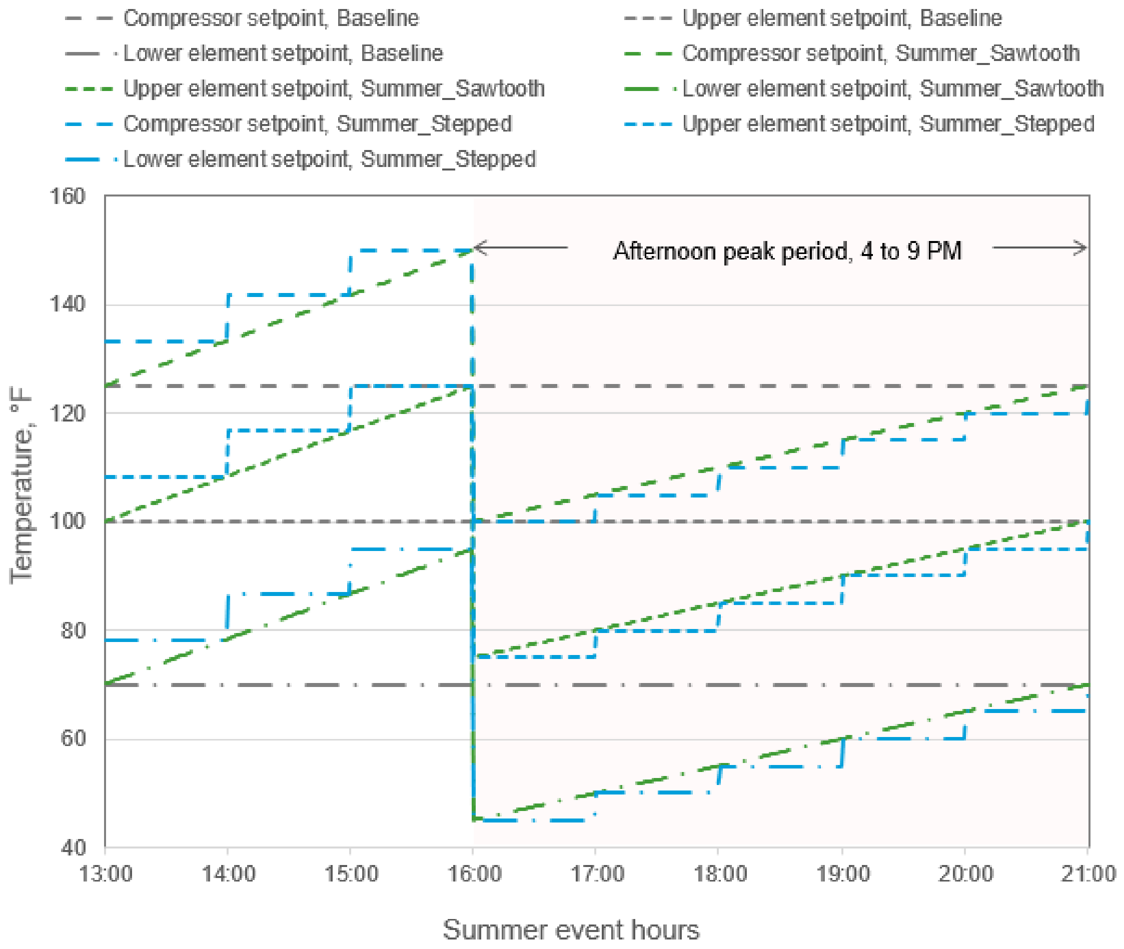


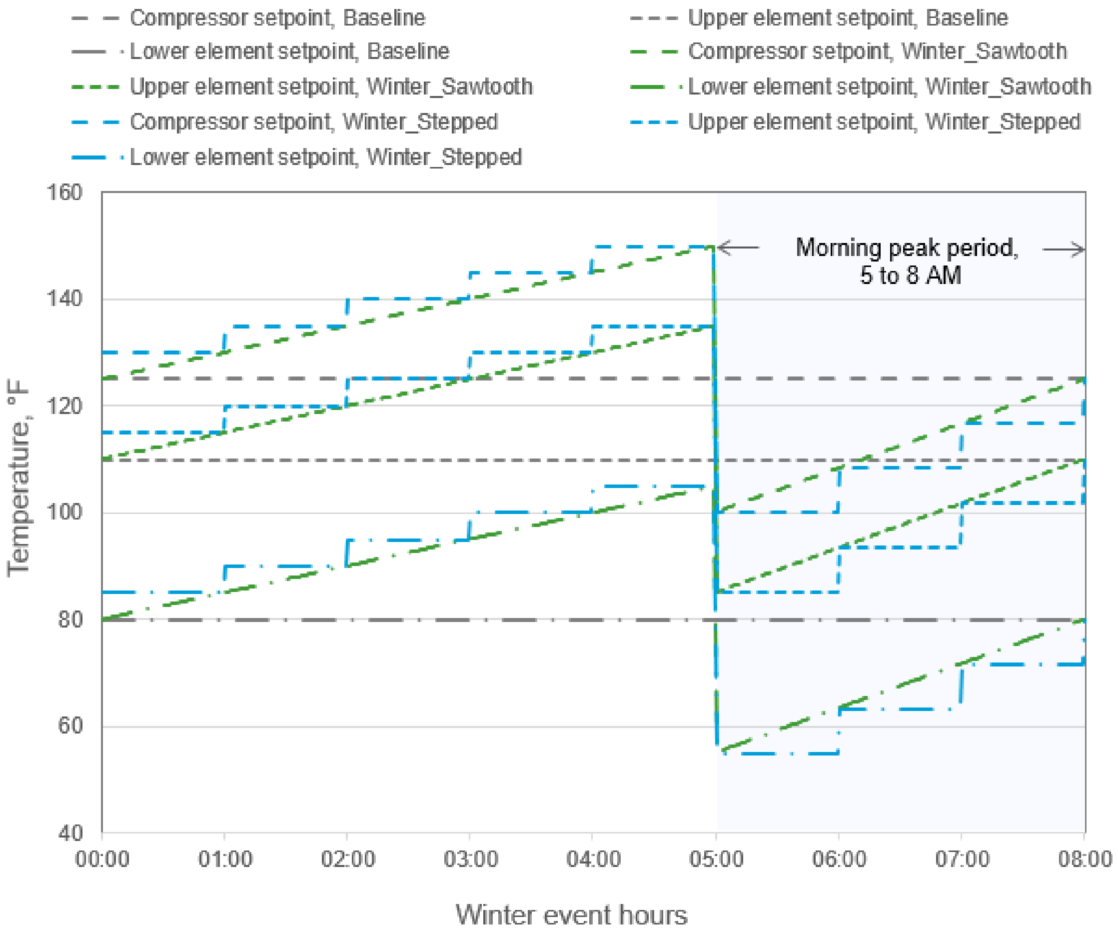
HPWH characteristic	50-gallon HPWH	66-gallon HPWH
Manufacturer	A. O. Smith	A. O. Smith
Model	HPTU-50CTA	HPTU-66CTA
Nominal storage capacity, gallons	50	67
Rated storage capacity, gallons	46	59
Draw pattern/usage	Medium	High
Uniform Energy Factor (UEF)	3.45 (NEEA Tier 3)	3.45 (NEEA Tier 3)
Estimated COP	2.9	3.1
CTA-2045-A compliant port	Yes	Yes
Input energy (each element), kW	4.5	4.5
Tank insulation UA-value, Btu/hr-°F	4.2	4.2
Recovery efficiency	407%	265%
First-hour rating of HP, gallons/hr	44.4	62.5
First-hour rating of ER, gallons/hr	57.3	78.6
First-hour rating of hybrid, gallons/hr	70	80
Tank height, inches	40.5	38.0
Tank diameter, inches	15.0	23.0
Maximum temperature, °F	150	150

Source: AHRI. (HP=heat pump component; ER=electric resistance elements)

Source: seekping.com, https://www.seekpng.com/ipng/u2w7y3w7a9e6o0y3_a-diagram-oh-an-integrated-heat-pump-water/

Summer & winter setpoint strategies





Scenarios for 50-/66-gallon HPWH demand events

Scenario characteristics	Baseline	Summer DR events		Winter DR events	
Garage temp. DR threshold, ºF	-	≥ 103		≤ 51	
Peak demand period start time	-	4 PM		5 AM	
Setpoint elevation start time	-	1 PM		12 AM	
Setpoint adjustment end time	-	9 PM		8 AM	
Standard HPWH setpoint, ºF	125	125			
Adjusted HPWH setpoint, ºF	-	150			
Setpoint ramp-up shape	-	Sawtooth	Stepped	Sawtooth	Stepped
Number of DR days	-	27		31	

Results

Scenario characteristics and simulation results	Baseline		Summer demand events				Winter demand events			
	50 gal.	66 gal.	50 gal.		66 gal.		50 gal.		66 gal.	
Setpoint ramp-up shape	-	-	Sawtooth	Stepped	Sawtooth	Stepped	Sawtooth	Stepped	Sawtooth	Stepped
Number of days involving demand response events	-	-	27				31			
Annual energy use by HPWH, kWh[1]	1,418	1,281	1,425	1,421	1,286	1,284	1,426	1,422	1,285	1,285
Percent difference from corresponding "Baseline" scenario	-	-	0.5%	0.6%	0.5%	0.5%	0.2%	0.3%	0.3%	0.3%
Peak demand event load shifted, kW	-	-	0.08	0.08	0.15	0.14	0.07	0.08	0.18	0.17
Proportion of time that electric-resistance heating is in use, annually	2.5%	1.6%	2.5%	1.6%	2.4%	1.5%	2.5%	1.6%	2.4%	1.5%

[1] All vacation days replaced with typical DHW days

Comparison to recent SMUD study[1]

Table 5-19. Heat pump water heaters

Water Heater Capacity	Count
50 Gallons	30
65 Gallons	3
80 Gallons	1
Total	34

Figure 5-10. Heat pump water heater efficiency

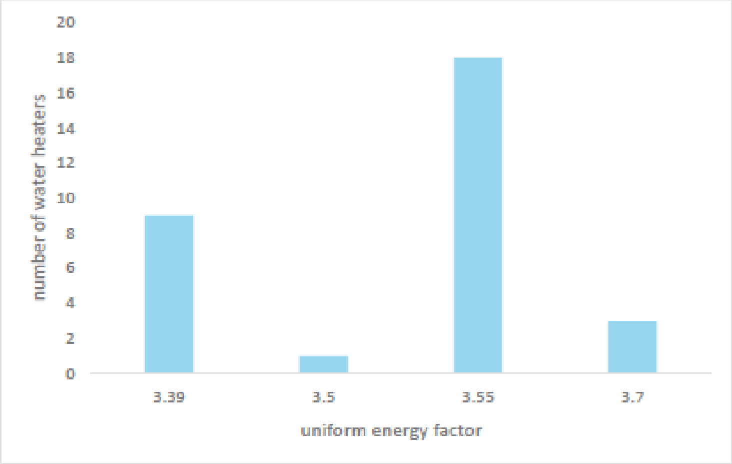


Table 5-4. Estimated savings and realization rates from single-family electrification projects

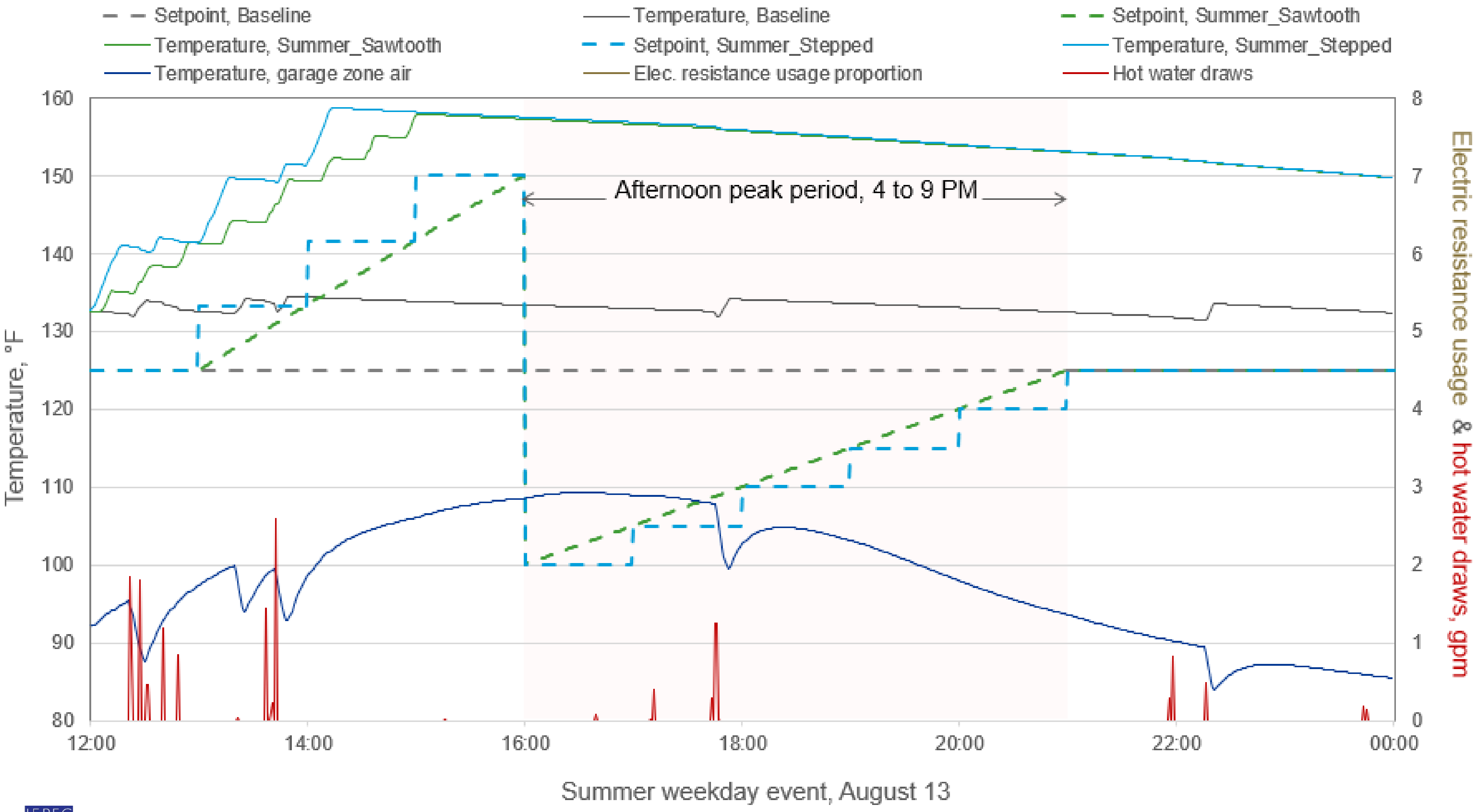
Measure	Estimated Increase in Load per unit (kWh)	Estimate Gas Savings per Unit (therms)	Estimate Gas Savings in kWh	Estimated Savings in Load per Unit (kWh)	Deemed Savings per Unit (kWh)	Realization Rate
HPSH, gas baseline	-1,169	219	6,413	5,244	7,525	70%
HPWH, gas baseline	-1,156	139	4,077	2,921	3,672	80%

Therms to kWh conversion factor = 29.3001

[1] McWilliams, J., Sadhasivan, G., *Residential Space and Water Heating Electrification Measurement, Verification, and Market Characterization Study Report,* for Sacramento Municipal Utility District, April 29, 2021, pp. 69, 78.

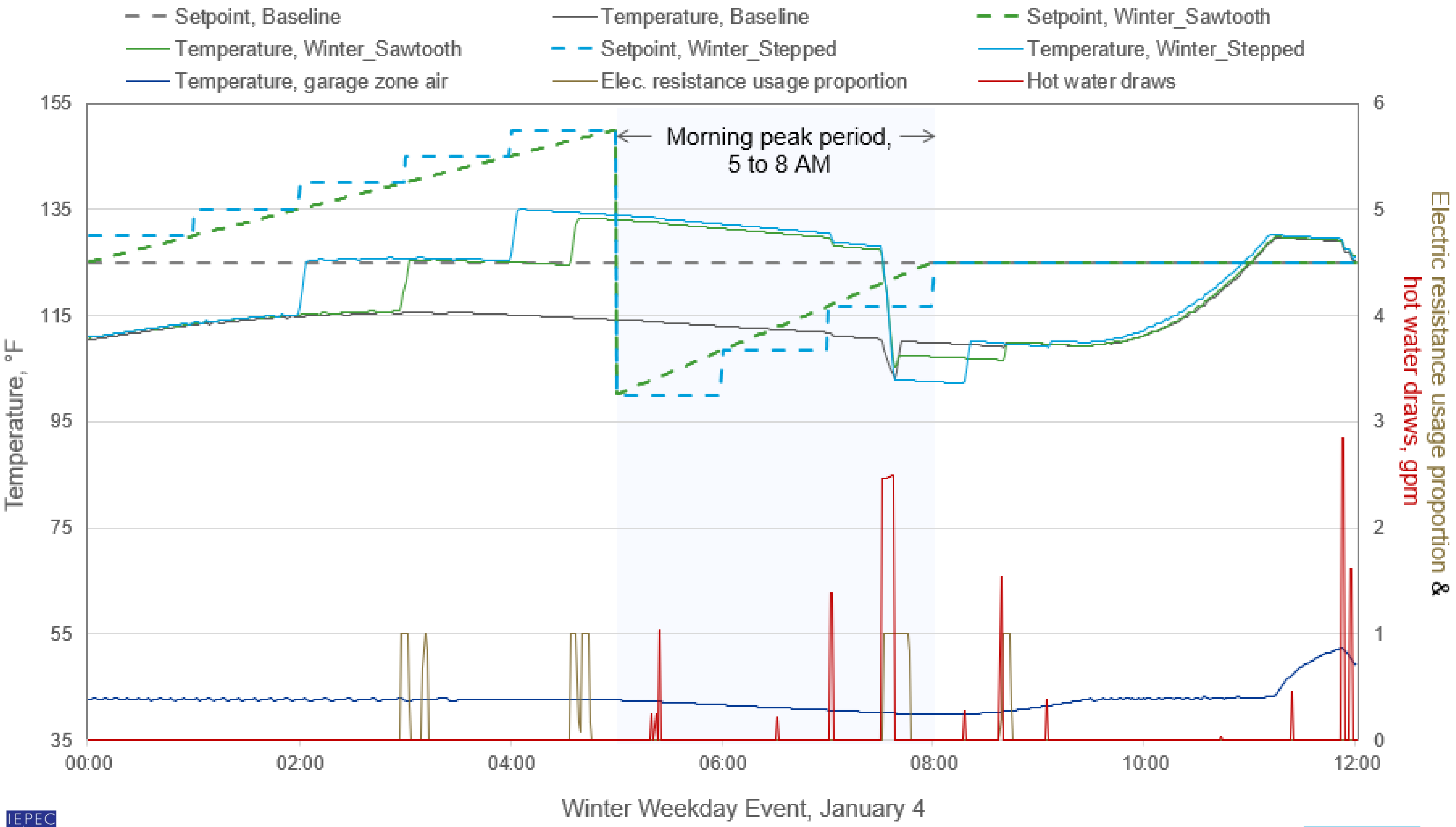
Summer event: before, during, and after

50-gallon HPWH



Winter event: before, during, and after

50-gallon HPWH



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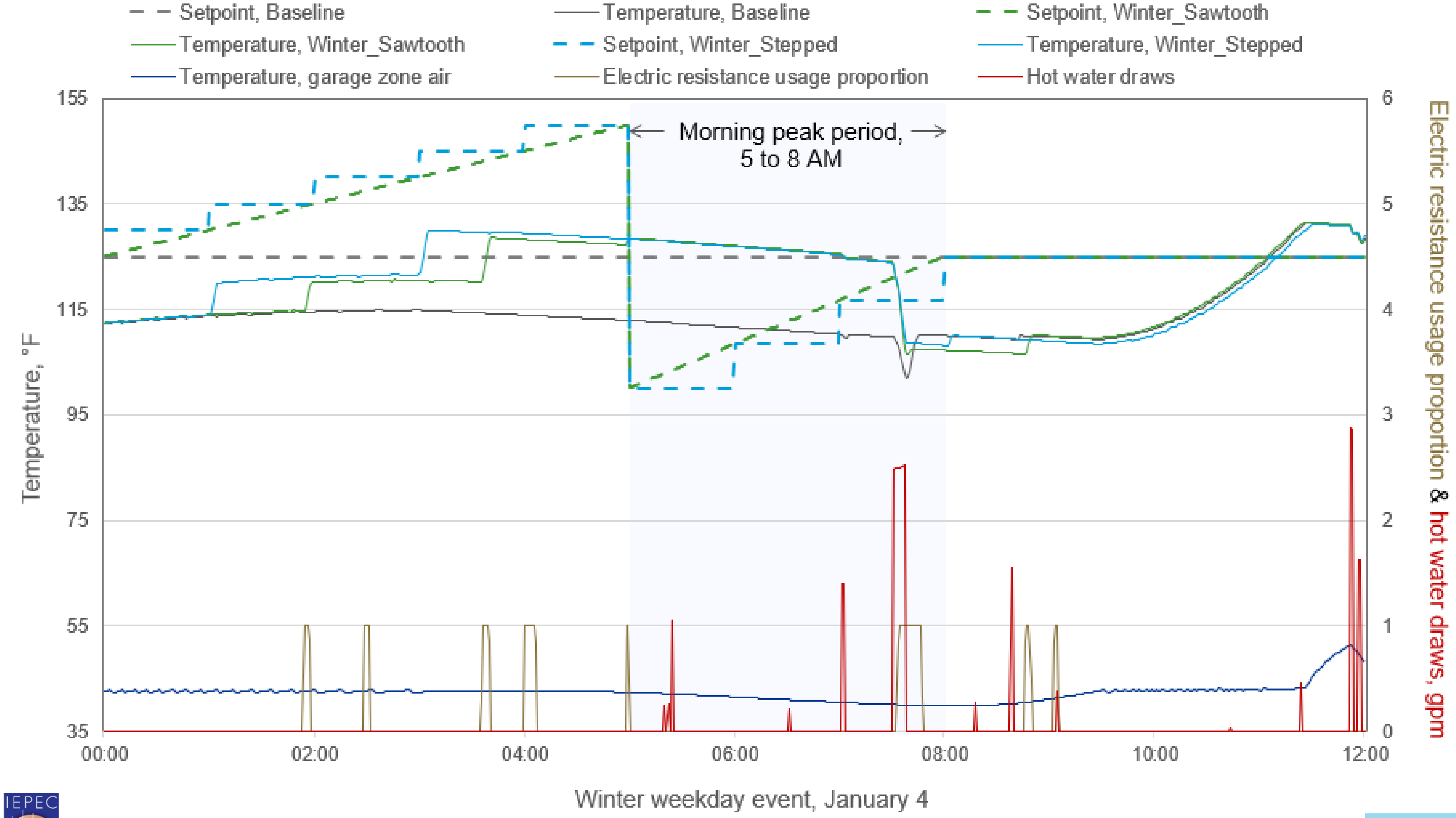
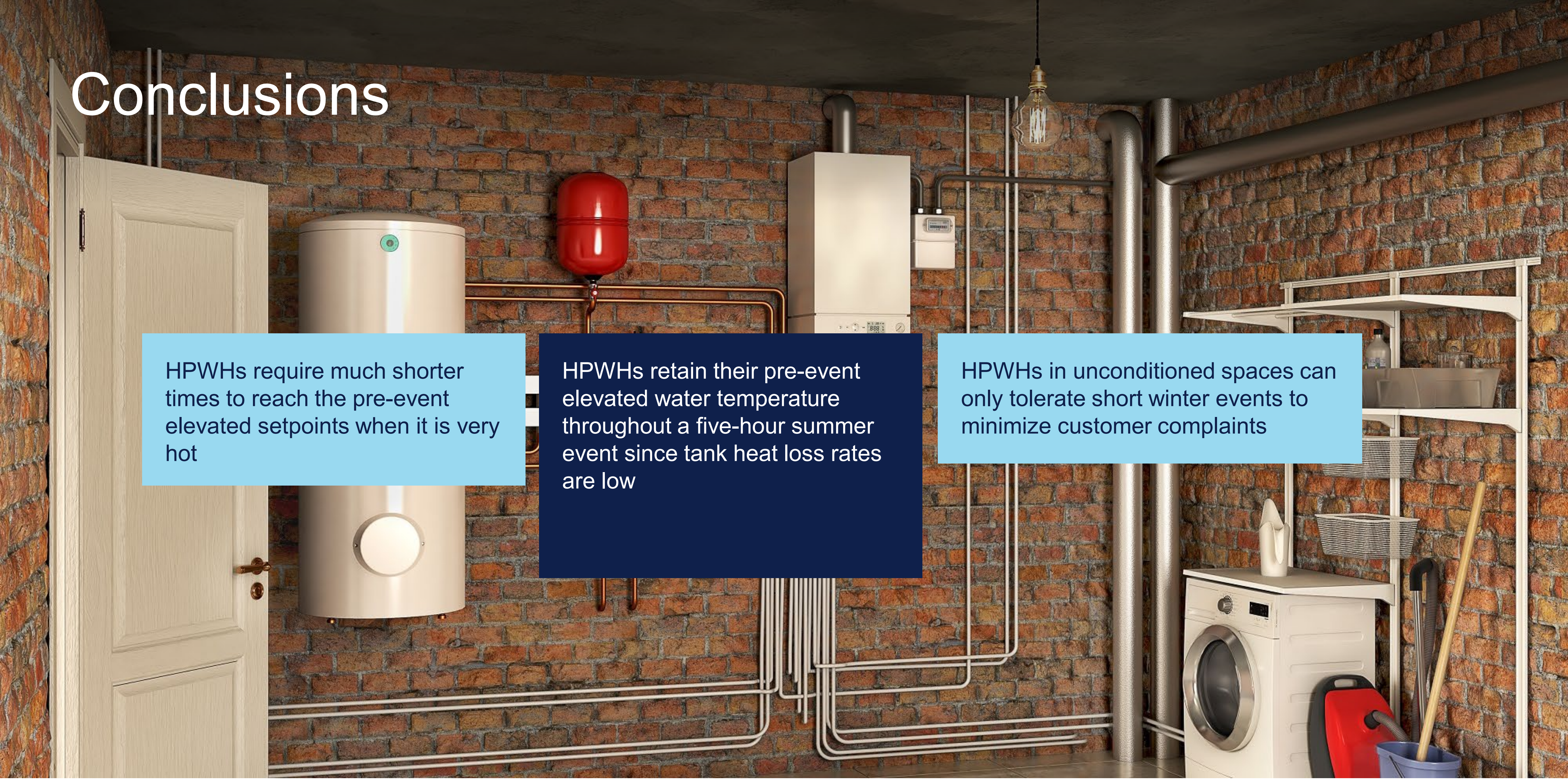
Winter event: before, during, and after

66-gallon HPWH



Conclusions

Conclusions



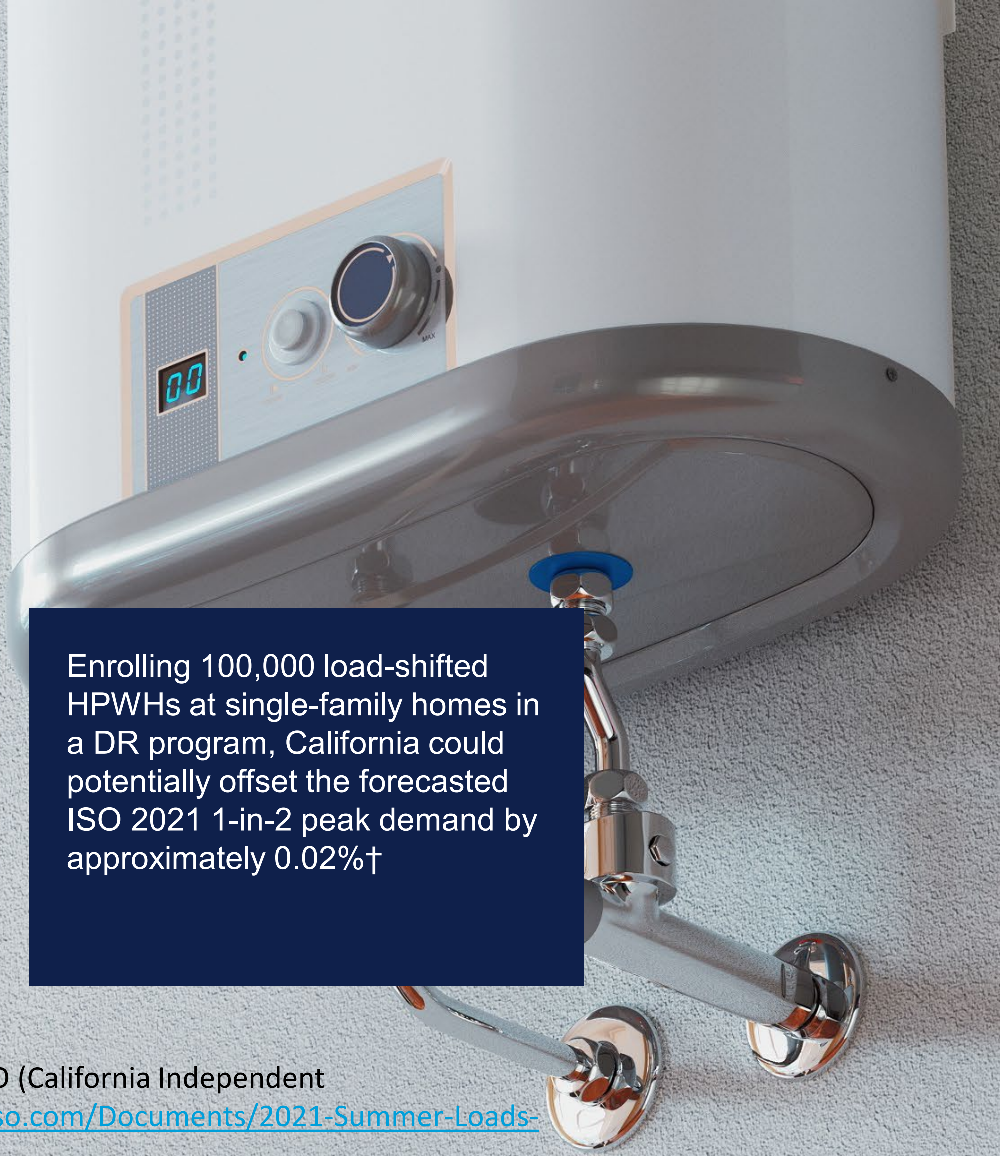
HPWHs require much shorter times to reach the pre-event elevated setpoints when it is very hot

HPWHs retain their pre-event elevated water temperature throughout a five-hour summer event since tank heat loss rates are low

HPWHs in unconditioned spaces can only tolerate short winter events to minimize customer complaints

DNV

More conclusions



Stepped ramp-up setpoint strategies (1-hour increments) work nearly as well as sawtooth ones at minimizing back-up electric resistance usage

Upsizing the HPWH can reduce annual energy consumption by nearly 10%

Enrolling 100,000 load-shifted HPWHs at single-family homes in a DR program, California could potentially offset the forecasted ISO 2021 1-in-2 peak demand by approximately 0.02%†

† The California ISO 2021 1-in-2 peak demand forecast is 45,837 MW according to CAISO (California Independent System Operator), *2021 Summer Loads and Resources Assessment*, p. 5. http://www.caiso.com/Documents/2021-Summer-Loads-and-Resources-Assessment.pdf.

Looking ahead

Future considerations

EnergyPlus does not always reliably adjust setpoints from .csv files

Proprietary control strategies for HPWHs make modeling energy consumption challenging

It would be beneficial for manufacturers to generate and release their own EMS controls subroutines for utilities or third-party implementers to use with EnergyPlus models

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