ET Summit 2023

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EMERGING TECHNOLOGIES COORDINATING COUNCIL

Central CO_2 Heat Pump Water Heater Performance and Load Shifting in Multifamily Buildings

Preliminary Findings

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Project Outline

- Market research and performance assessment of two SF multifamily central heat pump water heater (CHPWH) retrofits.
- Research topics:
  – Potential market size
  – Literature survey of field demonstrations
  – Evaluate system efficiency
  – Implement and evaluate load shifting capabilities
- Monitoring will continue through end of summer with final report to be published at the end of 2023.

Central Water Heater Market Base

- DHW accounts for 32% of energy consumption in USA multifamily buildings.
- About 1.9 million dwellings are in 58,000 California MF buildings with central DHW, nearly all with gas-fired systems[1], across building types and climate zones.
- With an average of 252 therms per year used for DHW in each dwelling[2], MF central hot water consumes about 480 million therms of natural gas per year in CA.
- MF sector is disproportionately represented by disadvantaged, low-income, and renter communities.
- The installed non-residential market base and energy consumption was estimated to be about 50% of the MF sector across offices, education, health, and lodging buildings[3] (240 million therms per year in CA).

1 – Based on data in Evergreen Economics, 2020, Multifamily Energy Use Study; Statewide CASE Team, 2022, All-Electric Multifamily Compliance Pathway Final CASE Report.

2 – DNV GL Energy Insights USA, 2020, California Residential Appliance Saturation Study.

3 - Based on data in Itron, 2006, California Commercial End-Use Survey; Cadmus Group, 2020, Commercial Building Stock Assessment 4; EIA commercial gas usage.

Host Sites and Installed Systems

	Site 1	Site 2
Year built	1914	1926
Dwellings	119	133
End-uses per residence	Three (kitchenette sink, bathroom sink, shower/tub)	
Stories	7	10
HPWH units	2 Mitsubishi Trane CO_2 QAHVs (136,000 Btu/h each)	
HPWH rated COP	4.11	
Primary storage tanks	8 (1,550 gallons total)	11 (2,150 gallons total)
Swing tank (gal)	200 gallon and 18 kW electric resistance	
Cost	$4,082/residence	$6,311/residence

Load Shift Strategy

- With the installed system, there are several settings that can be used to define “load-up and shed” modes of operation:
  - Which thermistor locations in the stratified storage volume are used to trigger calls for heat, to vary overall stored thermal potential
  - Hot water setpoints
  - Heat pump capacity (QAHVs can be ramped up for additional supply)
- Once programmed, these various modes can be triggered by external signals, such as through a CTA 2045 Ecoport.

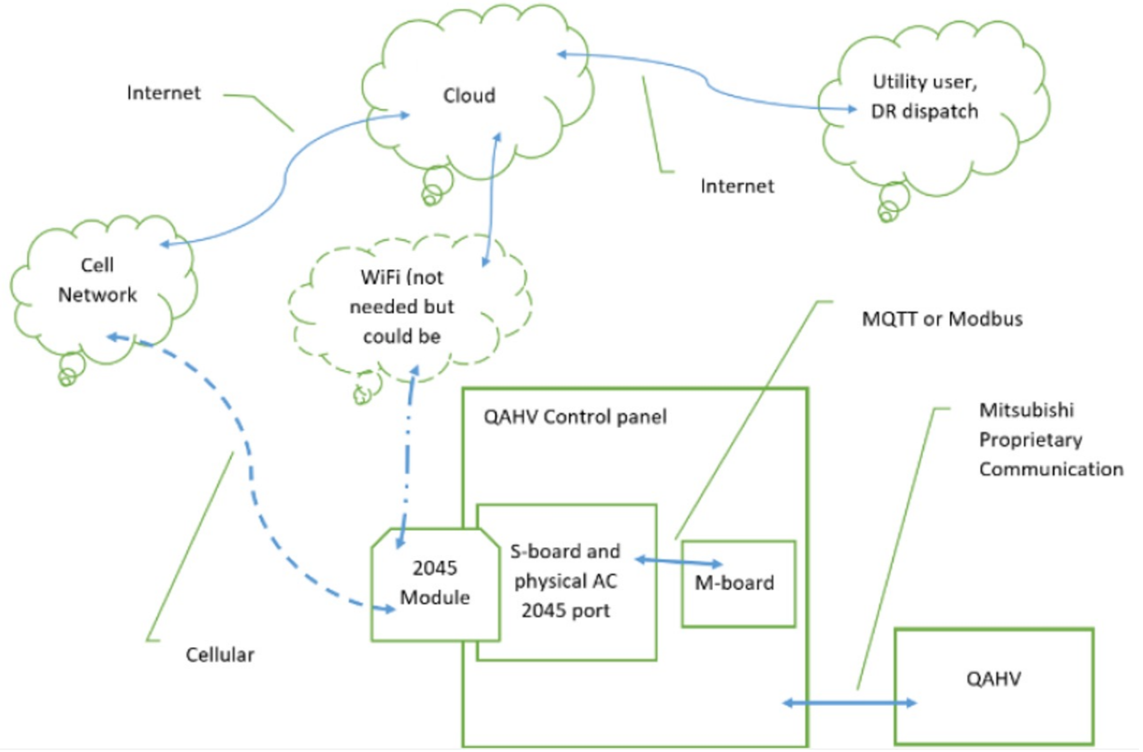
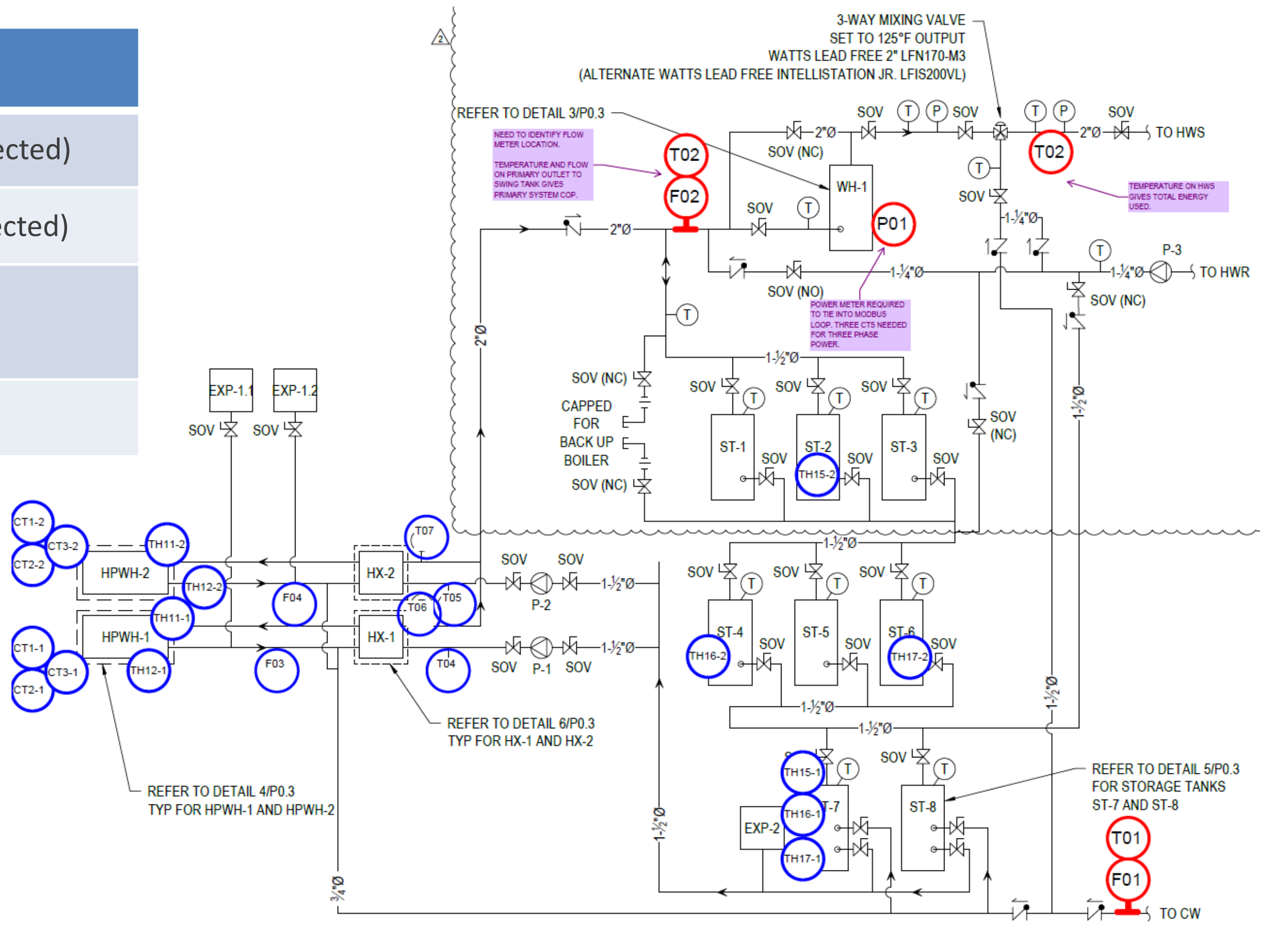


Image source: Spielman, 2022

Measurement Approach

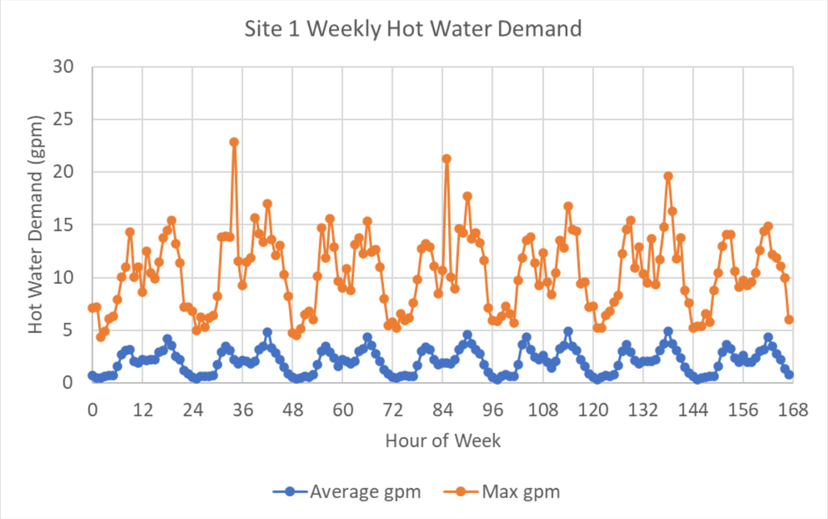
	Site 1	Site 2
Total monitoring period	Jan 24 – Oct 1 (expected)	Jan 20 – Oct 1 (expected)
Truncated monitoring period	March 9 – Oct 1 (expected)	May 3 – Oct 1 (expected)
Load shift controls implemented	April 21	
Data logging interval	1-minute	

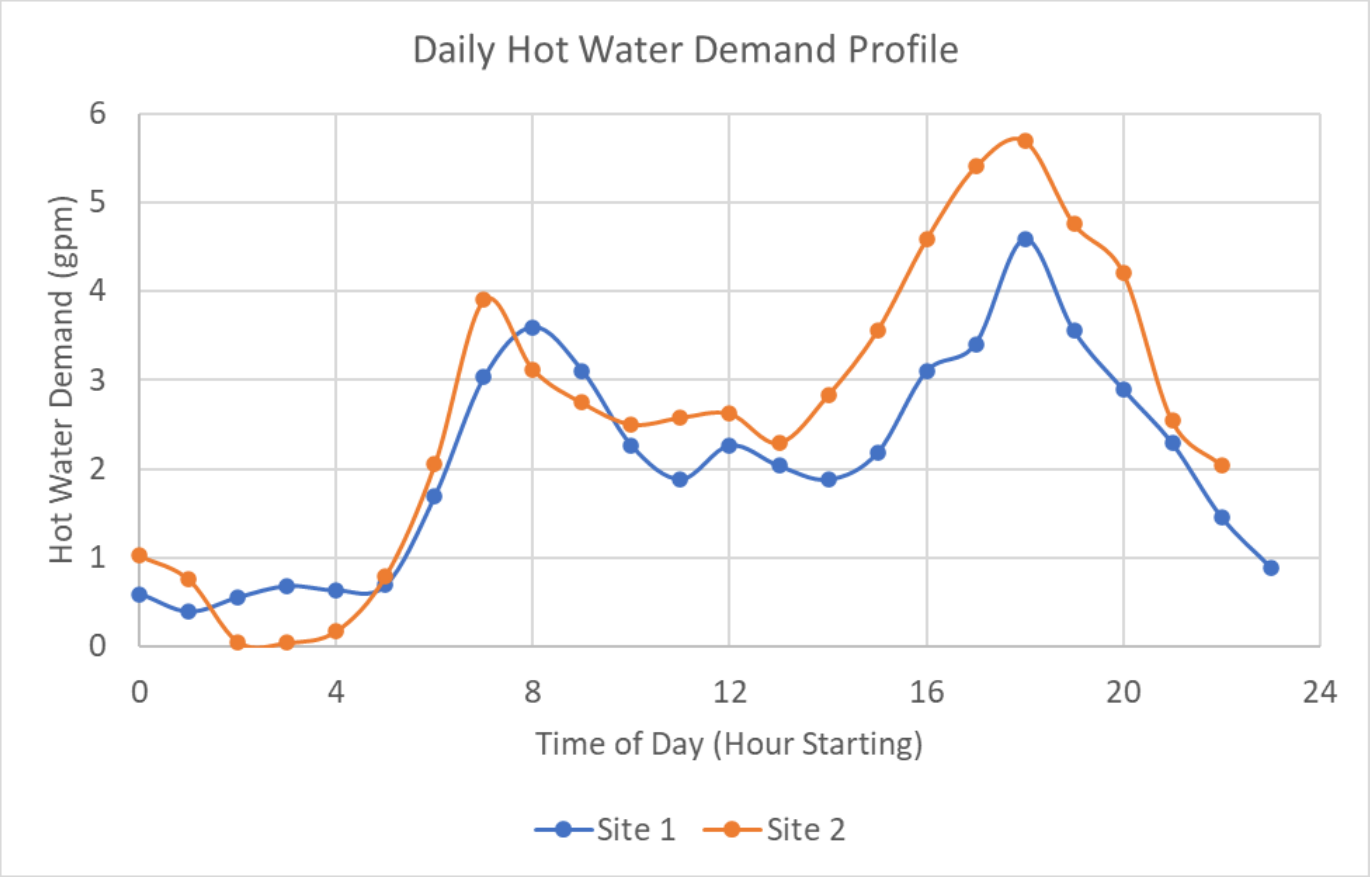
Schedule Parameter	Both Sites
First day of load shifting	April 21, 2023
Normal operating days	Tues, Thurs, Sun
Load shift days	Mon, Wed, Fri, Sat
Load shift day schedule	Mode 2 (load up): 12:00 - 15:59 Mode 3 (load shed): 16:00 - 20:59



Hot Water Load Profiles

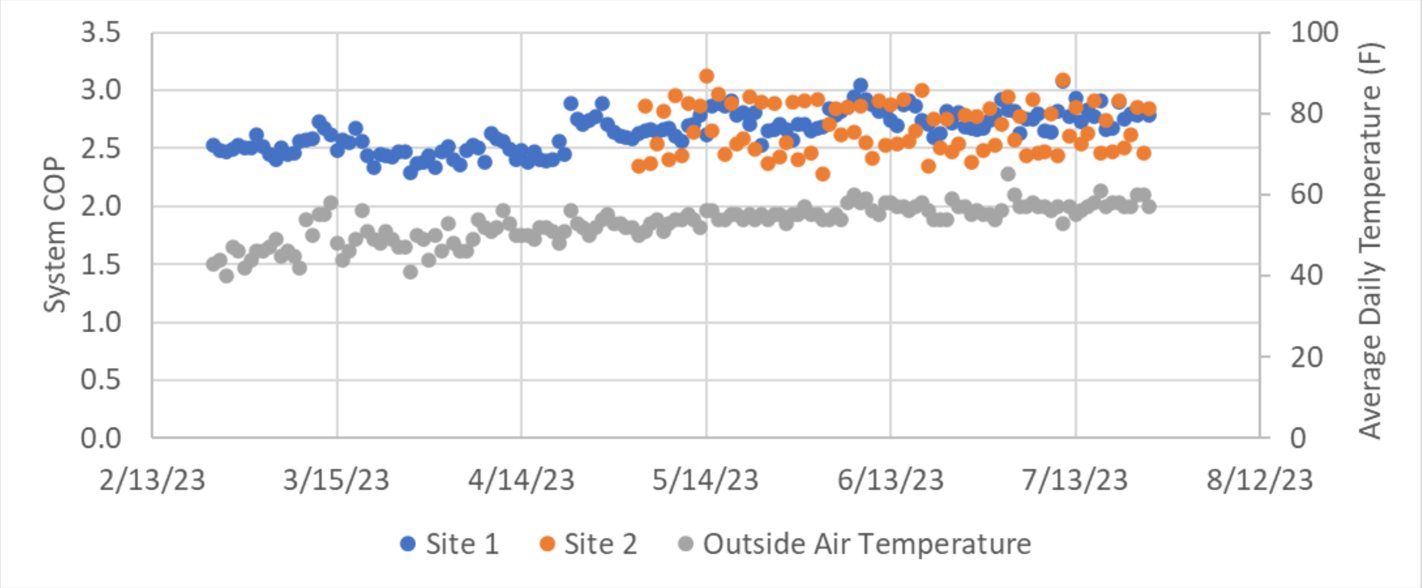
- Site 1: 24.8 gal/day-person
- Site 2: 27.4 gal/day-person





Efficiency and Energy Usage

	Site 1	Site 2
Period (days)	153	84
COP	2.3 to 3.1	
Baseline energy (therms)	4,549	3,780
CHPWH energy (kWh)	43,459	35,576
Baseline usage (million Btu)	454.8	377.9
CHPWH usage (million Btu)	148.3	121.4
Baseline GHG (tons CO_2-e)	24.9	20.6
CHPWH GHG (tons CO_2-e)	2.2	1.6



Method 1:

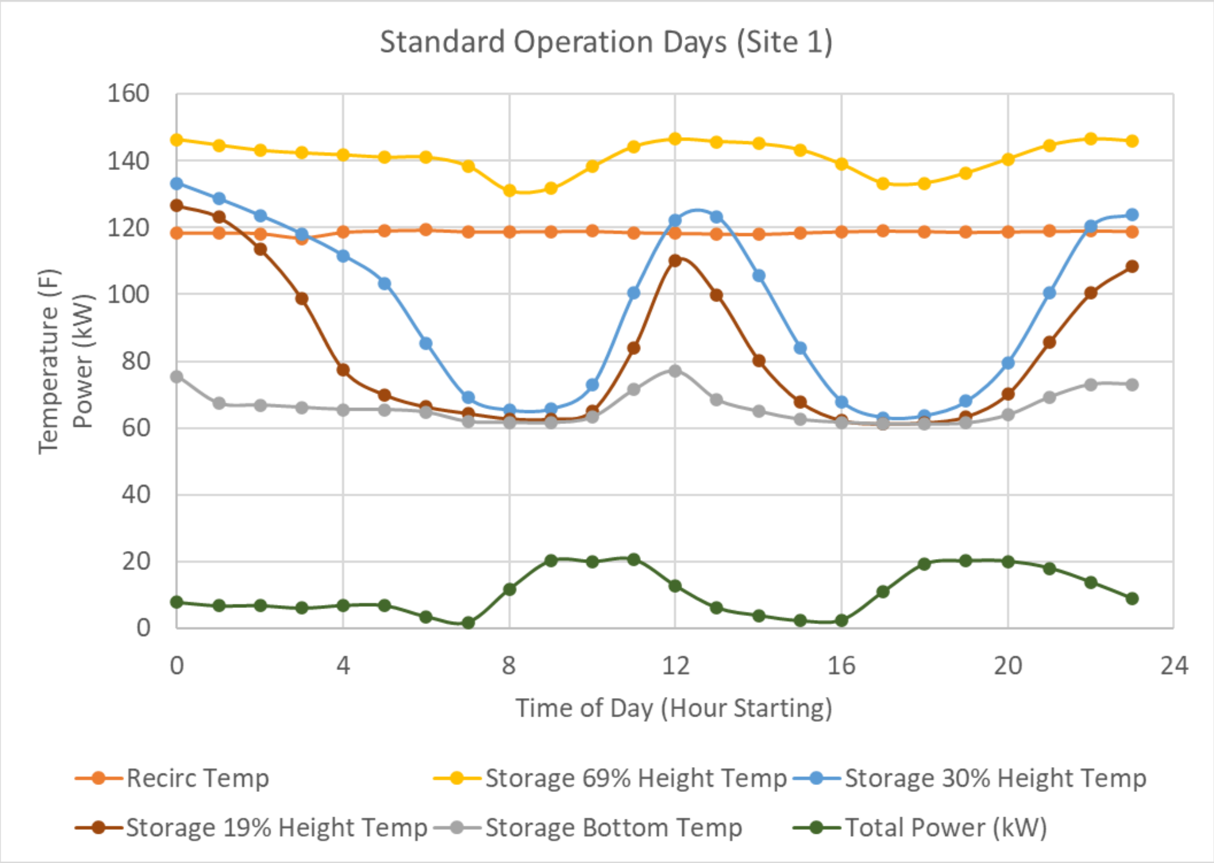
$$COP_{Sys} = \frac{Primary\ Load + Recirc\ Load}{Total\ Electric\ Use}$$

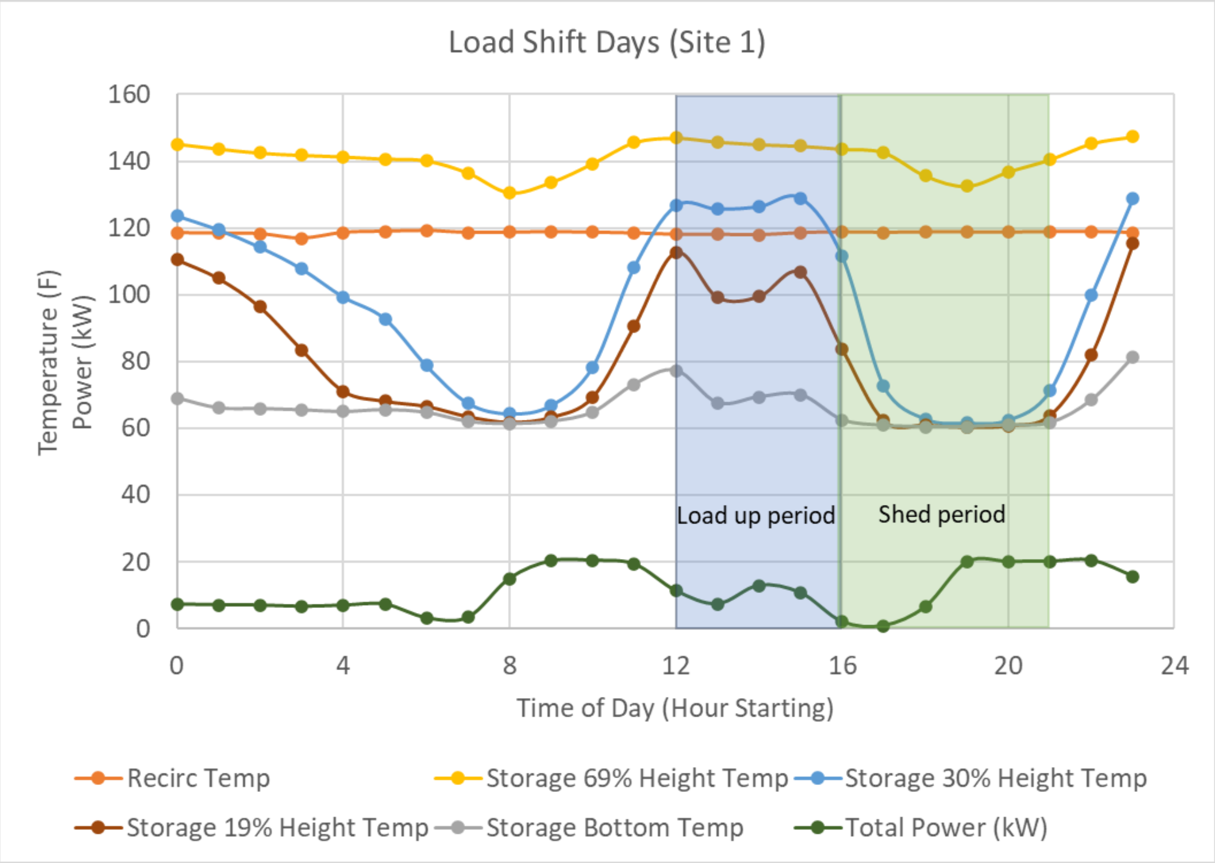
$$= \frac{500 * Flow_{CW} * (Temp_{OutMXV} - Temp_{CW}) + 500 * Flow_{RecircReturn} * (Temp_{OutMXV} - Temp_{RecircReturn})}{Power_{HPWH1} + Power_{HPWH2} + Power_{SwingTank}}$$

Method 2:

$$COP_{Sys} = COP_{equipment} * \frac{Electric\ Use_{HPWH}}{Total\ Electric\ Use} + COP_{resistance} * \frac{Electric\ Use_{Resistance}}{Total\ Electric\ Use}$$

Load Shift Results





Load Shift Results

Time of Day	Standard Day (kWh)	Difference (kWh)	Difference (%)
12 (load up)	12.67	-1.32	-10%
13 (load up)	6.14	1.29	21%
14 (load up)	3.87	9.09	235%
15 (load up)	2.33	8.41	361%
16 (shed)	2.57	-0.50	-19%
17 (shed)	11.03	-10.12	-92%
18 (shed)	19.28	-12.68	-66%
19 (shed)	20.20	-0.25	-1%
20 (shed)	20.09	0.04	0%
21	17.98	2.22	12%
22	13.82	6.66	48%
23	8.91	6.81	76%

- Load up: 70% energy increase
- Shed: 32% energy decrease
- Whole day: 6% energy increase

Next Steps

- Final report to be available at the end of 2023. Topics to be explored include:
  - Updated analysis across full monitoring period through summer
  - Implementation and analysis of refined load shifting control settings
  - Energy cost analysis based on host site electric rate schedules
  - GHG impacts analysis
  - Extrapolation to representative year (potentially other climate zones and total market potential impacts)
  - Recommendations for product development, load shifting controls, technology transfer, and program design

This project is funded by CalNEXT.

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The project report can be found at www.calnext.com in late 2023.