lighting design lab

CO_2 CHPHW for Efficiency, Decarbonization, and Load Shift in Bayview Towers – Part 2

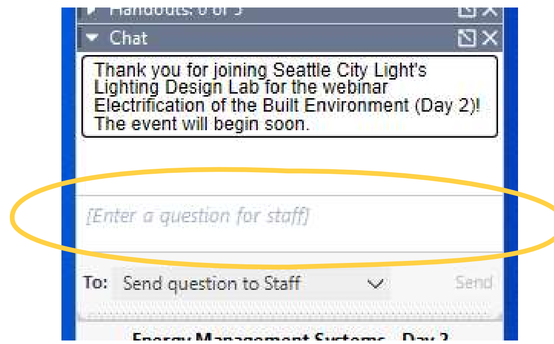
Presented by
Scott Spielman, Ecotope
&
Madison Johnson, Ecotope

August 1, 2023

Seattle City Light

Webinar Procedures

- All attendees are on mute
- Submit questions in chat at any time
- The webinar is being recorded
- Please take the after-class survey!



A couple different ways it might look to ask questions

Upcoming Events

Course	Day	Time
Pump Systems Fundamentals* – in-person training	Wed Aug 9	9:00am-5:00pm
Smart Buildings Exchange – hybrid conference	Aug 15-17	various
Demystifying Heat Pumps - Part 1	Thu Aug 24	10:00am-11:00am
Demystifying Heat Pumps - Part 2	Thu Aug 31	10:00am-11:00am

Relevant Recordings

Watch the previous webinar on this project from December 2022:
https://www.lightingdesignlab.com/course-recordings-and-handouts-2022#December

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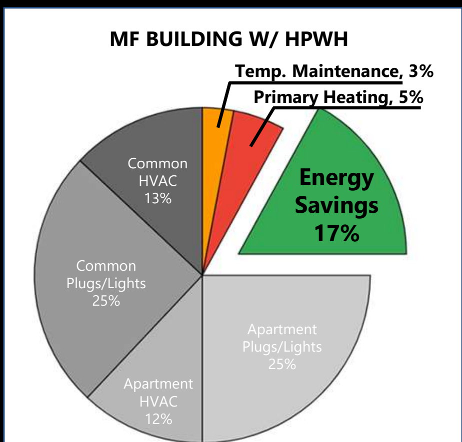
BPA Intro Slides

Bayview

Heat Pumps are a Solution



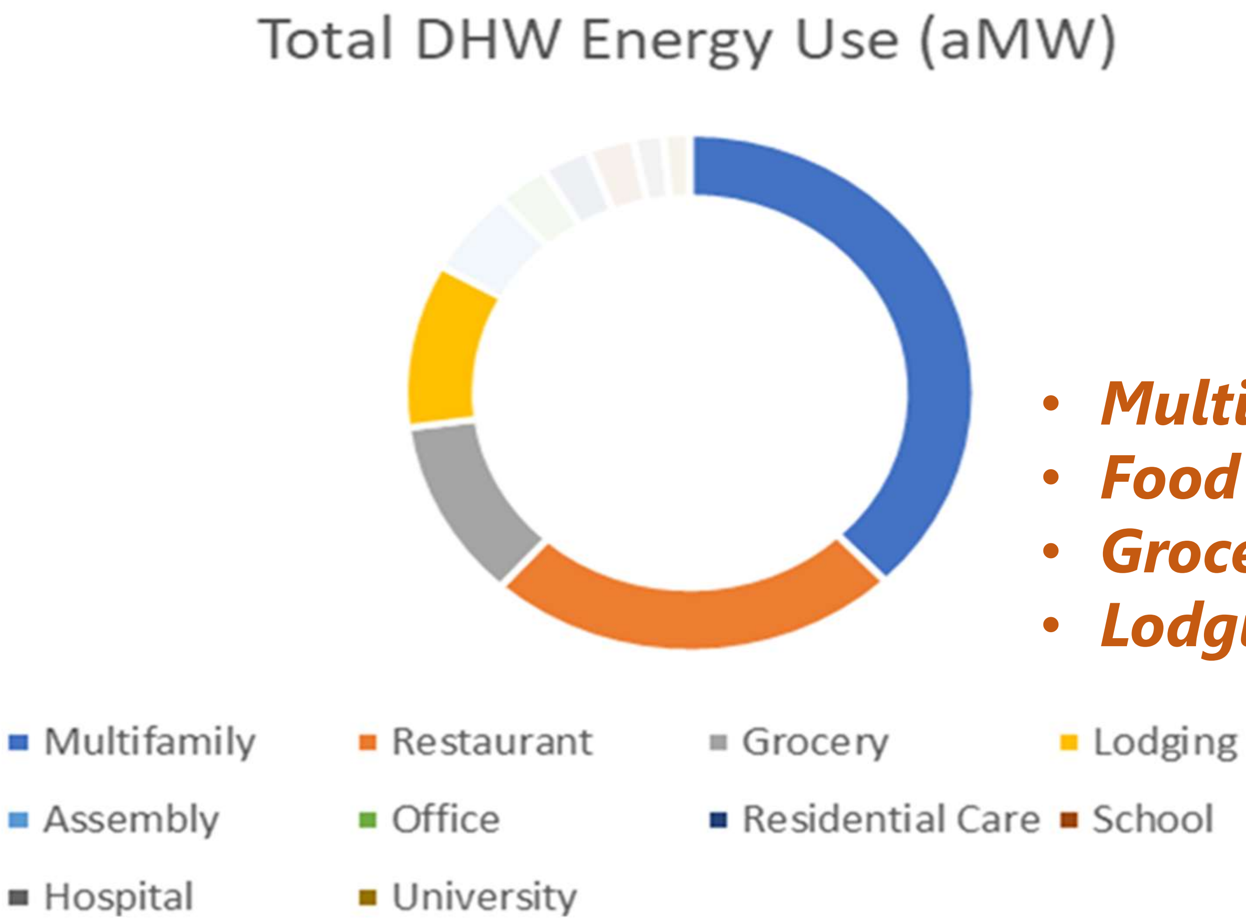
CHPWH systems cut energy usage down by 3x

ENERGY EFFICIENCY

GRID STABILITY

CODE REQUIREMENTS

DECARBONIZATION



- ***Multifamily***
- ***Food Service***
- ***Grocery***
- ***Lodging***

83 %

Bayview Tower Apartments

Scott Spielman, PE
Madison Johnson

August 1, 2023

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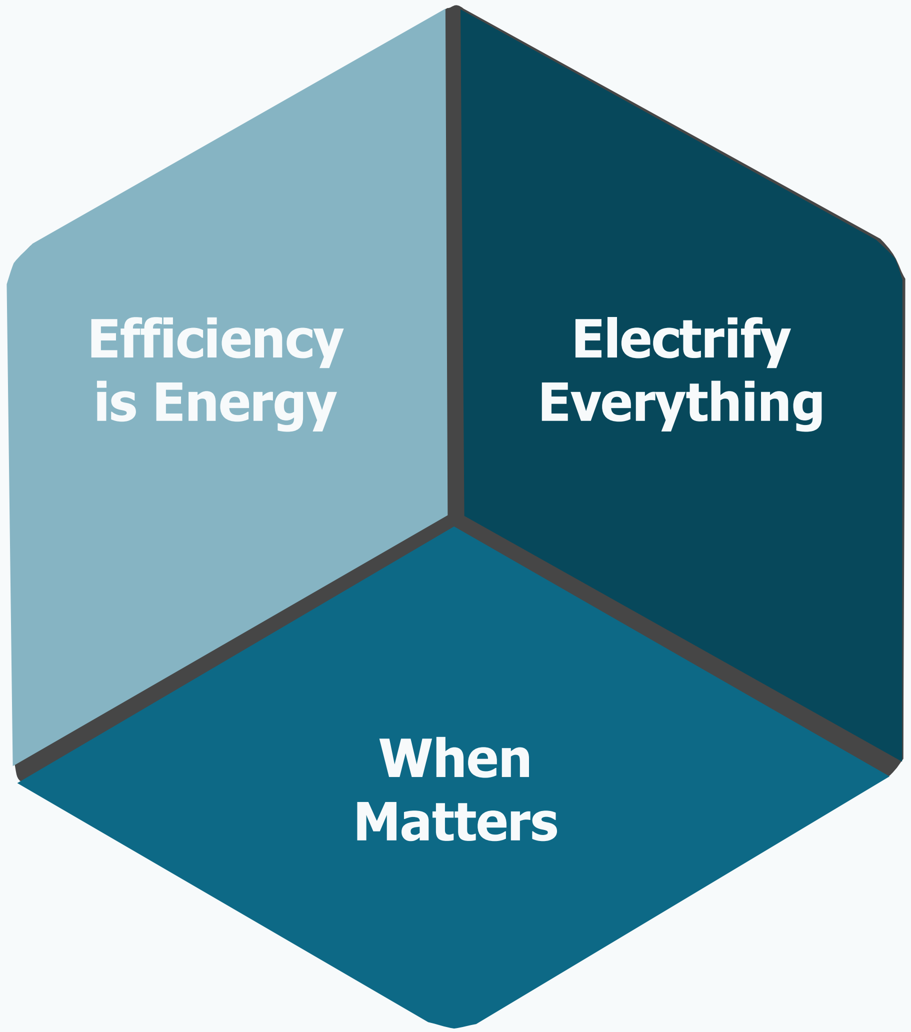
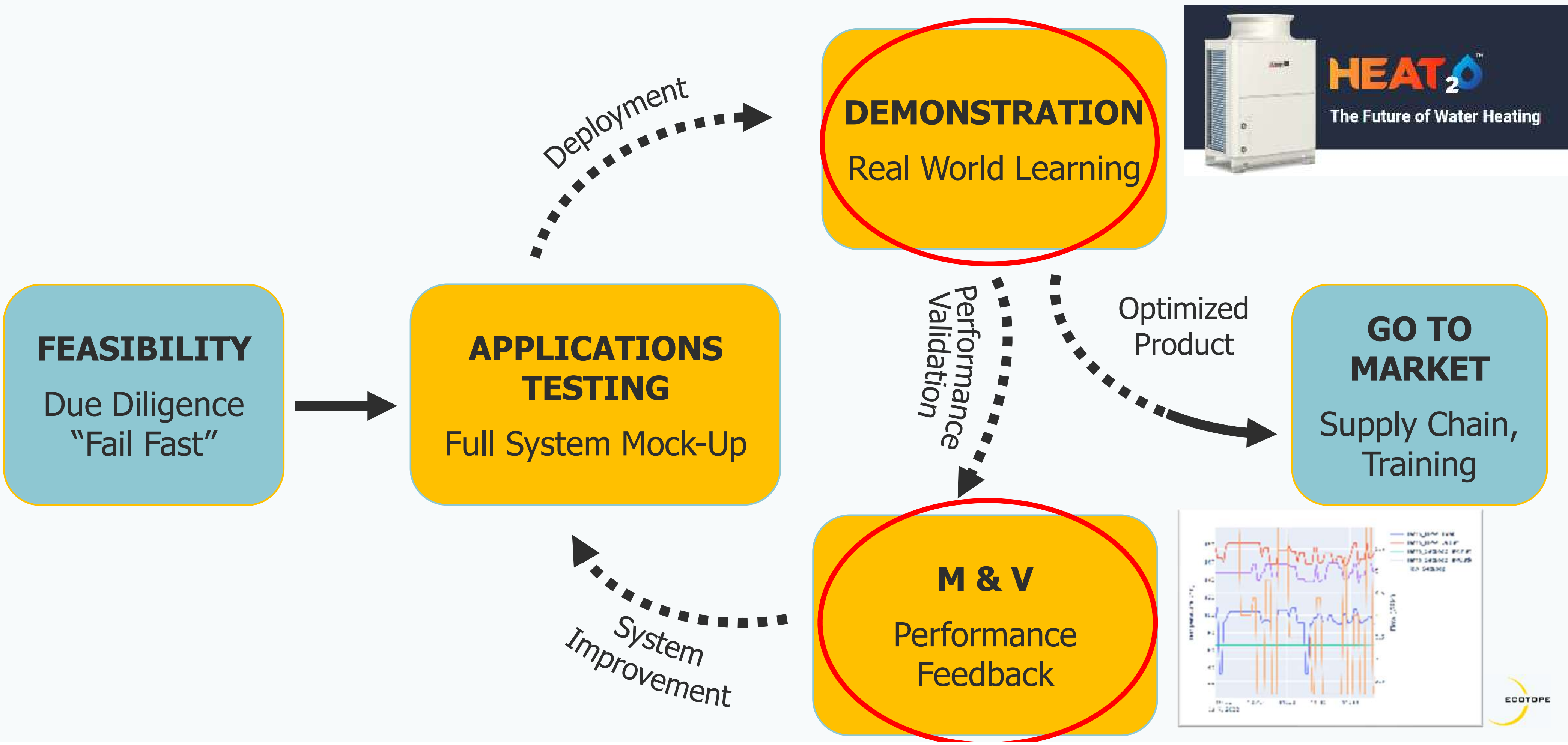
Big idea

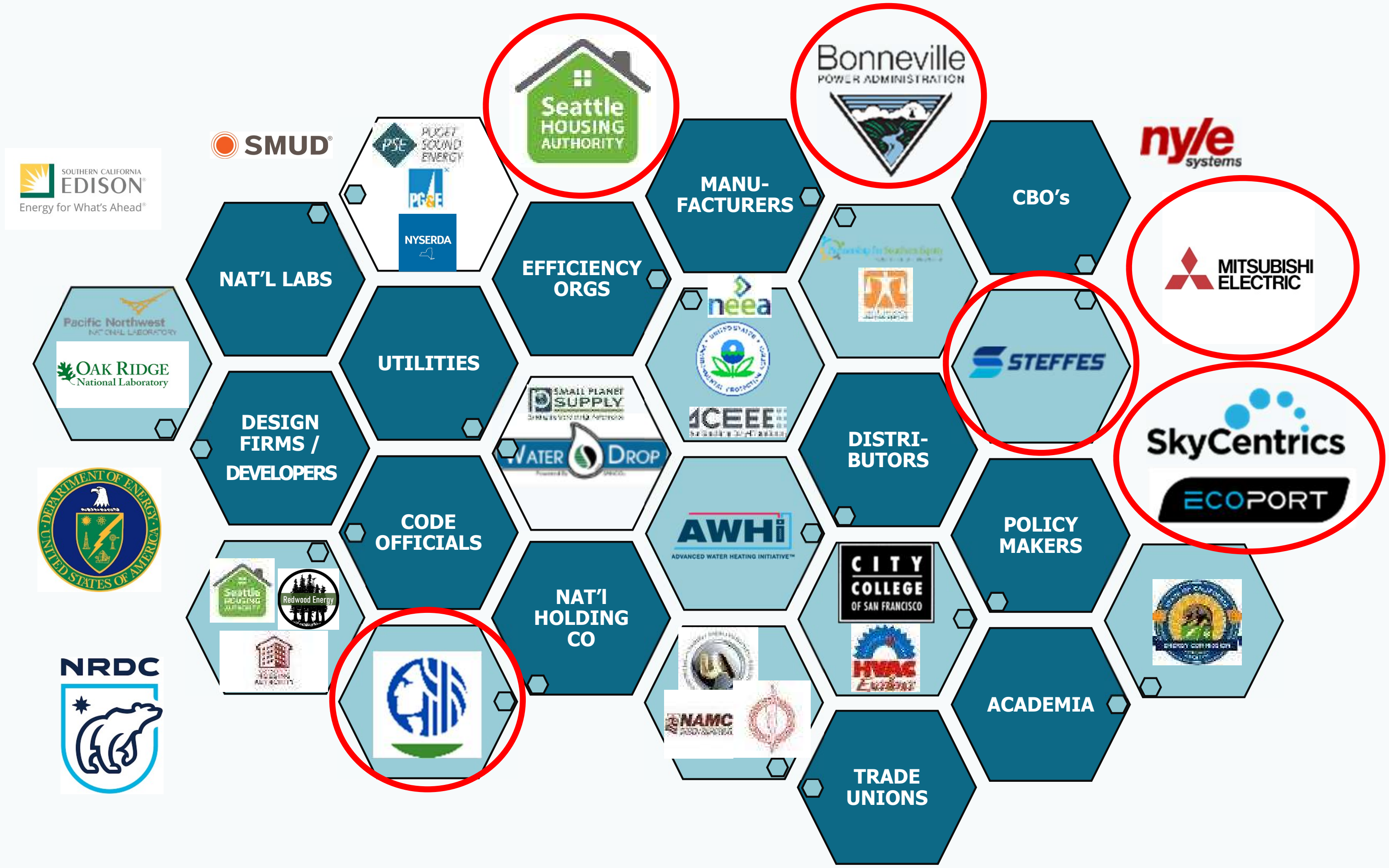
+ **Economic deployment of heat pump water heating systems is critical to building decarbonization**



Technology Innovation Model



Cross-functional approach is key



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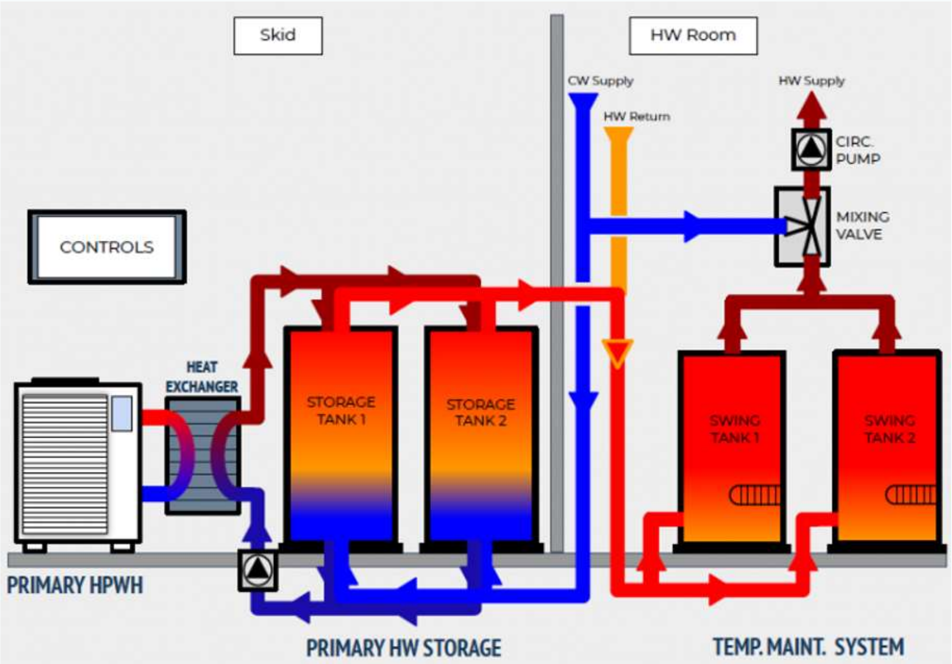
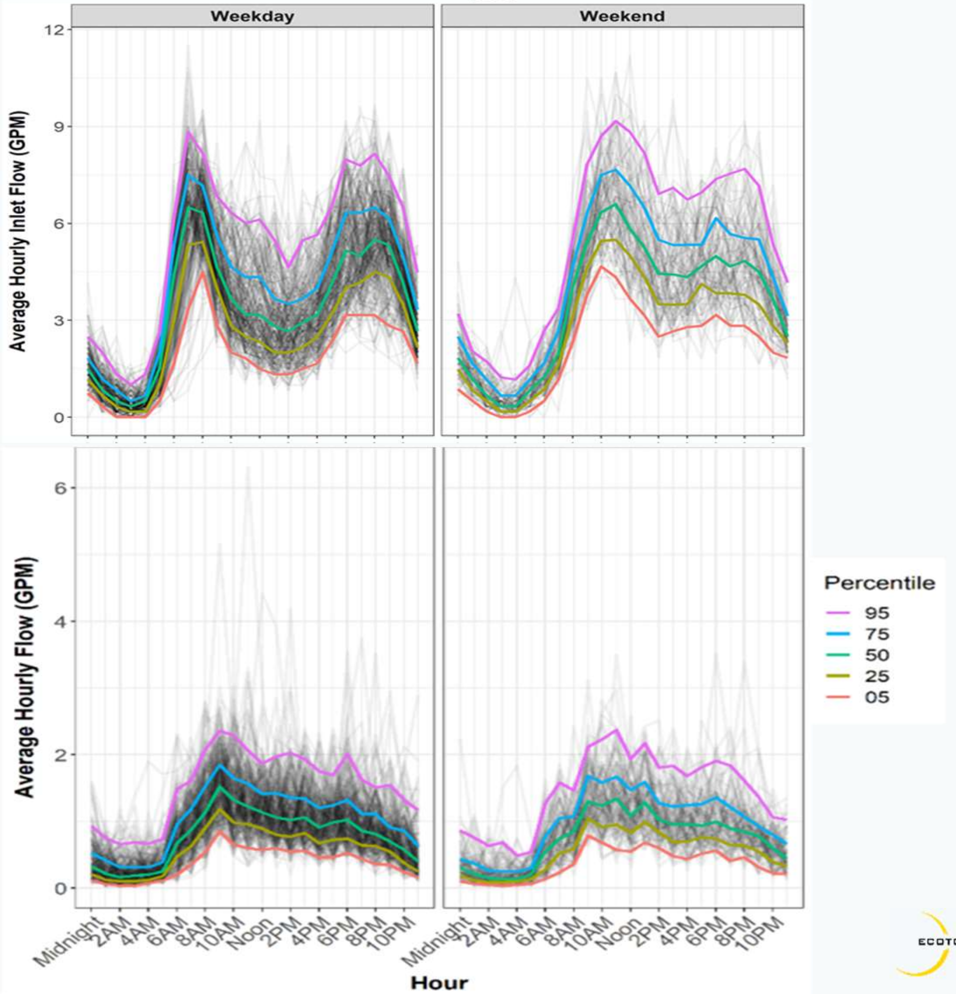
Bayview Tower Demonstration and Load Shifting

Building and system design

- 100-unit low-income senior housing building.
- Swing tank using existing equipment.





Project goals

+ Reliable hot water delivery with minimal tenant disruption.
+ Verify performance of HEAT2O system, achieve an annual COP greater than 2.5.
+ Identify opportunities to improve packaged system design.
+ Demonstrate packaged system approach to central HPWH retrofit.
+ Test Load Shifting and Demand Response.

Results

+ Hot water has been delivered for over a year reliably by the system.
+ Annual COP of ~2.3.
+ Opportunity to improve HX assembly controls and increase annual COP to 3.2.
+ Successful installation of packaged system.
+ Proven exceptional/consistent load shift system.

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Key findings

In its first 18 months of operation, the system operated at a COP of 2.3 and saved about 180,000 kWh. The research team identified opportunities to improve COP on future installations

The HEAT2O is a valuable utility asset for shifting or shaping loads; during Jun and July 2022, the HPWH shifted electric load twice a day – 6-9AM, 6-9PM – with 100% success.

The industry needs specifications for testing the HPWH defrost to provide better information for designers on heating capacity reduction from defrost (defrost derate)

System thermal storage and heating capacity are critical for effective load shifting and utility programs should require proper sizing of both

HPWH controls design and implementation are critical to load shifting. Utility programs should require proper controls on future installations

The industry needs additional load shift studies to develop best practices for load shift controls

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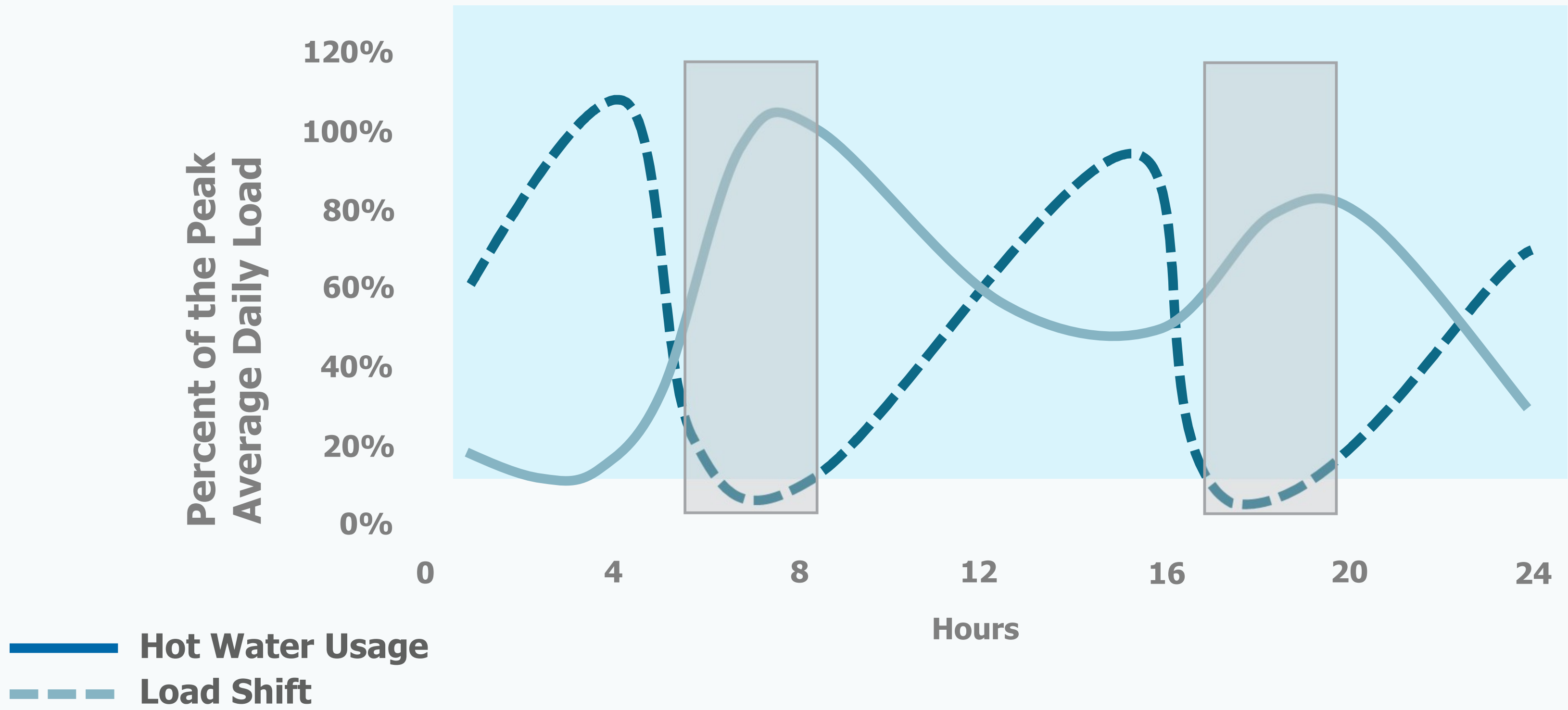
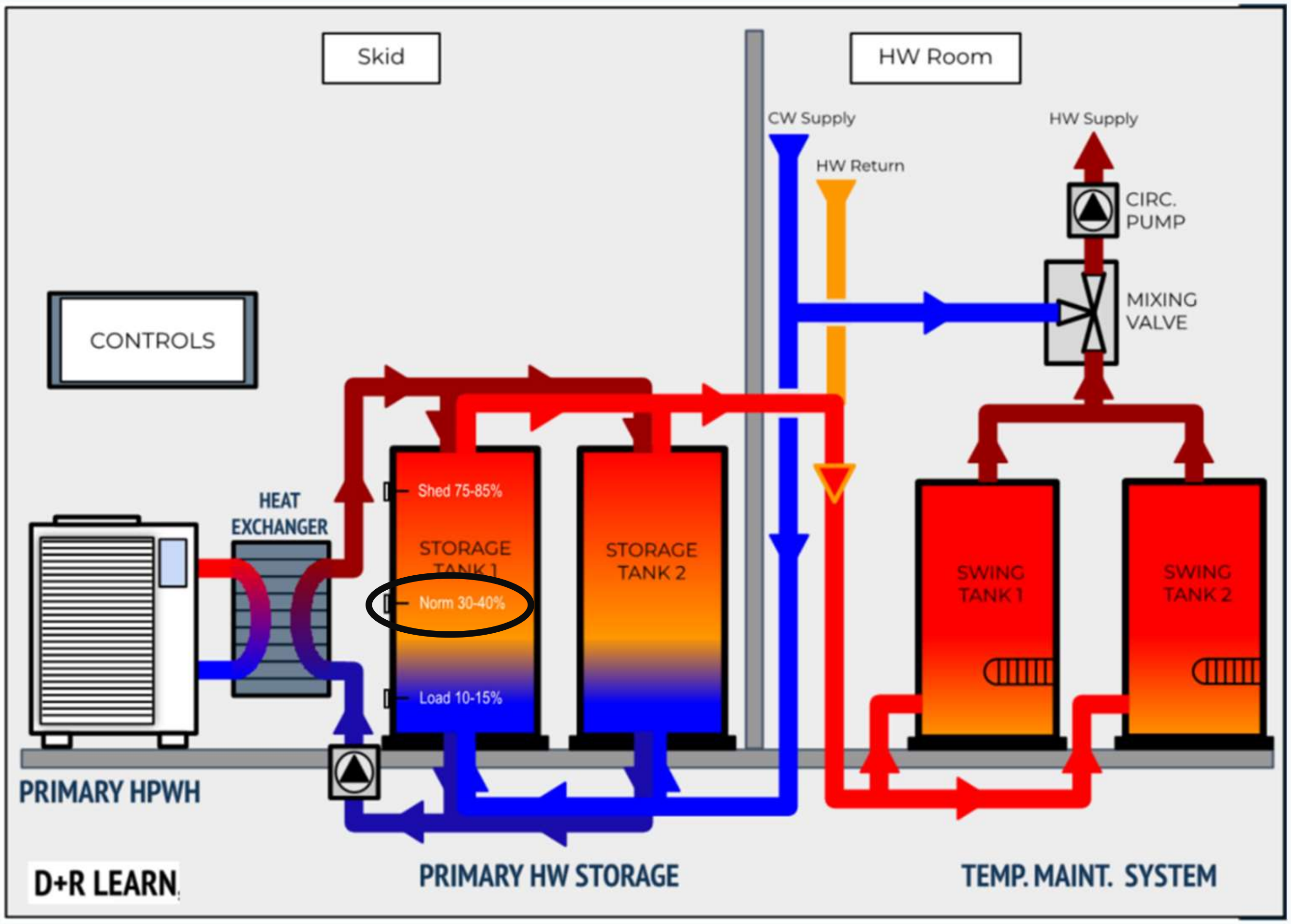
HPWH systems are a valuable utility resource for load shifting



Swing tank design



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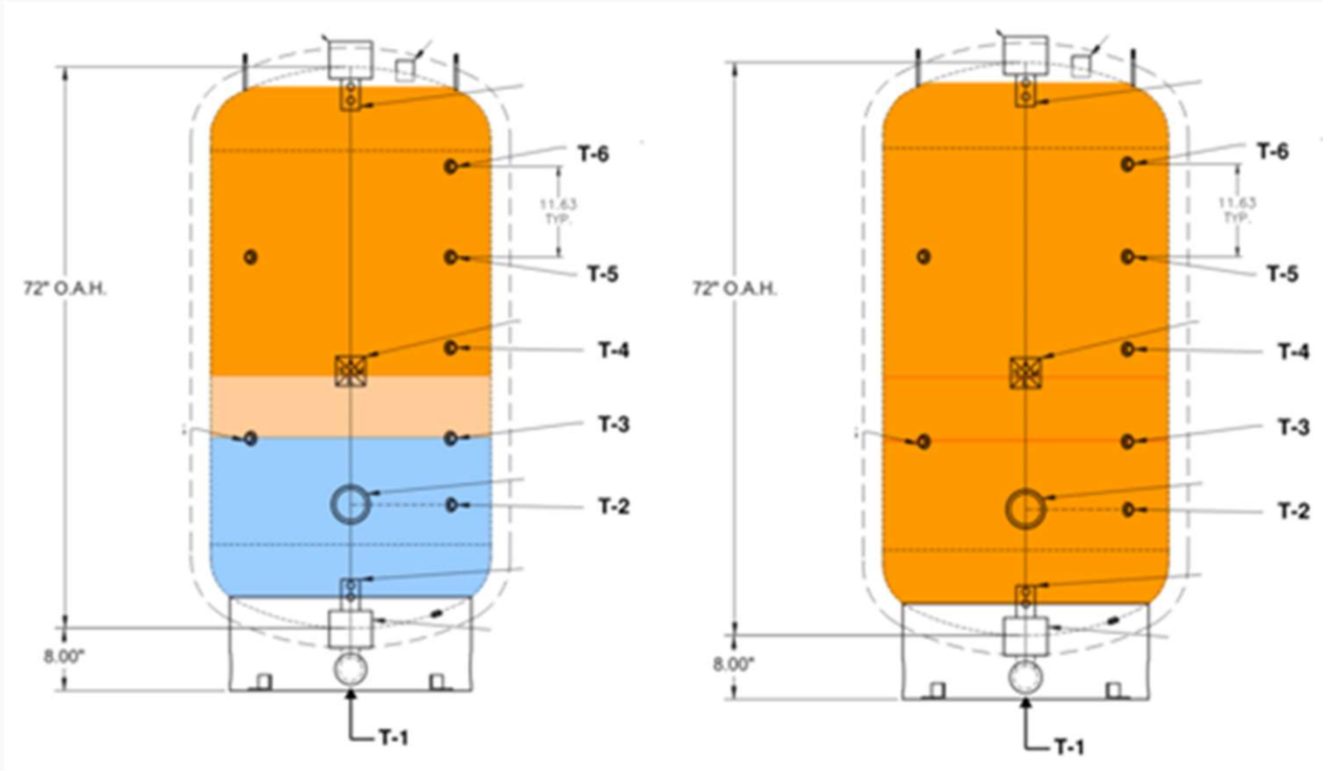
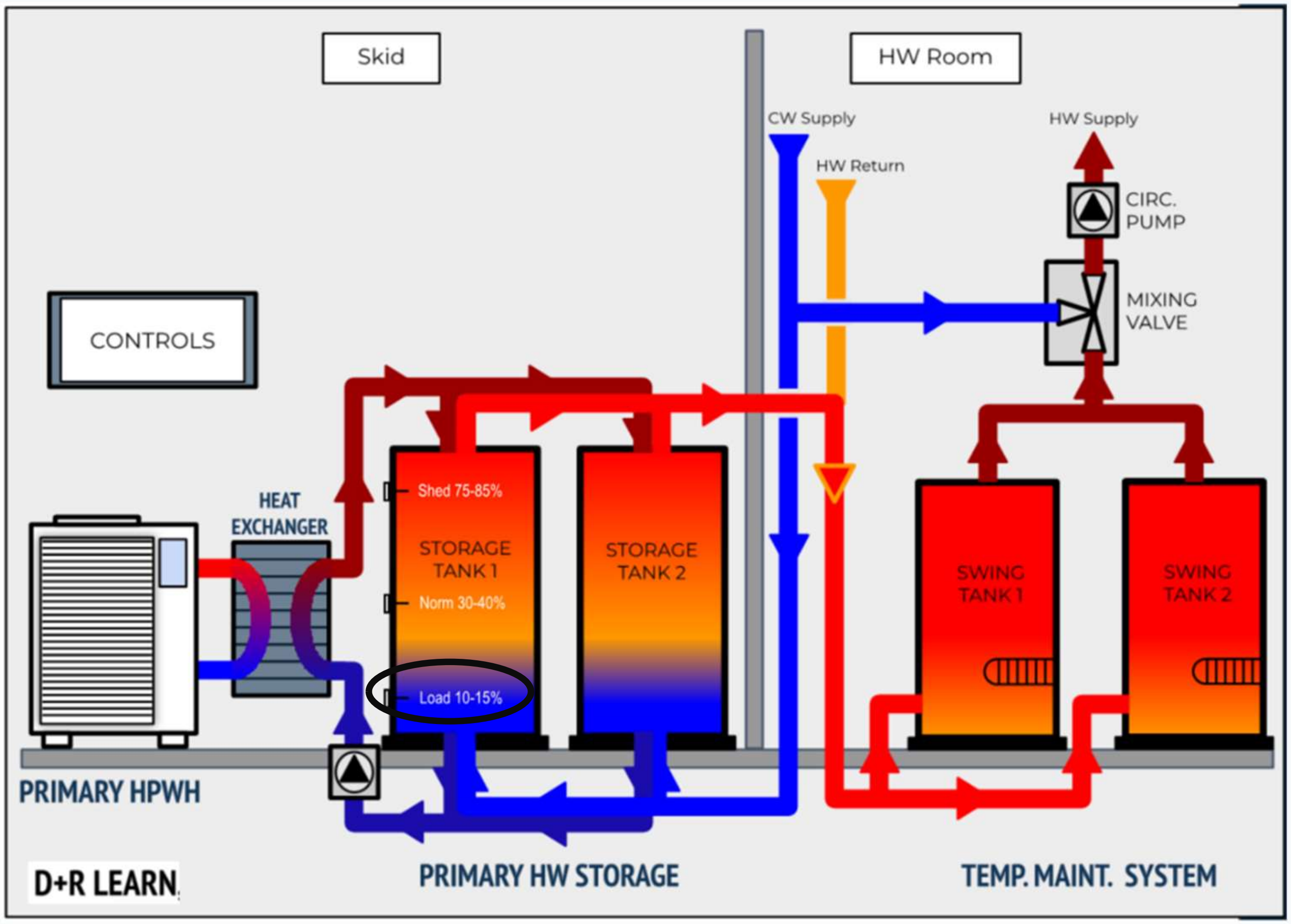
HPWH normal operations

+ ~40% Aquastat Fraction
+ Simple on/off logic
+ Long compressor cycles

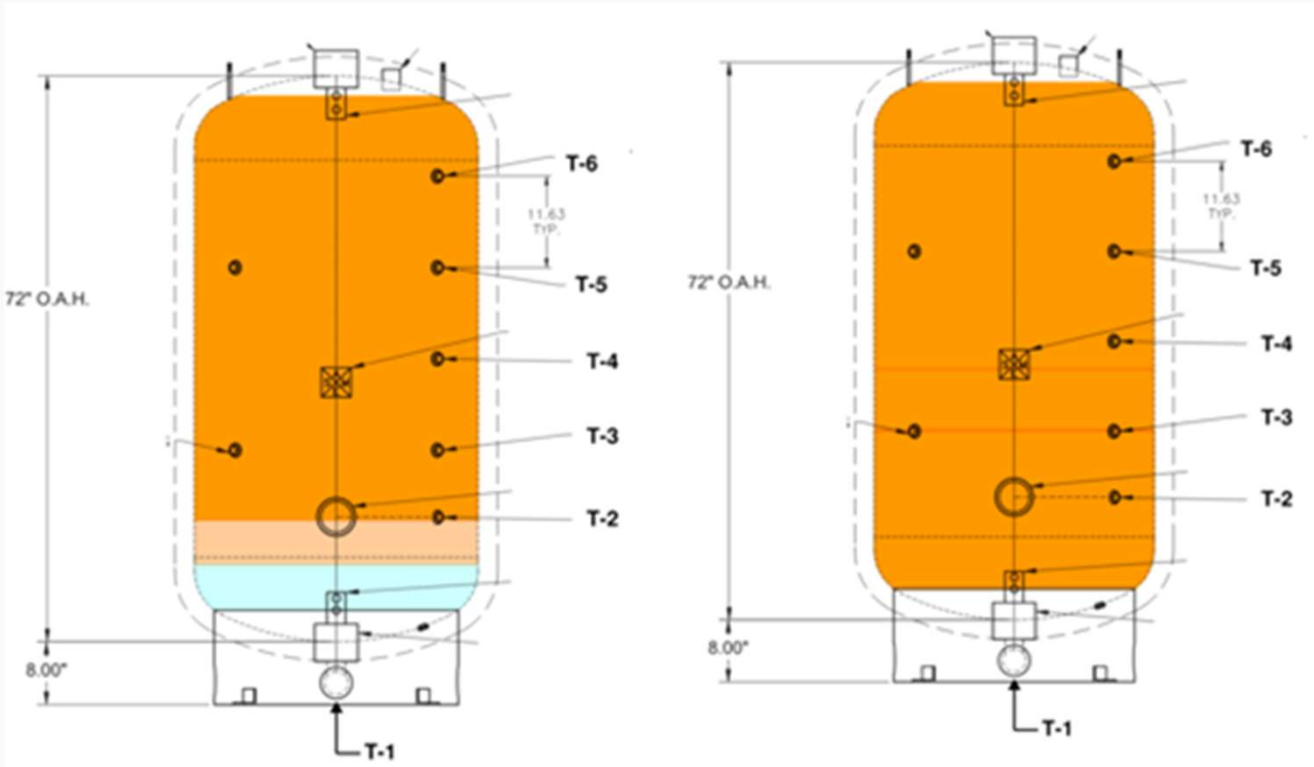


Swing tank design

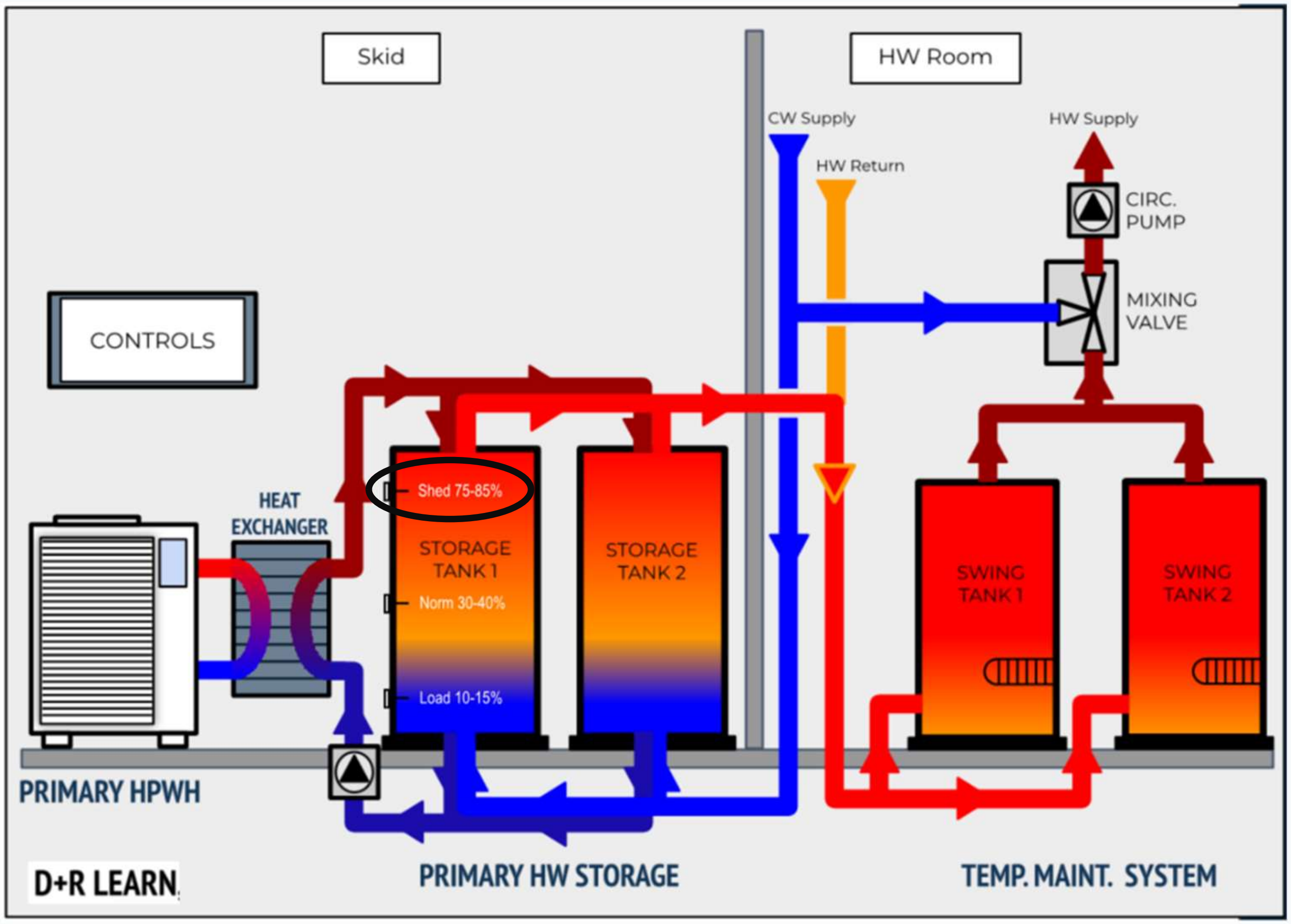


Load-up controls

+ ~20% Aquastat Fraction
+ Forces heat pump on
+ Short compressor cycles



Swing tank design



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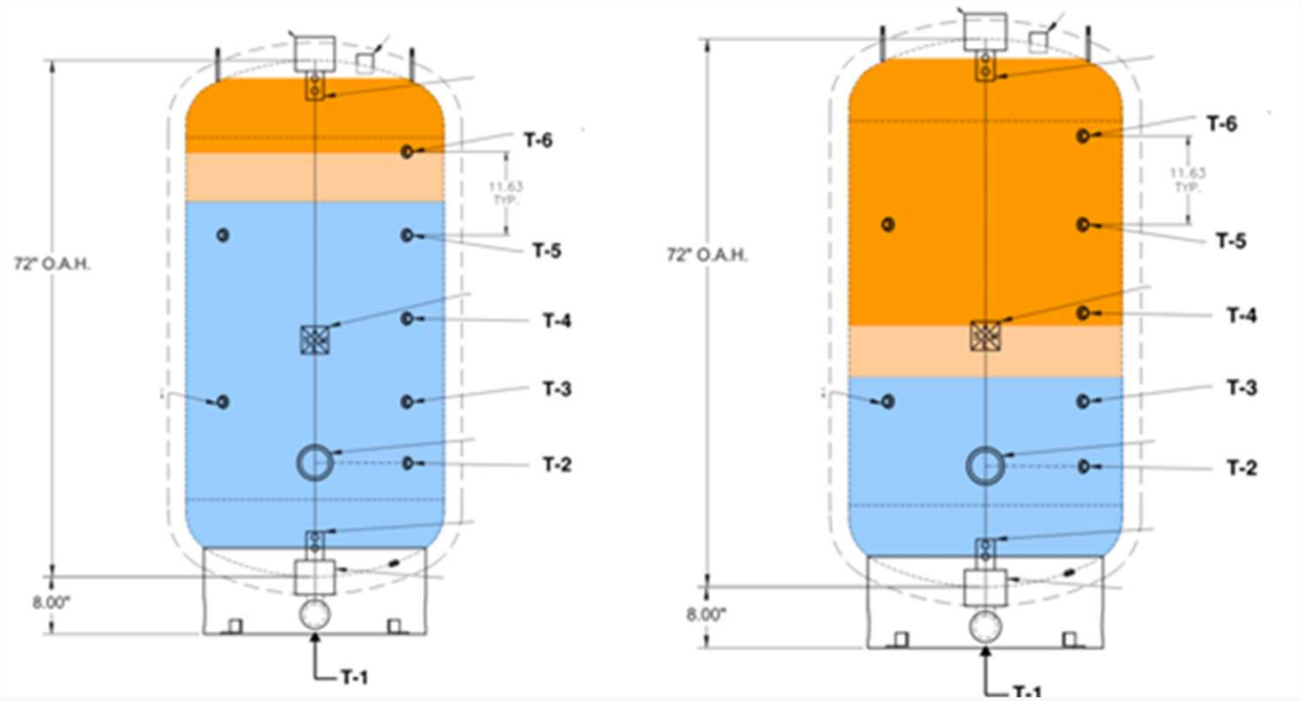
Shed controls

+ ~85% Aquastat Fraction
+ Keeps heat pump off
+ Prevents hot water loss



Control inputs

Control Change		Normal Operation	Load Up	Advanced Load Up	Shed	Critical Peak Event	Grid Emergency
Turn ON	Temperture	120°F	120°F	120°F	120°F	120°F	OFF
	Sensor Location	30-45%	5-20%	5-20%	75-90%	75-90%	OFF
	Outlet Water Temperature	150°F	150°F	160°F	150°F	140°F	OFF
Turn OFF	Temperture	135°F	135°F	135°F	135°F	135°F	OFF
	Sensor Location	30-45%	5-20%	5-20%	75-90%	75-90%	OFF

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Bayview M&V data – Summer demand reduction

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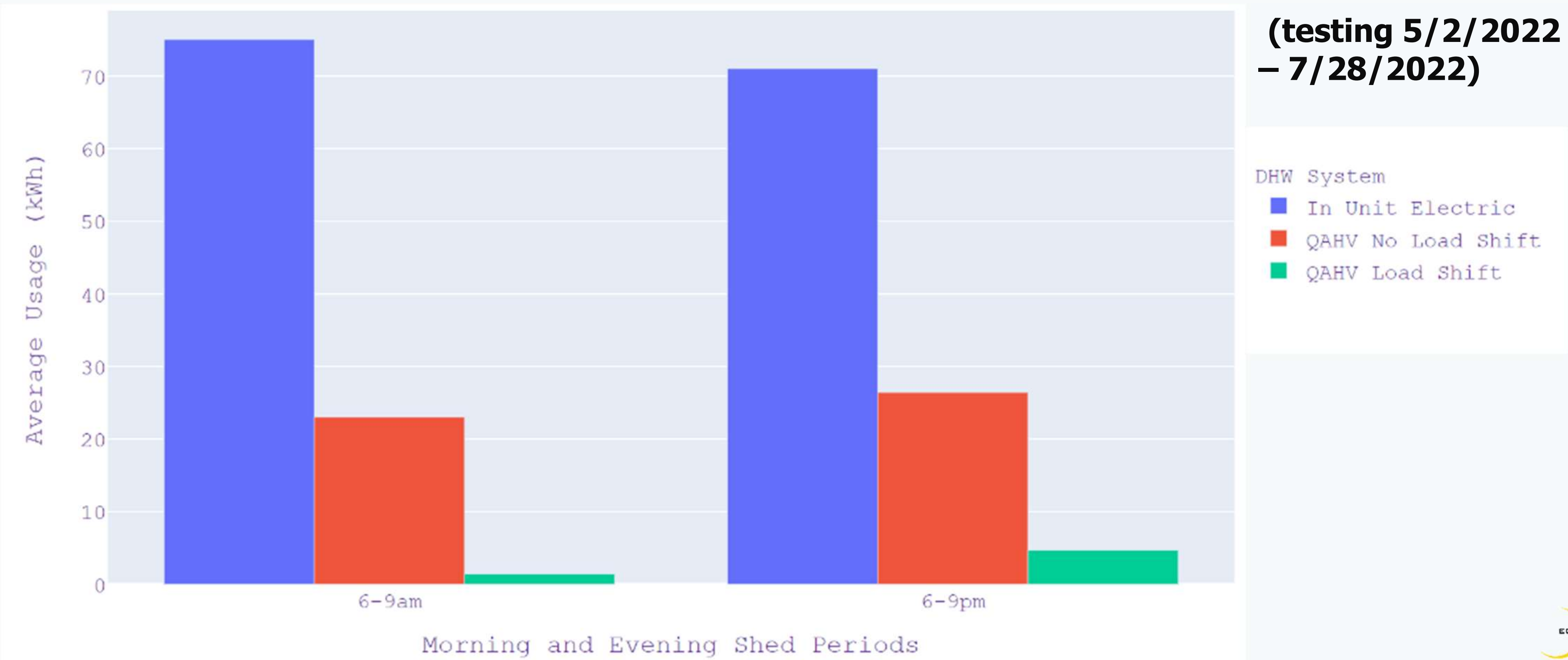

(testing 5/2/2022 – 7/28/2022)

Summary results

Start Date	End Date	Control Sequence	Percent Shed Met	Avg Outdoor Air Temp (°F)	Avg COP
5/2/2022	6/19/2022	Load Up: 5am-6am, 12pm-6pm Shed: 6am-9am, 6pm-9pm	91%	55	2.33
6/20/2022	7/27/2022	Load Up: 5am-6am, 10am-6pm Shed: 6am-9am, 6pm-9pm	100%	66	2.63
8/18/2022	10/2/2022	Load Up: 5am-6am, 10am-6pm Shed: 6am-10am, 6pm-10pm	85%	66	2.82
10/3/2022	12/15/2022	Load Up: 5am-6am, 10am-6pm Shed: 6am-10am, 6pm-10pm System was not re-programmed after daylight savings, schedule shifted back 1 hour after 11/6/2022	62%	47	2.24
12/16/2022	1/1/2023	Baseline operation. Heat pump struggled with two shed periods per day under winter conditions. System was set to normal operation to allow hot water generation to catch up	-	39	2.1
1/2/2023	3/5/2023	Baseline operation. Miscommunication resulted in a lack of commands sent to the heat pump on scheduled start date and improper commands sent later in the month that did not allow the system to load shift properly	-	-	-
3/6/2023	3/19/2023	Load Up: 12am-6am Shed: 9am-1pm (Building's peak water use)	54%	44	2.13
3/20/2023	4/20/2023	Load Up: 5am-6am Shed: 6am-9am	88%	46	2.32

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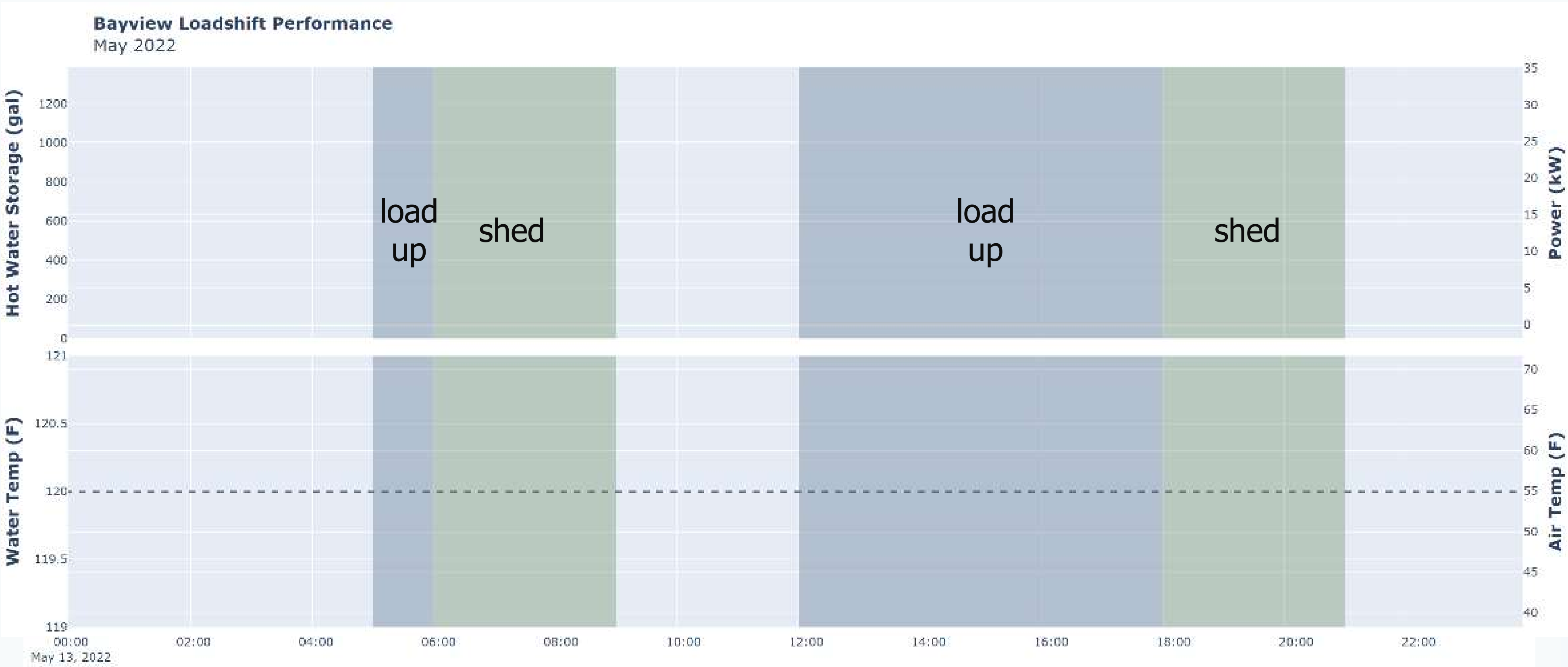
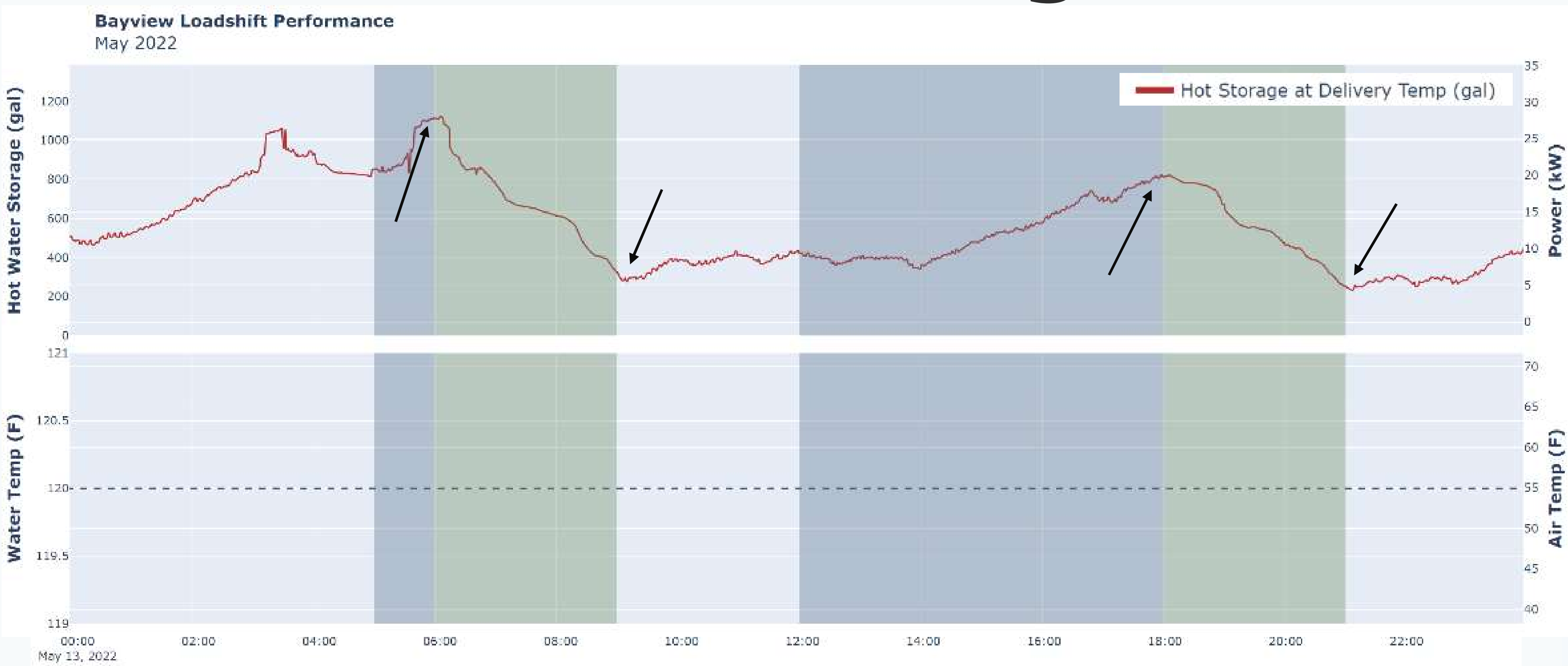
Ideal system behavior – Load shift schedule



Ideal system behavior – Hot water storage



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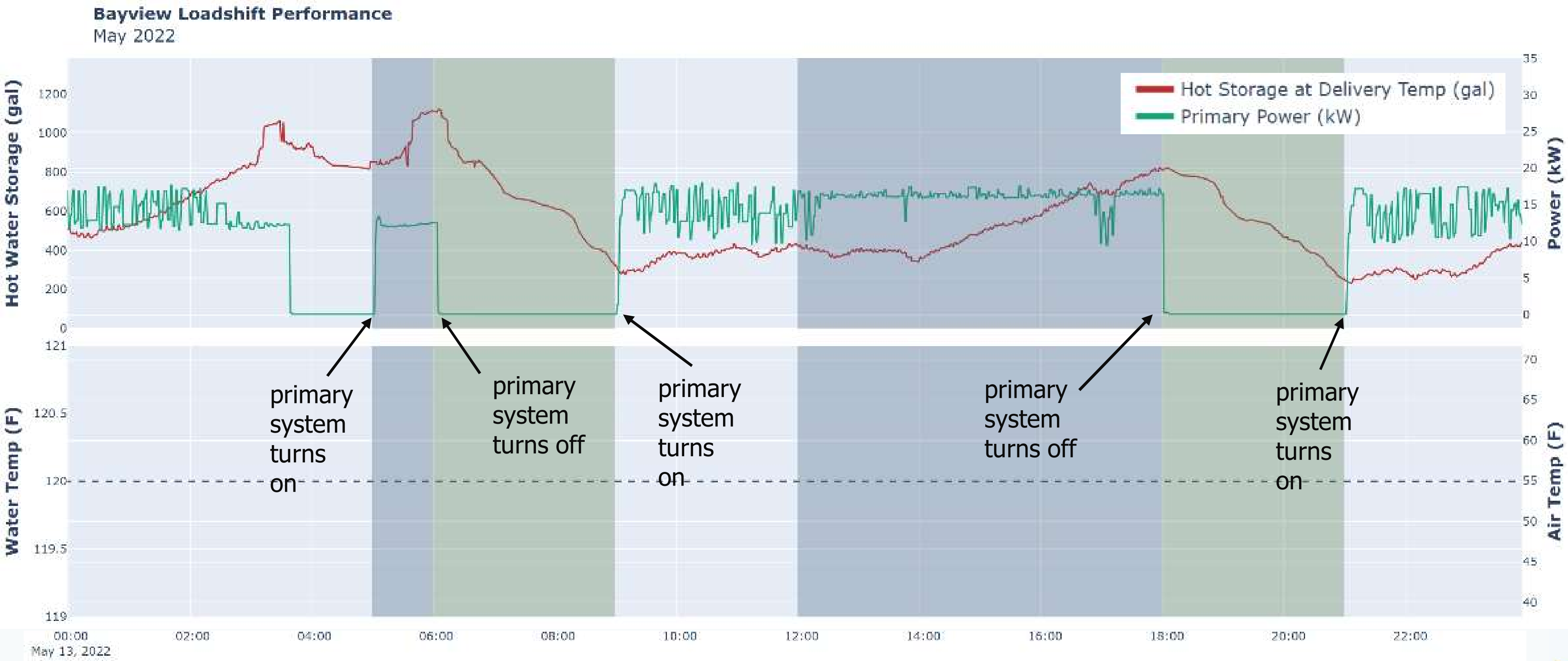
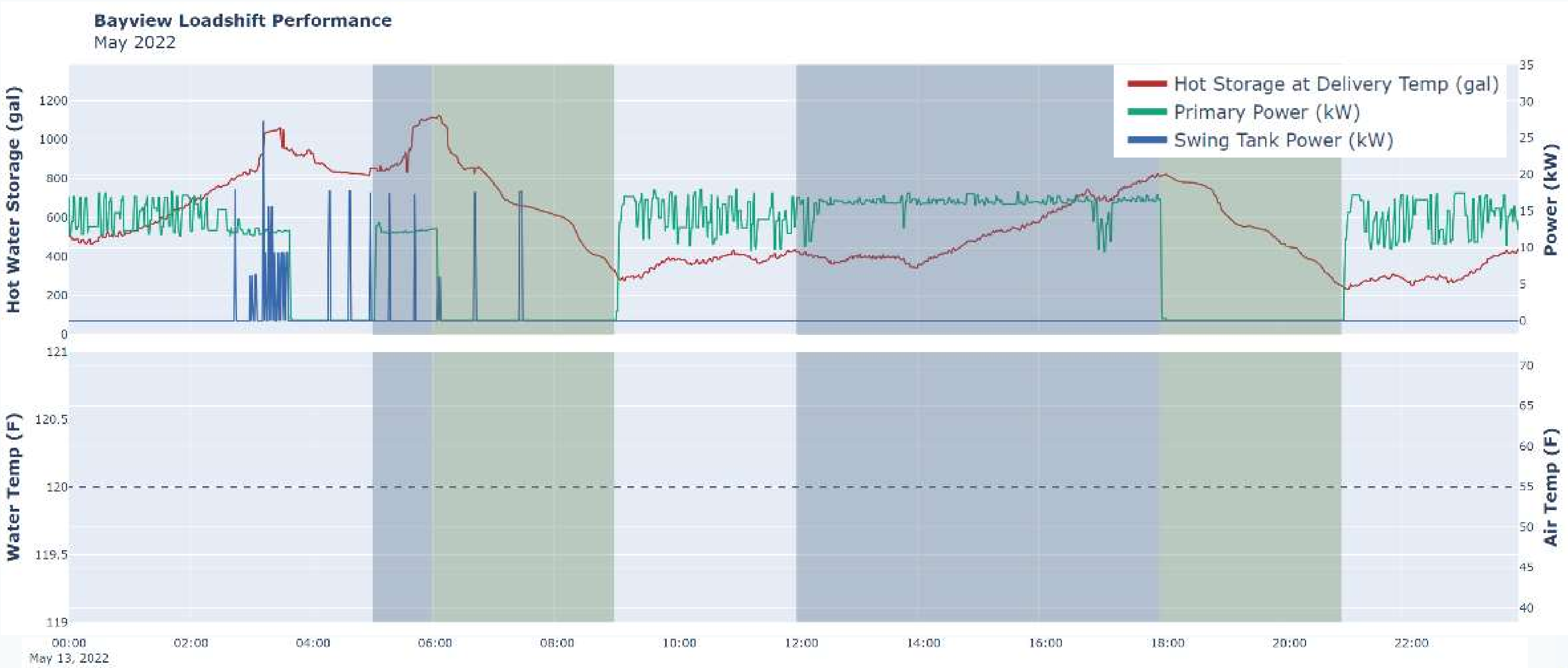
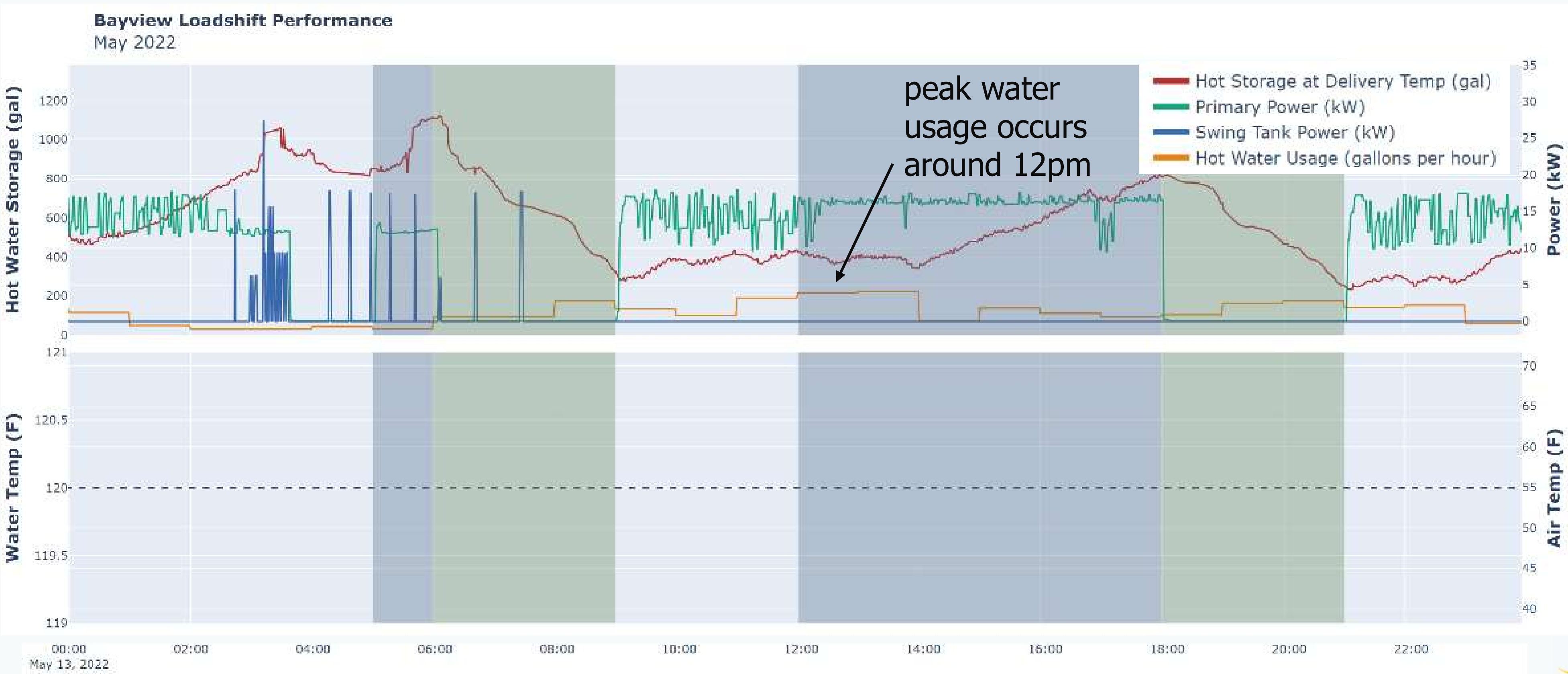
Ideal system behavior – Power draw



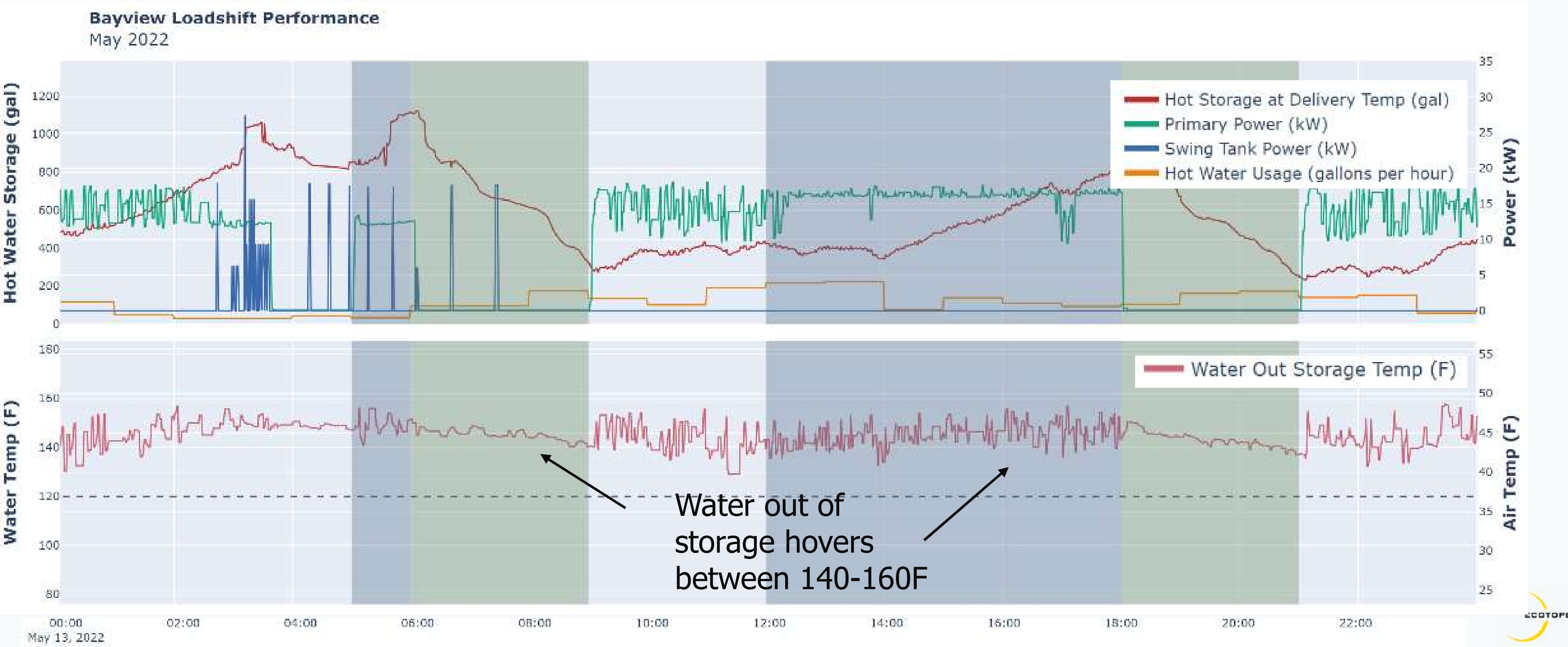
Ideal system behavior –Power draw



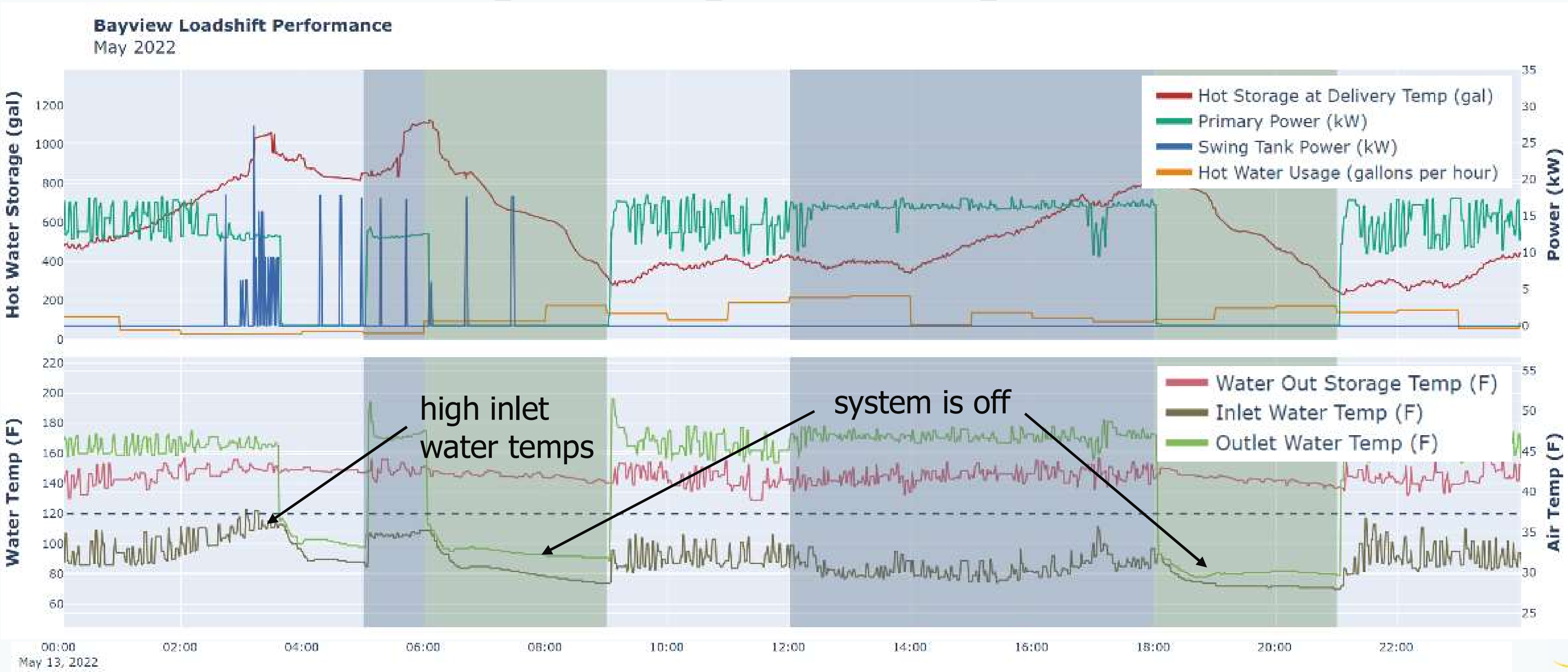
Idea system behavior –Hot water demand



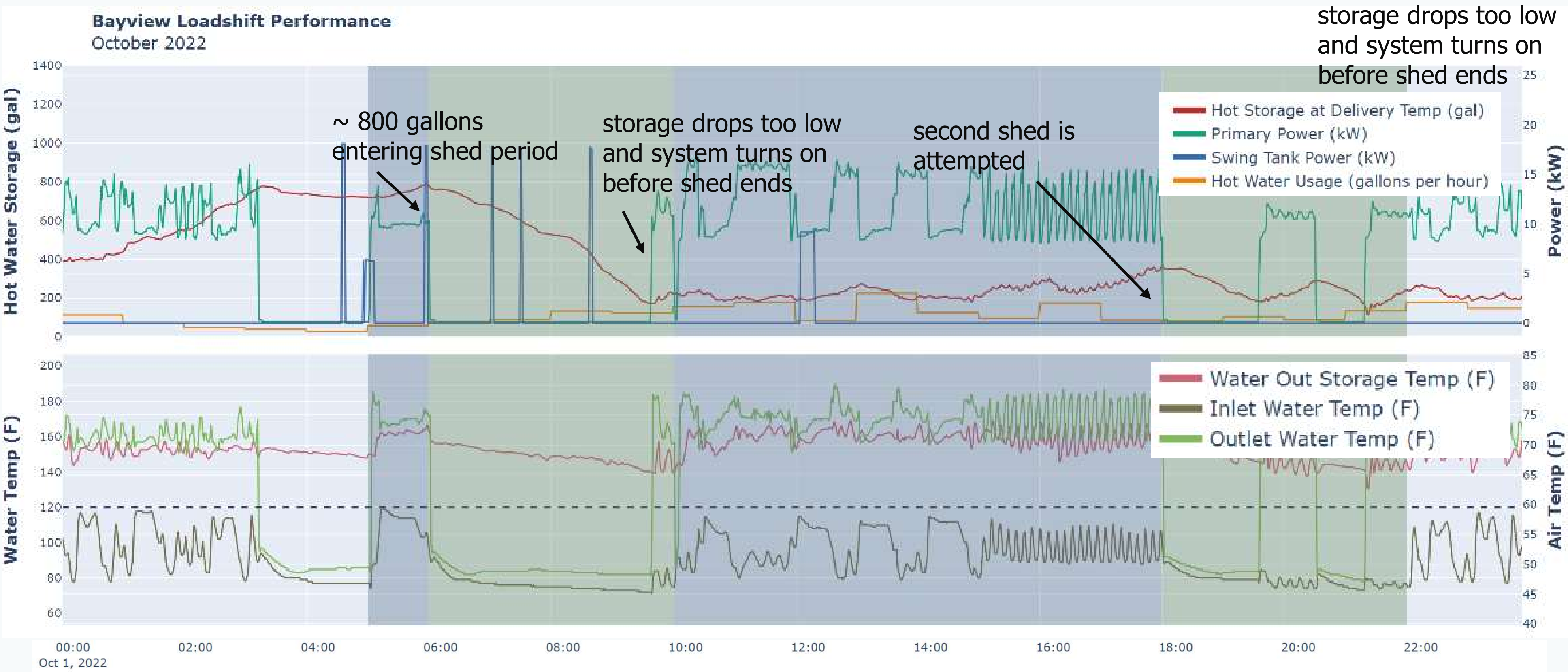
Ideal system behavior –Storage temperatures



Idea system behavior –Heat pump temperatures



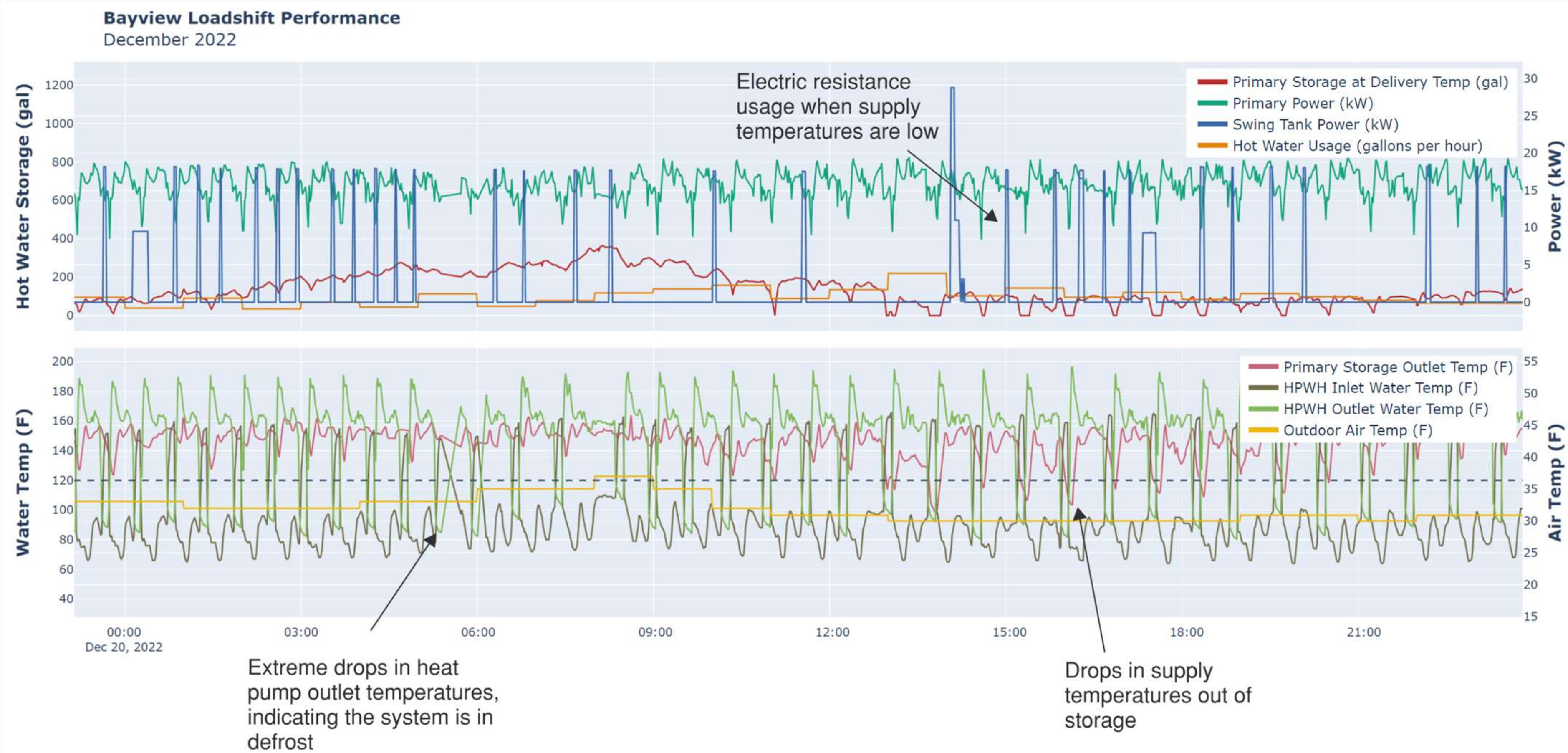
Partial shed periods



Lessons learned: defrost derating

+ **Hot Gas Defrost**
+ **20% Defrost during worst case days in December**

Defrost

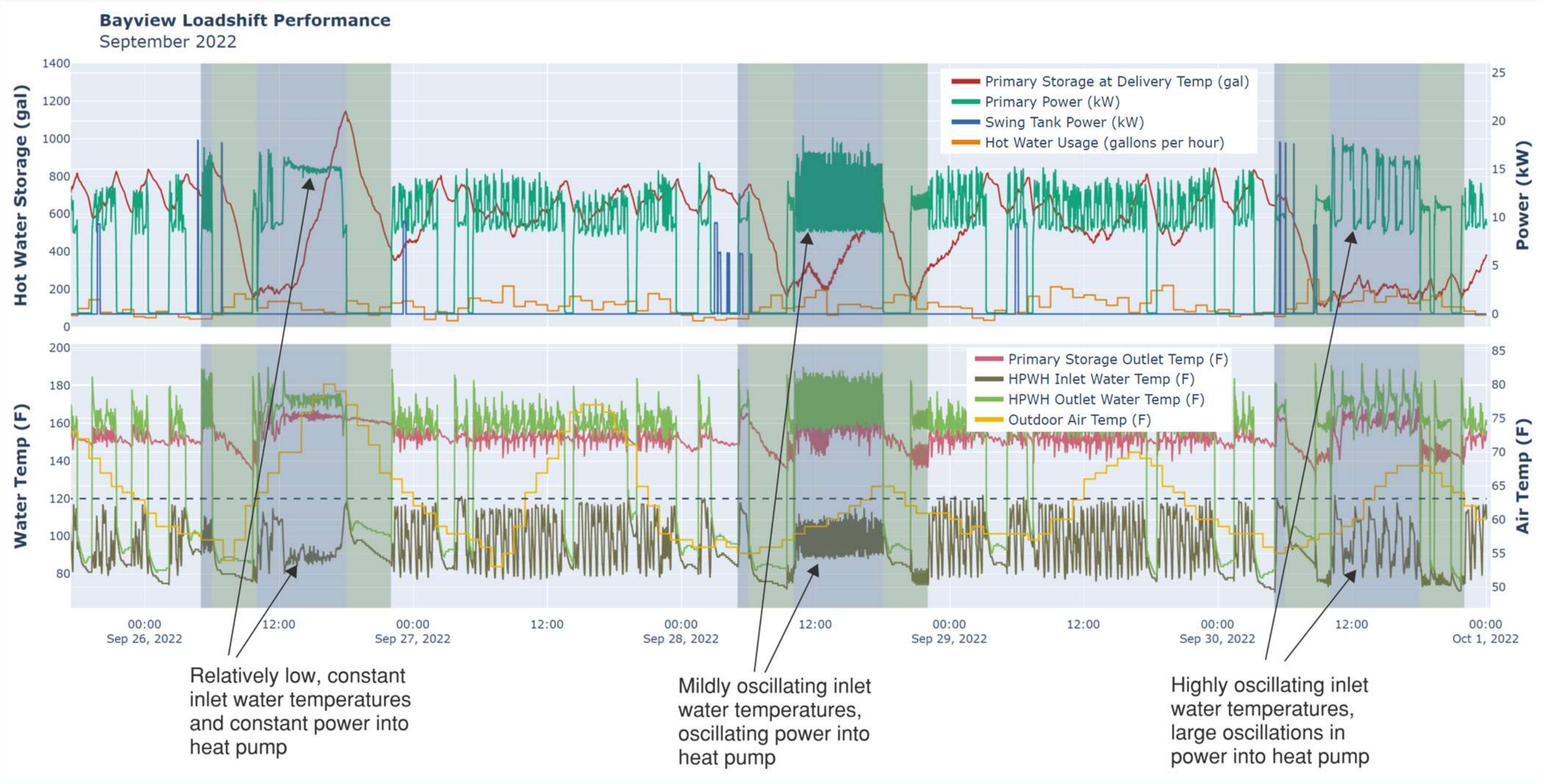


Bayview Loadshift Performance
December 2022
Hot Water Storage (gal)
Power (kW)
Primary Storage at Delivery Temp (gal)
Primary Power (kW)
Swing Tank Power (kW)
Hot Water Usage (gallons per hour)
Electric resistance usage when supply temperatures are low
Water Temp (F)
Air Temp (F)
Primary Storage Outlet Temp (F)
HPWH Inlet Water Temp (F)
HPWH Outlet Water Temp (F)
Outdoor Air Temp (F)
00:00
Dec 20, 2022
03:00
06:00
09:00
12:00
15:00
18:00
21:00
Extreme drops in heat pump outlet temperatures, indicating the system is in defrost
Drops in supply temperatures out of storage

Opportunities: heat exchanger assembly

+ **Overall system COP could be increased from 2.3 to 3.2 with improved heat exchanger controls**
+ **Mitsubishi is working to design a pre-packaged skid**

Inlet water temperature



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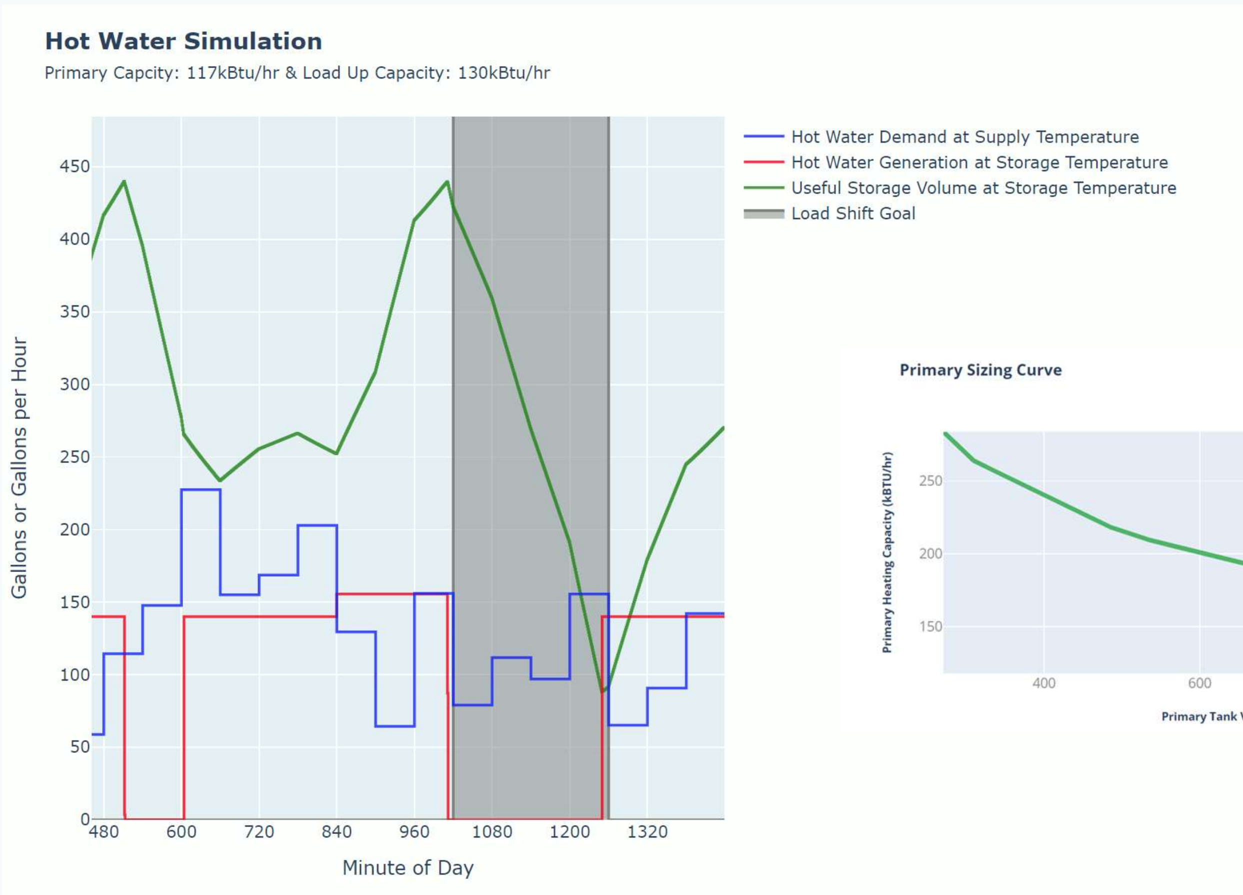
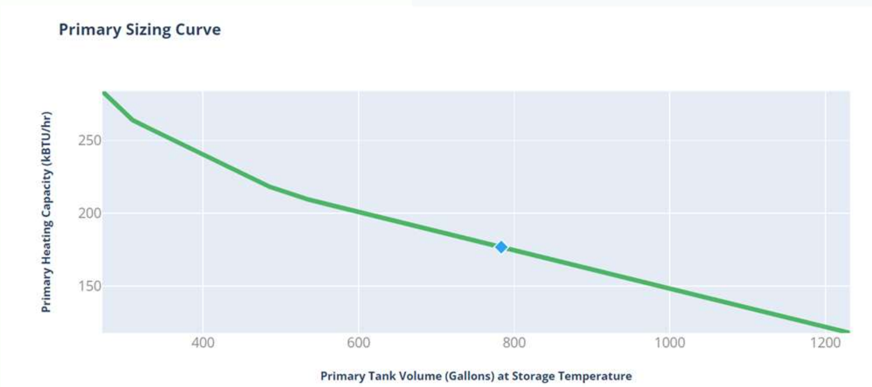
Simulations





Market-rate simulations

Load Shape: Market Rate Shed: 6-9 AM, 6-9 PM						
	Gallons Per Day Per Person	17	19	21	23	25
	Percentile Day	50%	69%	84%	93%	98%
Storage, Capacity	(210 gal, 320kBTU/hr)	0.61	0.55	0.5	0.5	0.46
	(270 gal, 280kBTU/hr)	0.57	0.52	0.49	0.45	0.43
	(330 gal, 260kBTU/hr)	0.52	0.48	0.43	0.39	
	(410 gal, 240kBTU/hr)	0.61	0.55	0.51		
	(490 gal, 220kBTU/hr)	0.65	0.61	0.57		
	(590 gal, 200kBTU/hr)	0.73	0.68	0.65	0.61	
	(690 gal, 190kBTU/hr)	0.78	0.76	0.75	0.71	
	(780 gal, 180kBTU/hr)	0.81	0.79	0.77	0.72	
	(860 gal, 170kBTU/hr)	0.87	0.83	0.81	0.79	0.77
	(930 gal, 160kBTU/hr)	0.92	0.87	0.83	0.81	0.79
	(1000 gal, 150kBTU/hr)	0.96	0.91	0.87	0.83	0.81
	(1050 gal, 140kBTU/hr)	0.99	0.94	0.89	0.85	0.82
	(1100 gal, 130kBTU/hr)	1	0.97	0.92	0.88	0.85
	(1150 gal, 130kBTU/hr)	1	0.99	0.94	0.9	0.87
	(1190 gal, 120kBTU/hr)	1	1	0.97	0.93	
	(1230 gal, 120kBTU/hr)	1	1	0.98	0.95	

Load Shape: Market Rate Shed: 5-9 PM						
	Gallons Per Day Per Person	17	19	21	23	25
	Percentile Day	50%	69%	84%	93%	98%
Storage, Capacity	(210 gal, 320kBTU/hr)	0.74	0.71	0.68	0.63	0.59
	(270 gal, 280kBTU/hr)	0.71	0.64	0.59	0.56	0.52
	(330 gal, 260kBTU/hr)	0.7	0.65	0.63	0.6	0.57
	(410 gal, 240kBTU/hr)	0.56	0.53	0.47	0.47	0.48
	(490 gal, 220kBTU/hr)	0.63	0.58	0.53	0.55	0.49
	(590 gal, 200kBTU/hr)	0.75	0.7	0.65	0.59	0.55
	(690 gal, 190kBTU/hr)	0.85	0.79	0.74	0.67	0.63
	(780 gal, 180kBTU/hr)	0.93	0.86	0.82	0.78	0.78
	(860 gal, 170kBTU/hr)	1	0.98	0.92	0.72	0.73
	(930 gal, 160kBTU/hr)	0.98	0.87	0.84	0.83	0.81
	(1000 gal, 150kBTU/hr)	1	0.97	0.95	0.91	0.88
	(1050 gal, 140kBTU/hr)	1	1	1	0.97	0.93
	(1100 gal, 130kBTU/hr)	1	1	1	1	0.98
	(1150 gal, 130kBTU/hr)	1	1	1	1	1
	(1190 gal, 120kBTU/hr)	1	1	1	1	0.97
	(1230 gal, 120kBTU/hr)	1	1	1	1	0.98

Affordable housing simulations

Load Shape: Senior Affordable (Bayview) Shed: 6-9 AM, 6-9 PM						
	Gallons Per Day Per Person	17	19	21	23	25
	Percentile Day	50%	69%	84%	93%	98%
Storage, Capacity	(120 gal, 180kBTU/hr)	0.69	0.64	0.6	0.57	0.54
	(200 gal, 170kBTU/hr)	0.67	0.66	0.67	0.65	0.62
	(270 gal, 160kBTU/hr)	0.71	0.68	0.59	0.55	0.5
	(340 gal, 160kBTU/hr)	0.99	0.9	0.85	0.78	0.72
	(410 gal, 150kBTU/hr)	1	0.96	0.9	0.82	0.78
	(480 gal, 140kBTU/hr)	1	1	0.97	0.82	0.64
	(550 gal, 130kBTU/hr)	1	1	0.97	0.78	
	(610 gal, 130kBTU/hr)	1	1	0.98	0.77	0.58
	(680 gal, 120kBTU/hr)	1	1	0.95	0.71	
	(855 gal, 130kBTU/hr)	1	1	1	0.97	0.79

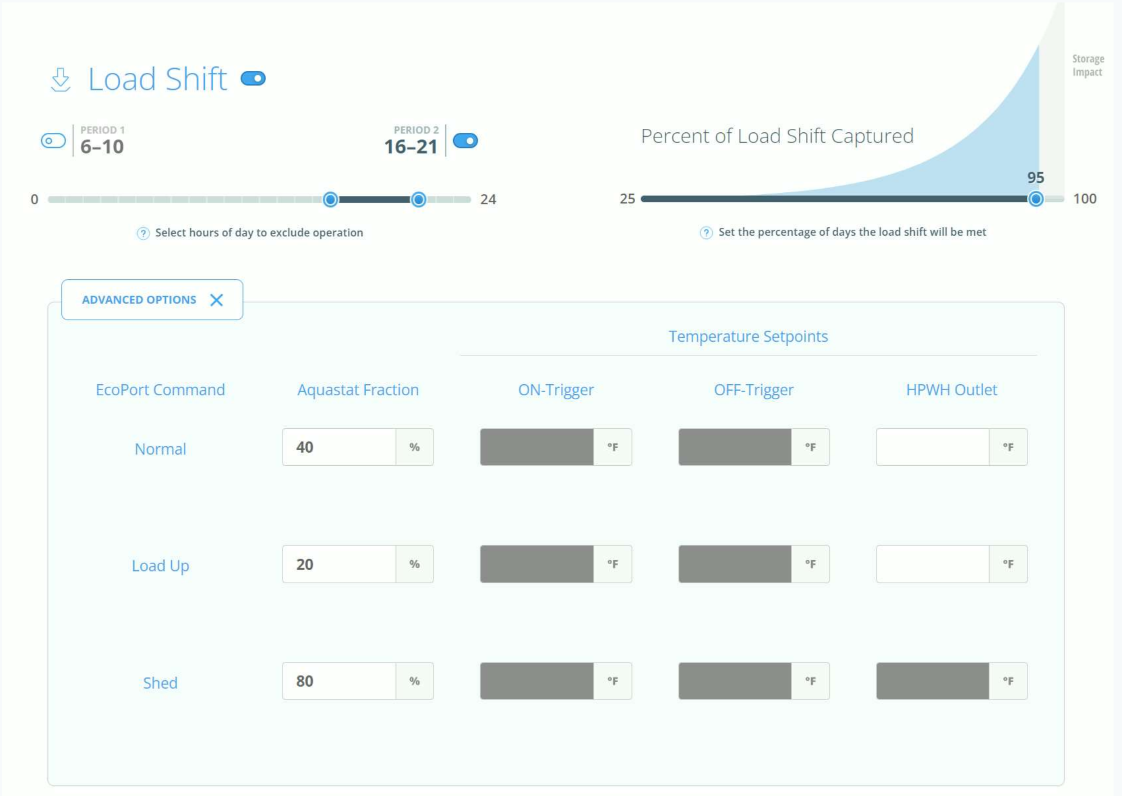
Load Shape: Senior Affordable (Bayview) Shed: 5-9 PM						
	Gallons Per Day Per Person	17	19	21	23	25
	Percentile Day	50%	69%	84%	93%	98%
Storage, Capacity	(120 gal, 180kBTU/hr)	0.7	0.65	0.62	0.55	0.51
	(200 gal, 170kBTU/hr)	0.76	0.7	0.64	0.57	0.53
	(270 gal, 160kBTU/hr)	0.6	0.54	0.51	0.44	0.43
	(340 gal, 160kBTU/hr)	0.59	0.65	0.63	0.59	0.5
	(410 gal, 150kBTU/hr)	0.83	0.78	0.7	0.63	0.55
	(480 gal, 140kBTU/hr)	0.86	0.79	0.75	0.66	0.62
	(550 gal, 130kBTU/hr)	0.9	0.85	0.92	0.72	0.58
	(610 gal, 130kBTU/hr)	0.98	0.91	0.92	0.77	0.84
	(680 gal, 120kBTU/hr)	1	0.99	0.96	0.78	0.54
	(855 gal, 130kBTU/hr)	1	1	1	0.94	0.73

Bayview Sizing

Buildings of the future vision

Improved tools to optimize sizing and controls

+ Update Ecosizer for improved load shift sizing (In progress).
+ Develop test protocol for quantifying defrost derate (Needs Funding).
+ Update Ecosim with lab and field results (Needs Funding).
+ Add load shifting to Ecosim (Needs Funding).
+ Develop time-of-use pricing algorithms for load shifting (Needs Funding).
+ Integrate real-time feedback to optimize control strategy (Needs Funding).



Bayview Tower Apts – Interactive Tour

https://www.thinglink.com/card/1507453763189735425

Questions?

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