BUILDINGENERGY NYC

Multifamily Central Heat Pump Water Heating Retrofits: Learning the Hard Way

El Hadji Niang and Nick Young,
Association for Energy Affordability

Curated by Amalia Cuadra (EN-POWER)

Northeast Sustainable Energy Association (NESEA)
October 12, 2023

ASSOCIATION FOR ENERGY AFFORDABILITY INC.

Multifamily Central Heat Pump Water Heating Retrofits

Learning the Hard Way

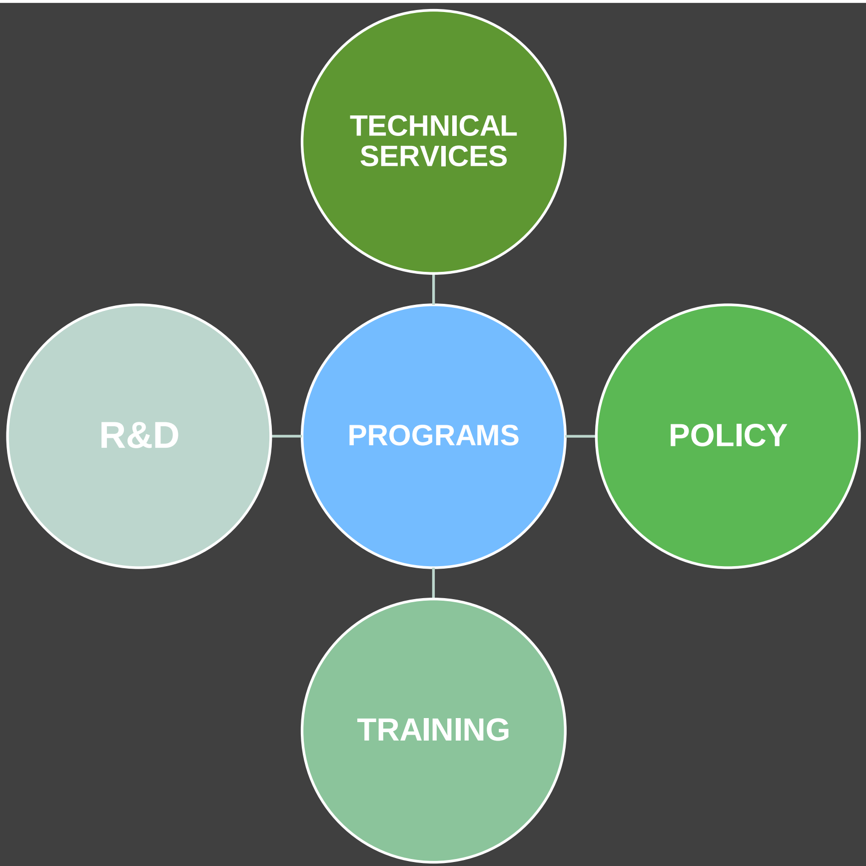
Nick Young (he/him)
Director, Zero Carbon Buildings

El Hadji Niang
Energy Efficiency Engineer

October 12, 2023

BuildingEnergyNYC 2023

About AEA

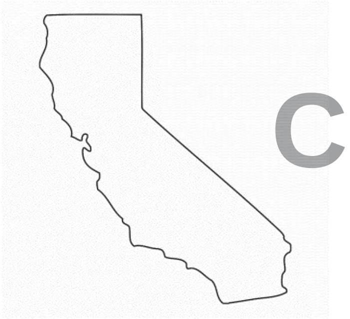

TECHNICAL SERVICES
R&D
PROGRAMS
POLICY
TRAINING

The Challenge

Electrify Existing Central Fossil Fuel Domestic Hot Water

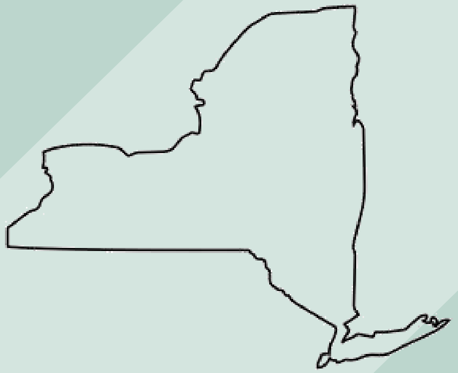
Funding

Project Funding Sources

	FEDERAL	STATE	REGIONAL	OWNER
 NY	Department of Energy · United States of America	New York State of Opportunity · NYSERDA	conEdison	$
 CA		State of California Energy Commission Since 1975 · LIWP Multifamily · TECH Clean California	BAYREN · SoCalREN	$

The Projects

New York Projects



Project Sites – New York

Site	Install Type	Dwelling Units	HPWH Product	Recovery (btu/hr)	Storage Volume (gal)	Storage Ratio (gal/ton)	Status
Bronx 1	Retrofit	65	Lync	988k	975	12	Construction Complete – Pending electrical service
Bronx 2	Retrofit	38	Lync	658k	585	11	Construction Complete – Pending electrical service
Bronx 3	Retrofit	40	Lync	658k	575	10	Construction Complete – Pending electrical service
Bronx 4	Retrofit	21	Lync	420k	585	17	Construction Complete – Pending electrical service
Bronx 5	Retrofit	38	Aermec	455k	475	13	Construction complete \ Pending Control Wiring & Electrical service
Far Rockaway	Retrofit	119	Lync	988k	1500	18	Construction Complete - Pending Startup (10/17/2023)
Manhattan	Retrofit	50	Mitsubishi	408k	900	26	Construction Complete - Pending electrical service

Bronx 1


DOMESTIC HOT WATER
DOMESTIC COLD WATER
GLYCOL
GLYCOL
GLYCOL


WATER

Bronx 2

Bronx 4


HOT WATER
DOMESTIC HOT WATER
GLYCOL
DOMESTIC HOT WATER
GLYCOL
GLYCOL

Bronx 5

Manhattan

Manhattan 2

California Projects

Project Sites - California

Site	Install Type	Dwelling Units	HPWH Product	Recovery (btu/hr)	Storage Volume (gal)	Storage Ratio (gal/ton)	Status
San Francisco 1	Retrofit	81	Mitsubishi	273k	357	16	Complete
San Francisco 2	Retrofit	133	Mitsubishi	273k	2,150	95	Complete
San Francisco 3	Retrofit	119	Mitsubishi	273k	1,350	59	Complete
East Palo Alto	Retrofit Retrofit	28 20	Mitsubishi	273k 273k	300 300	13 13	Complete
San Diego	Retrofit	74	Mitsubishi	273k	785	35	Contracting
Fontana	Retrofit	90	Mitsubishi	136k 136k	300 600	26 52	Contracting
Fresno	Retrofit	53 53	WaterDrop	139k 139k	505 505	44 44	Commissioning

San Francisco 1

San Francisco 2

San Francisco 3

East Palo Alto

Fresno

The Equipment

Lync Aegis A

		Models		
		250	350	500
Refrigerant		R744 (CO_2)		
Capacity (77°F ambient)	MBH	210	329	494
Capacity (14°F ambient)	MBH	133	223	310
Input Power	kW	16.1	26.8	41.9
Power Supply		480 V / 3 ph / 60 Hz		
Sound Pressure	dB(A)	68	73	76
Configuration		HP, Secondary Hx Skid, Tank(s)		
Storage Volume	Gal	250, 500		

Mitsubishi Heat$_2$O

MITSUBISHI ELECTRIC TRANE HVAC US

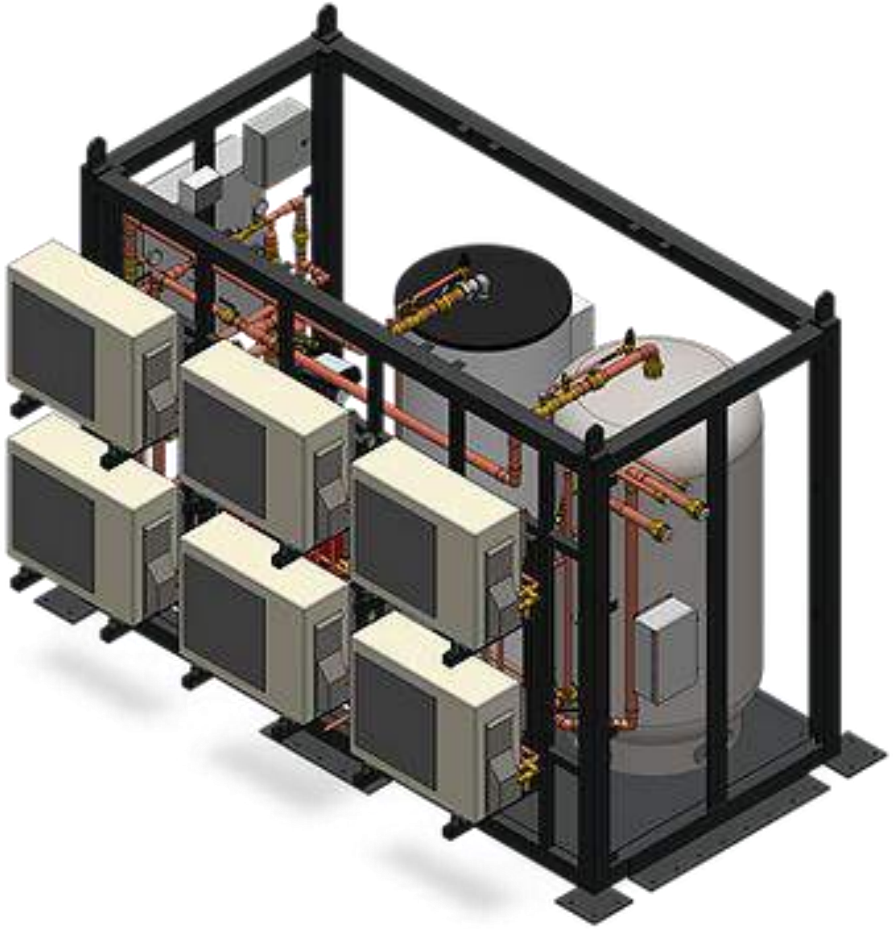
		Model
		QAHV
Refrigerant		R744 (CO_2)
Capacity (77°F ambient)	MBH	136
Capacity (15°F ambient)	MBH	136
Input Power	kW	16.1
Power Supply		208/230V* / 3 ph / 60 Hz
Sound Pressure	dB(A)	56
Configuration		HP, Secondary Hx (Skid), Tank(s)
Storage Volume	Gal	175, 285, 500

*480V will be available in future

Aermec NRK700

		Model
		Aermec NRK700
Refrigerant		R410A
Capacity (45°F ambient)	MBH	593
Capacity (12°F ambient)	MBH	455
Input Power (45°F ambient)	kW	57.2
Power Supply		460V* / 3 ph / 60 Hz
Sound Pressure	dB(A)	59.9 at 33ft
Configuration		2-pipe heat pump unit
Storage Volume		Custom engineered per project

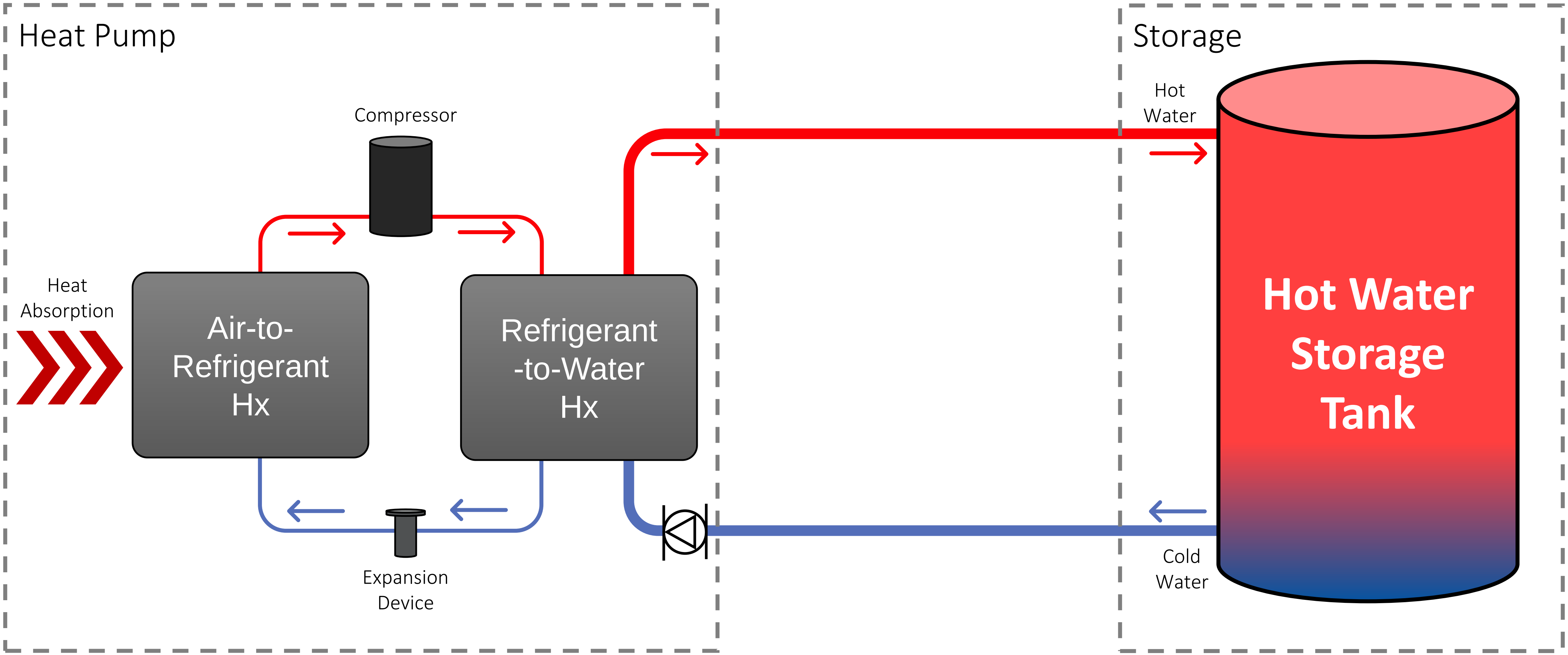
WaterDrop



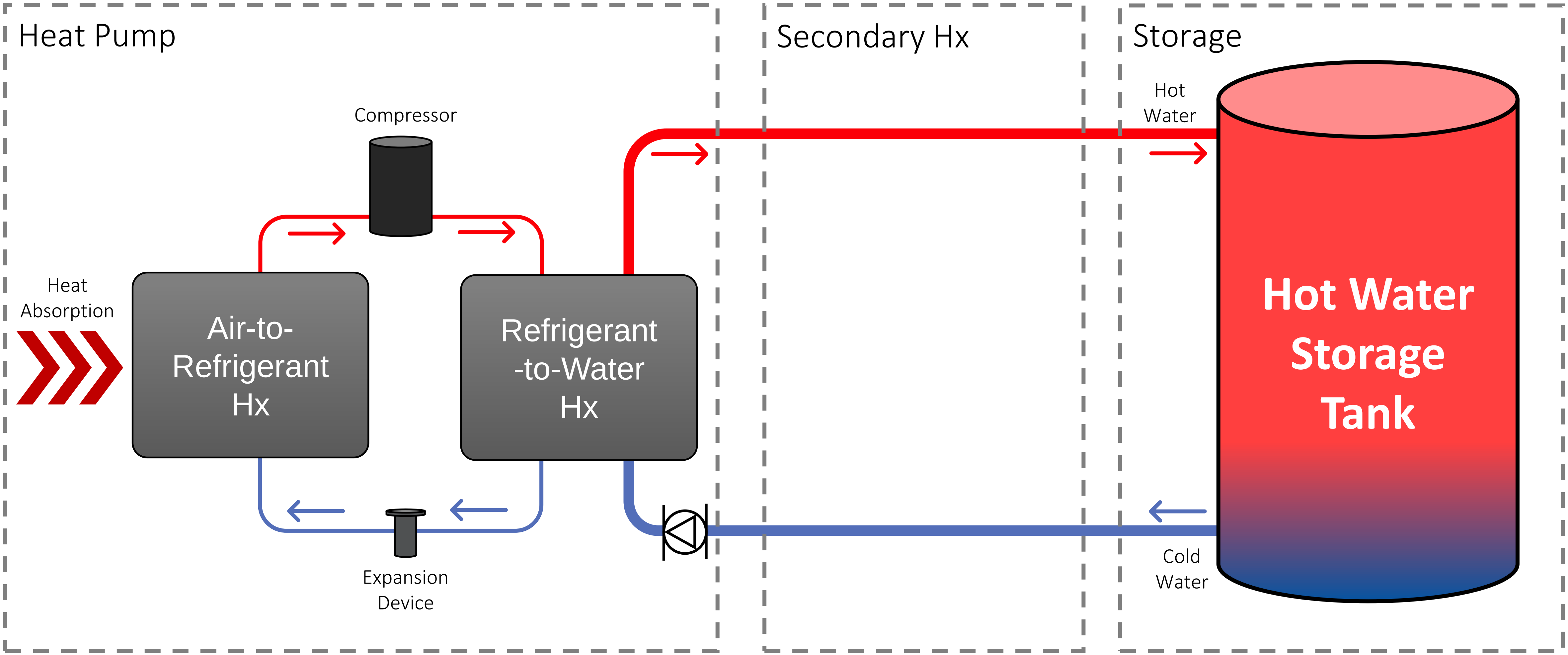
		Model
		WaterDrop / Droplet
Refrigerant		R744 (CO_2)
Capacity (77°F ambient)	MBH	31-185
Capacity (15°F ambient)	MBH	31-185
Input Power	kW	16.1
Power Supply		208/230V* / 3 ph / 60 Hz
Sound Pressure	dB(A)	37 per HP (up to 12)
Configuration		Factory-Built Skid
Storage Volume	Gal	175, 285, 500

Components

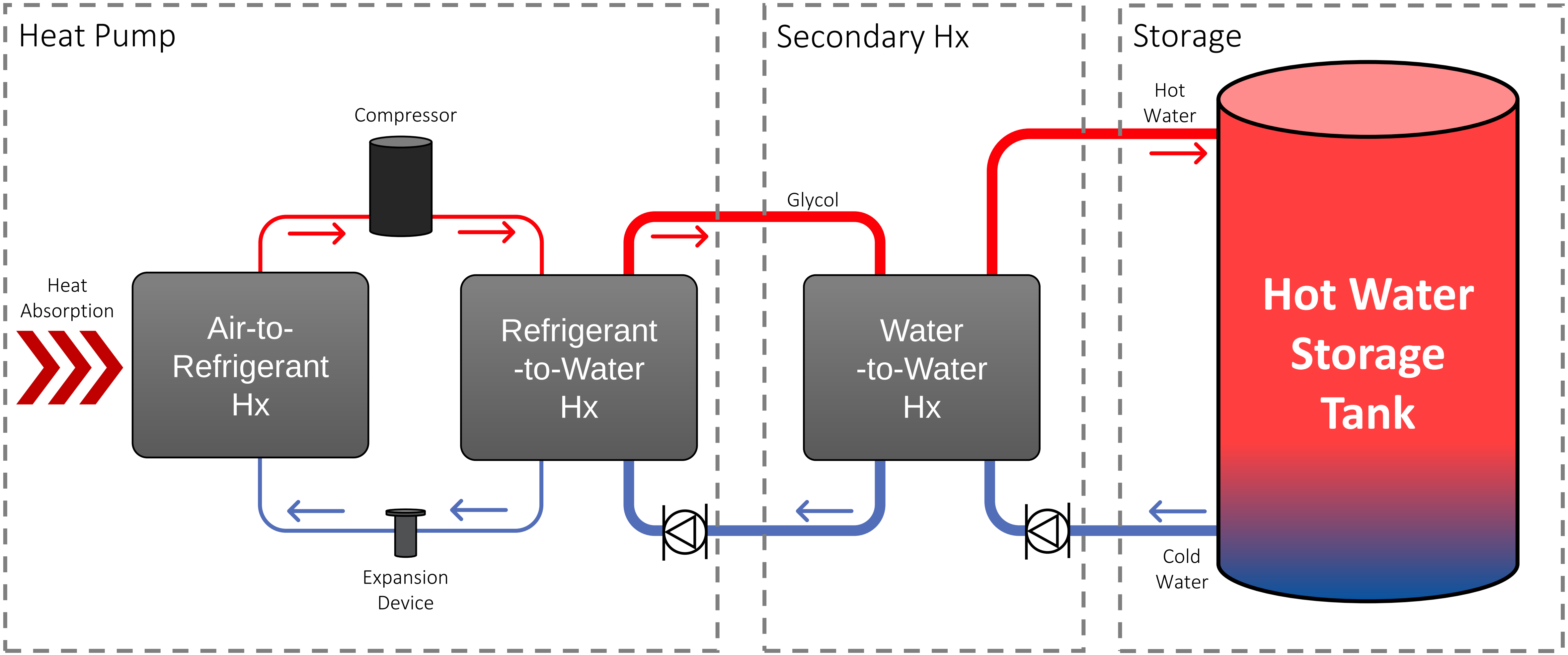
Basic HPWH Components



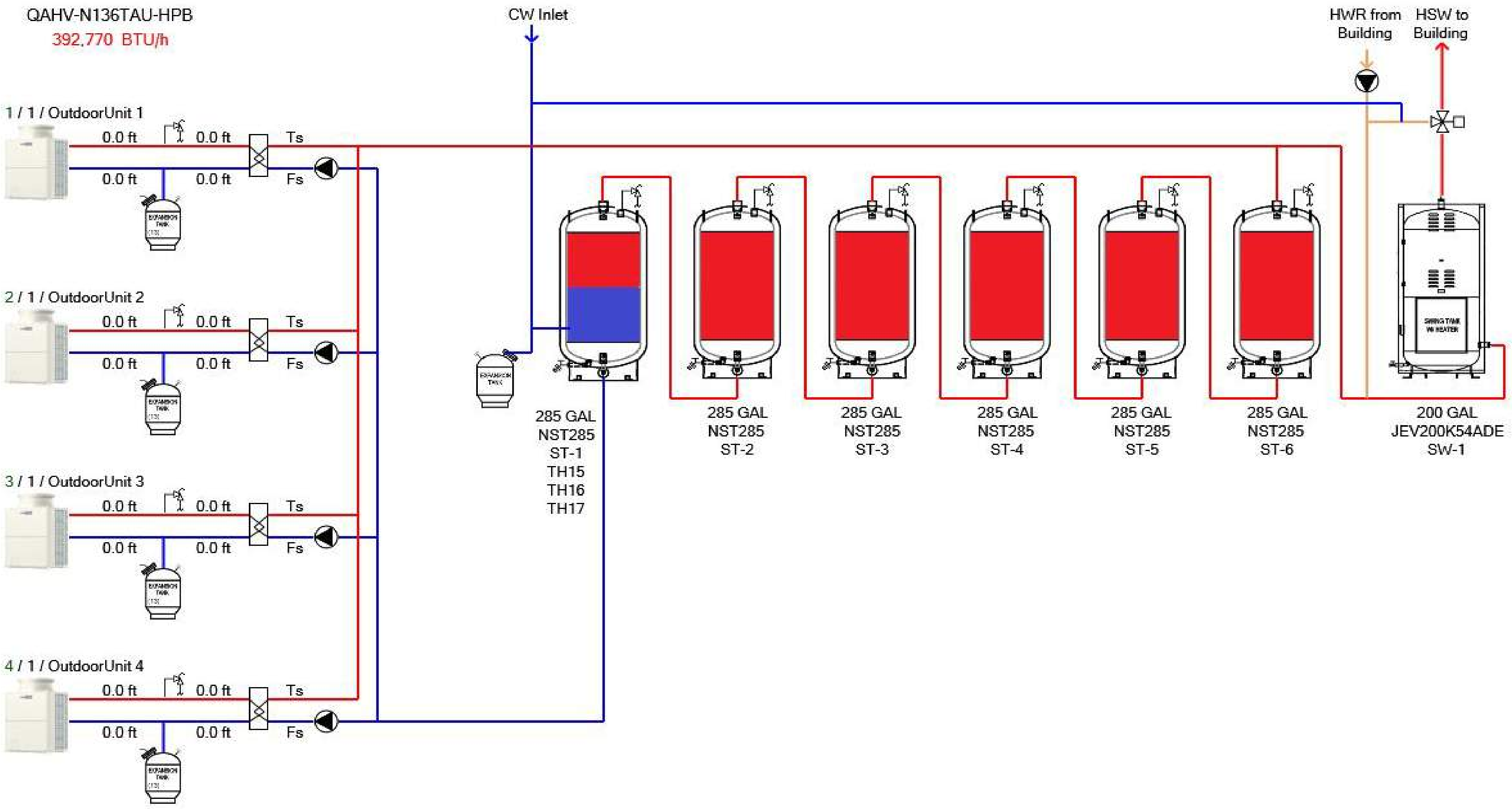
HPWH + Secondary Heat Exchanger



HPWH + Secondary Heat Exchanger



Full System Diagram Example



Design Considerations

Impact of Outdoor Air Temperature

Rated Capacity vs. Needed Capacity

e360a performance for 140F LWT

H2O inlet temperature (f)	40	40	40	40	40	40	40	40	40	40
H2O outlet temperature (f)	130	140	140	140	140	140	140	140	140	140
Ambient DB (f)	10	24	30	40	50	60	70	80	90	100
Ambient RH	50%	50%	50%	50%	50%	50%	50%	50%	50%	50%
Heating capacity (kbtu/h)	98	126	141	171	205	241	287	333	351	351
Cooling capacity (kbtu/h)	60	76	88	112	140	171	211	252	269	269
Unit heating COP	2.4	2.4	2.5	2.8	3.0	3.2	3.4	3.6	3.8	3.9
H2O flow rate (gpm)	2.2	2.5	2.8	3.4	4.1	4.8	5.7	6.6	7.0	7.0
H2O flow rate (gph)	130	151	169	205	245	288	343	399	420	420

Pay Attention when sizing and selecting equipment!

Sizing Example – Aermec NYK

PERFORMANCE SPECIFICATIONS

AERMEC – NYK Series

		NYK 500
Heating performance * °F / 120.0 °F, Outside air 47 °F (2)		
Heating capacity	BTU/h	347,087
Input power	kW	35.02
Heating total input current	A	53
COP	kW/kW	2.904
Water flow rate system side	gpm	62.09
Heating performance * °F / 120.0 °F, Outside air 17 °F (3)		
Heating capacity	BTU/h	243,246
Input power	kW	34.43
COP	kW/kW	2.071
Water flow rate system side	gpm	62.09

(1) Reference conditions: AHRI std 550/590 I-P; Service side water 54.0°F / 44.0°F; Outside air 95°F
(2) Reference conditions: AHRI std 550/590 I-P; Service side water * °F / 120.0°F; Outside air 47°F
(3) Reference conditions: AHRI std 550/590 I-P; Service side water * °F / 120.0 °F; Outside air 17 °F

29% DIFFERENCE

Sizing Example – Aermec NYK

Property with 500,000 btu/hr of domestic hot water load.

To meet load:

- **New York**
  - 3x Aermec NYK 500 units
- **San Francisco**
  - 2x Aermec NYK 500 units

But with more storage capacity, you could install **2 in NYC** and **1 in SF** and meet your needs.

Audience Challenge: Rated Capacity

Aegis A Specifications

Lync® by WATTS

What is the nominal rated capacity in MBH of the “500” unit below?

At what outdoor temperature?

			250	350	500
	Nominal Heating Capacity** @ **77°F air**	MBH	210	329	494
	Input Power**	kW	16.1	26.8	41.9
	Nominal Recovery Capacity	GPH	233	365	549
	COP		3.8	3.6	3.5
	Outlet water temperature range		140-185°F		
	Ambient temperature range		-4-113°F		
Performance					

Electrical Capacity

Electrical Upgrades May Be Needed

Depending on added electrical load, may need to upgrade electrical service

Heat Pump Electrical Requirements

Lync by WATTS

			250	350	500
Electric	FLA	A	35.4	38.8	73.8
	MCA	A	55	72	110
	MOP	A	80	110	175
	Power Supply			480 V / 3 ph / 60 Hz	

nyle water heating systems

Voltage	Total RLA (Compressor + Fan)	Wire & Disconnect Sizing	
		MCA	MOCP/MFS
208-230/3/60	105	135	150
440-480/3/60	52	67	70

Heat Pump Electrical Requirements

MITSUBISHI ELECTRIC

Unit Type		QAHV-N136TAU-HPB(-BS)
Nominal Heating Capacity (208/230V)	Btu/h (kW)	136,480 (40)
Guaranteed Operating Range *1	°F (°C)	-13 to 109.4 (-25 to 43)
Outlet Water Tempertaure Range	Primary Circuit only, °F (°C)	120 to 176 (48.9 to 80)
	With secondary HEX, °F (°C)	120 to 158 (48.9 to 70)
Inlet Water Temperature Range	°F (°C)	41 to 145 (5 to 62.7)
External Dimensions (H x W x D)	In. (mm)	72.3 x 48.0 x 29.9 (1837 x 1220 x 760)
Net Weight (Dry)	Lbs. (kg)	868 (394)
Operating Weight	Lbs. (kg)	882 (400)
External Finish		Acrylic painted steel plate <MUNSELL 5Y 8/1 or similar>
Electrical Power Requirements	Voltage, Phase, Hertz	208/230V, 3-Phase, 60Hz
Minimum Circuit Ampacity (MCA)	A	67
Maximum Overcurrent Protection (MOP)	A	110

Heat Pump Electrical Requirements

			250	350	500
Electric	FLA	A	35.4	38.8	73.8
	MCA	A	55	72	110
	MOP	A	80	110	175
	Power Supply		480 V / 3 ph / 60 Hz		

480 V unit will require step up transformer.

Considerations:

- Cost
- Noise
- If multiple heat pump units – one large transformer vs individual transformer for each outdoor unit

Electrical Upgrades

Utility Costs

Utility Costs

When calculating utility cost, do not forget to include **demand charges**!

- More heat pumps = higher demand charges

Also look into future **electrical rate changes** or potential to switch to different electric rates to reduce costs.

More reasons to **minimize heat pumps** and **maximize storage** capacity.

Equipment Location

Indirect Gas DHW vs HPWH

Generating domestic hot water with a **steam boiler** only requires a tankless coil.

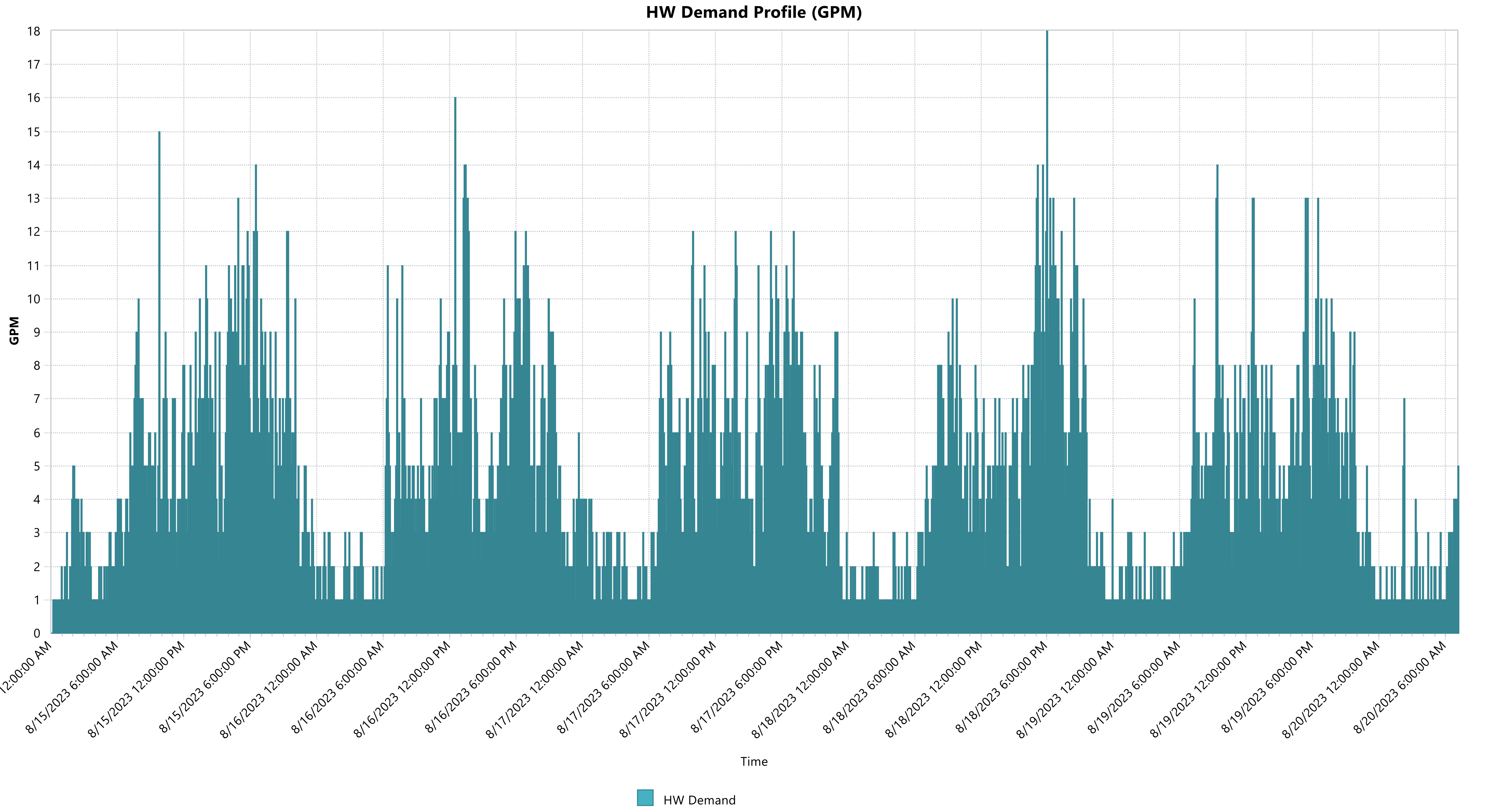
Takes up virtually no space in the building.

Indirect Gas DHW vs HPWH

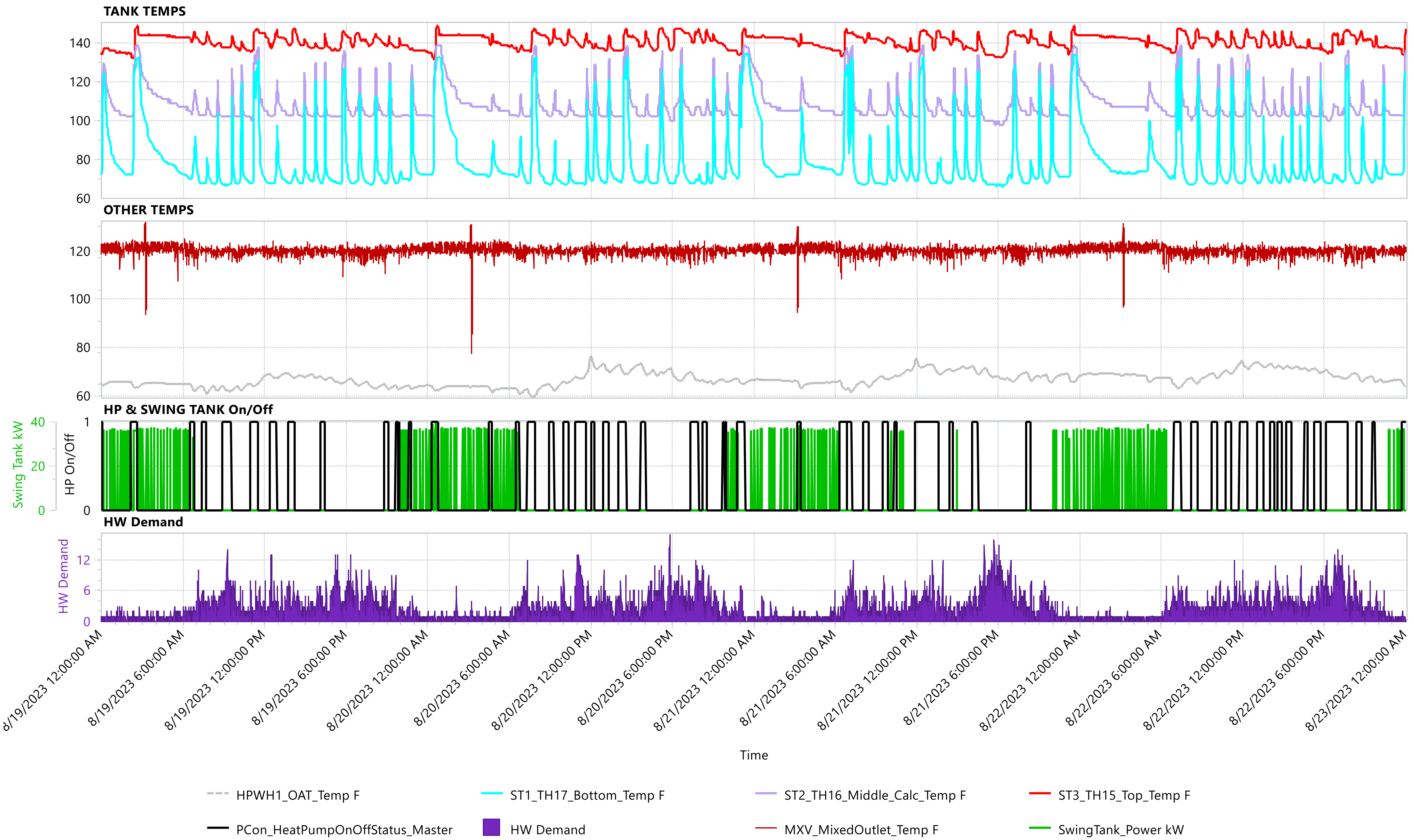
Generating domestic hot water with **heat pumps** requires outdoor units, storage tanks, heat exchangers, and electrical equipment.

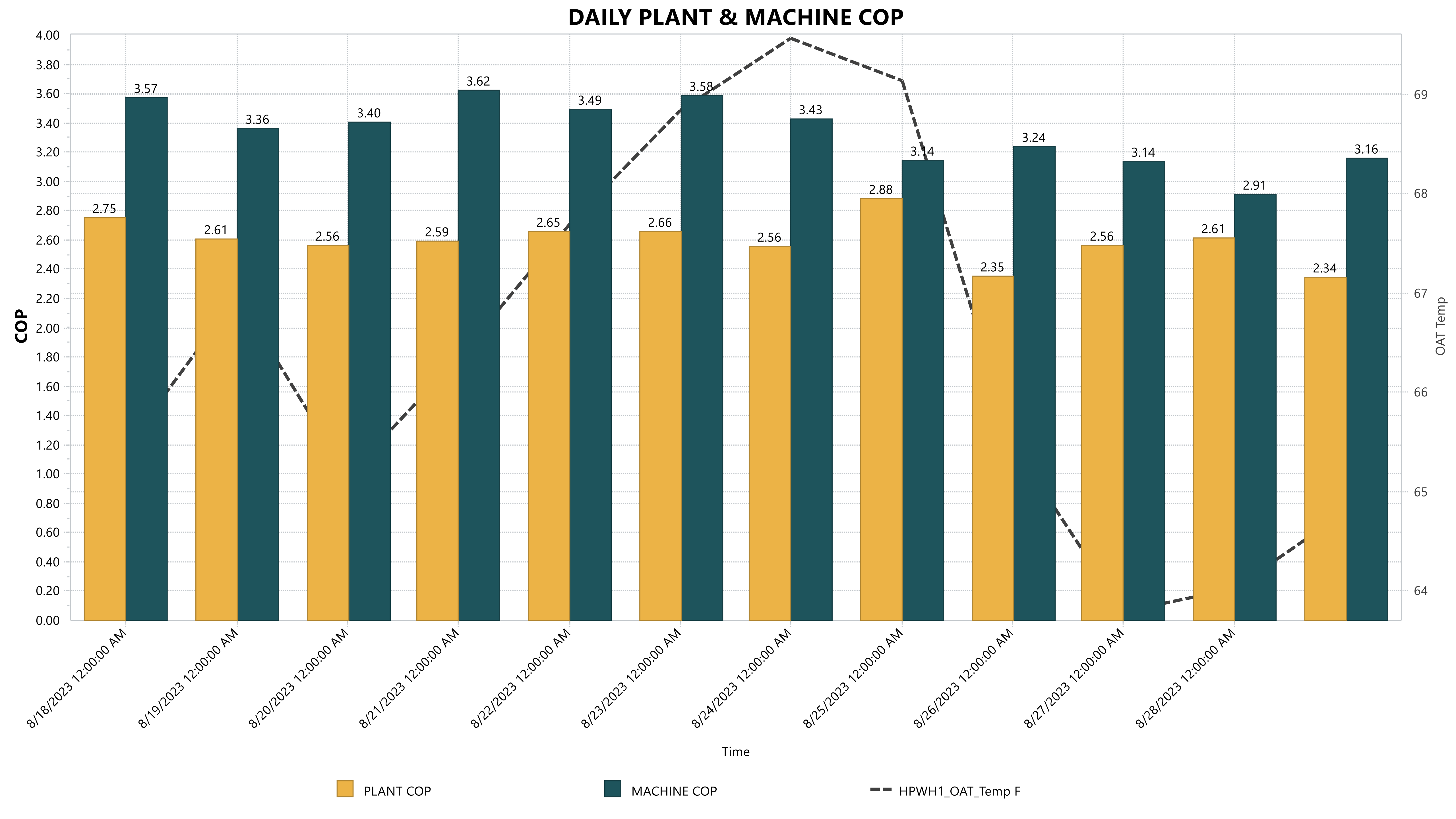
Performance Data

San Francisco 1

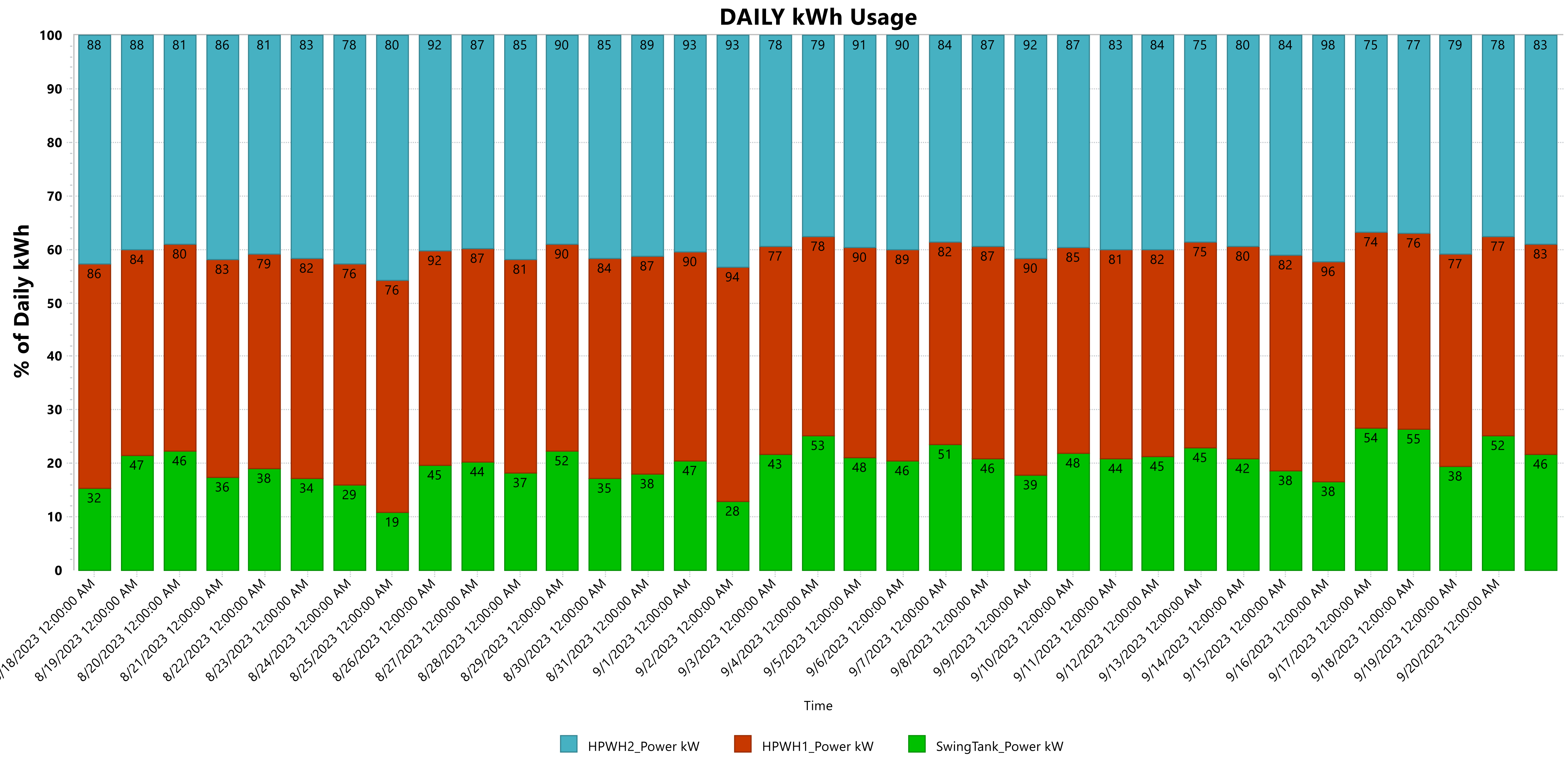

HW Demand Profile (GPM)
GPM
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
12:00:00 AM
8/15/2023 6:00:00 AM
8/15/2023 12:00:00 PM
8/15/2023 6:00:00 PM
8/16/2023 12:00:00 AM
8/16/2023 6:00:00 AM
8/16/2023 12:00:00 PM
8/16/2023 6:00:00 PM
8/17/2023 12:00:00 AM
8/17/2023 6:00:00 AM
8/17/2023 12:00:00 PM
8/17/2023 6:00:00 PM
8/18/2023 12:00:00 AM
8/18/2023 6:00:00 AM
8/18/2023 12:00:00 PM
8/18/2023 6:00:00 PM
8/19/2023 12:00:00 AM
8/19/2023 6:00:00 AM
8/19/2023 12:00:00 PM
8/19/2023 6:00:00 PM
8/20/2023 12:00:00 AM
8/20/2023 6:00:00 AM
Time
HW Demand

PLANT OPERATION





DAILY PLANT & MACHINE COP
COP
OAT Temp
Time
4.00
3.80
3.60
3.40
3.20
3.00
2.80
2.60
2.40
2.20
2.00
1.80
1.60
1.40
1.20
1.00
0.80
0.60
0.40
0.20
0.00
69
68
67
66
65
64
2.75
3.57
2.61
3.36
2.56
3.40
2.59
3.62
2.65
3.49
2.66
3.58
2.56
3.43
2.88
3.14
2.35
3.24
2.56
3.14
2.61
2.91
2.34
3.16
8/18/2023 12:00:00 AM
8/19/2023 12:00:00 AM
8/20/2023 12:00:00 AM
8/21/2023 12:00:00 AM
8/22/2023 12:00:00 AM
8/23/2023 12:00:00 AM
8/24/2023 12:00:00 AM
8/25/2023 12:00:00 AM
8/26/2023 12:00:00 AM
8/27/2023 12:00:00 AM
8/28/2023 12:00:00 AM
PLANT COP
MACHINE COP
HPWH1_OAT_Temp F



DAILY kWh Usage
% of Daily kWh
Time
HPWH2_Power kW
HPWH1_Power kW
SwingTank_Power kW

What’s next for these projects?

- Construction completion and startup
- Ongoing commissioning
- Data collection and testing
  - Load shifting – CTA 2045
  - Recirc return locations
  - Low-speed / low-dB operation at night
- Recommendations to manufacturers
  - Packaging of systems & components
  - System configurations
  - Contractor training
- Reporting

Learning the hard way

What we've learned so far

- **Deploy flow meters on existing system to avoid oversizing HPWH plant**
  - Can be the difference between a project penciling or not
  - Can be difficult to find enough straight pipe for flow meters
- **Size large equipment carefully!**
  - Limited options to choose higher capacity units were essential to comply with NYC Building Code and minimize on-site operator involvement

What we've learned so far

- **Address recirculation losses & crossover before electrifying**
  - How much are recirc losses and how much can they be reduced?
  - Addressing recirc losses and crossover may be extremely labor intensive
  - We have seen buildings where recirculation is 60%+ of existing DHW load
  - MUST be addressed first to electrify cost-effectively!

What we’ve learned so far

- **Space planning can be very hard.**
  - Securing outdoor space for unit installation presented a major challenge, particularly ensuring service clearances and tube-pull space for existing buildings.
  - May end up with tons of new equipment crammed into tiny spaces.

What we've learned so far

- **Existing structural capacity will constrain installation locations**
  - The weight of large HPWH units often strain existing building structures.
  - Avoiding rooftop installations is usually necessary to prevent overloading or major structural upgrades that would drastically increase project costs.

What we’ve learned so far

- **Cold weather complicates HPWH design.**
  - Must be careful when selecting equipment to use rated capacity at local design conditions.
  - Provide adequate provisions for freeze protection such as glycol, heat trace, or both to prevent freezing of pipes.
  - Does a system allow for drain-back of water during a power outage?
- **Try to avoid putting air-source HPWH inside.**
  - Installing Air-to-Water Heat Pumps in indoor mechanical rooms isproblematic:
    - How to handle exhaust/discharge of cold air?
    - How to ensure tempered make-up air to prevent potential pipe freezing due to frigid winter air influx?
  - Best to locate air-source HPWH outside

What we’ve learned so far

- **Code was not written for HPWH.**
  - Complying with minimum clearance requirements per code (e.g., 8ft from the property line) presented regulatory challenges.
- **Large heat pumps are not silent**
  - Ground installation of large equipment with high dBA rating can pose issues if AHJ has noise ordinance, or cause resident complaints
- **Plumbers are not HVAC contractors**
  - Plumbers are used to thermistors & aquastats, not complex BMS-level controls
  - Complex HVAC-level controls not a good fit for plumbers to install

There are more …

- Challenges in Retrofitting with Existing DHW Systems
- Limited Pool of Experienced Plumbing Contractors
- Electrical Service Capacity Limitations
- Electrical End Box Challenges
- Protection from Tenant Waste
- Coordination with Utility Companies
- Weather-Resilient Design
- Booster Installation Challenges
- Lead Time Impact
- In-Unit Access Coordination:
- Cost Justification Challenges
- Utility Upgrade Inconvenience
- Change Order Complexity

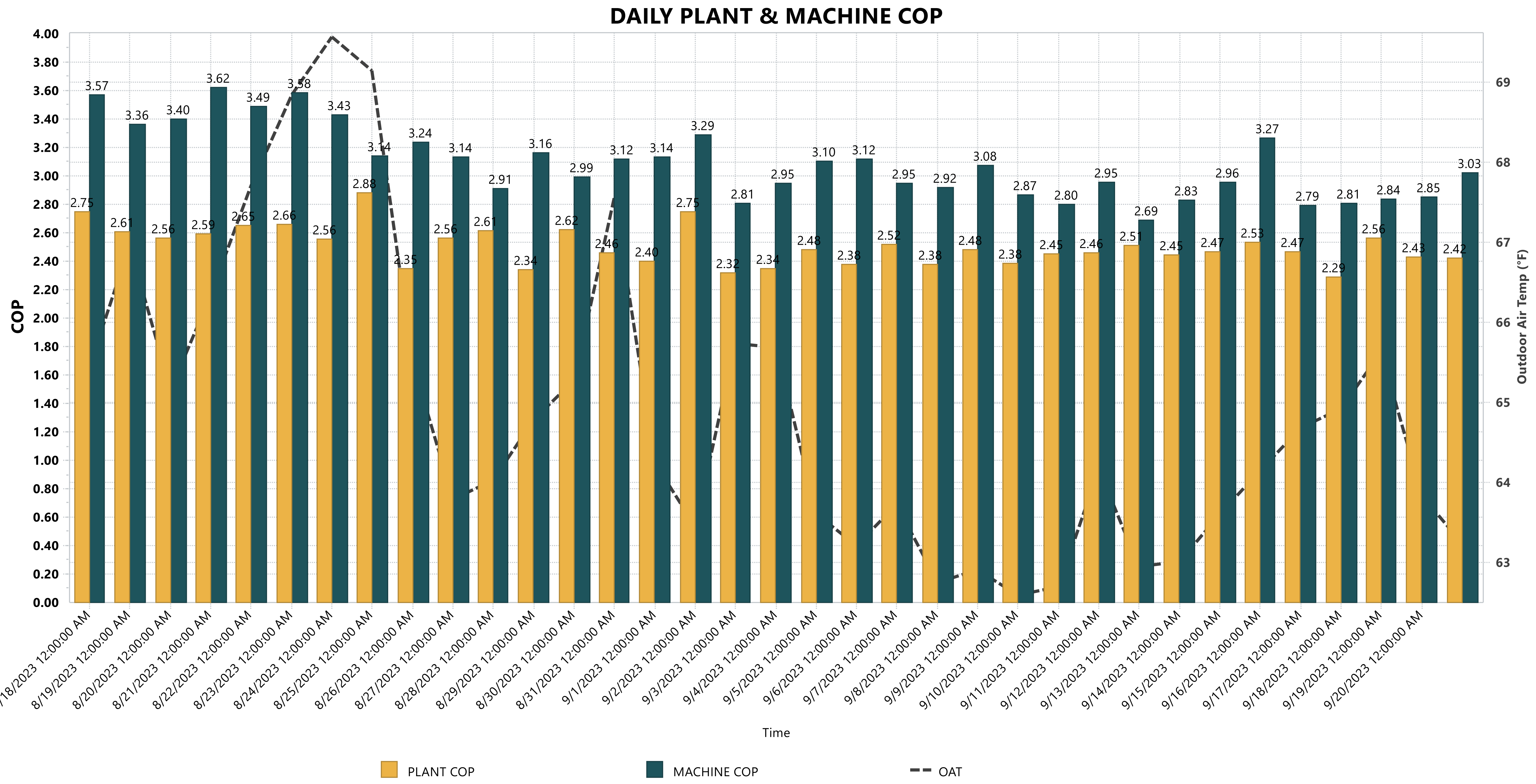
Thank You!

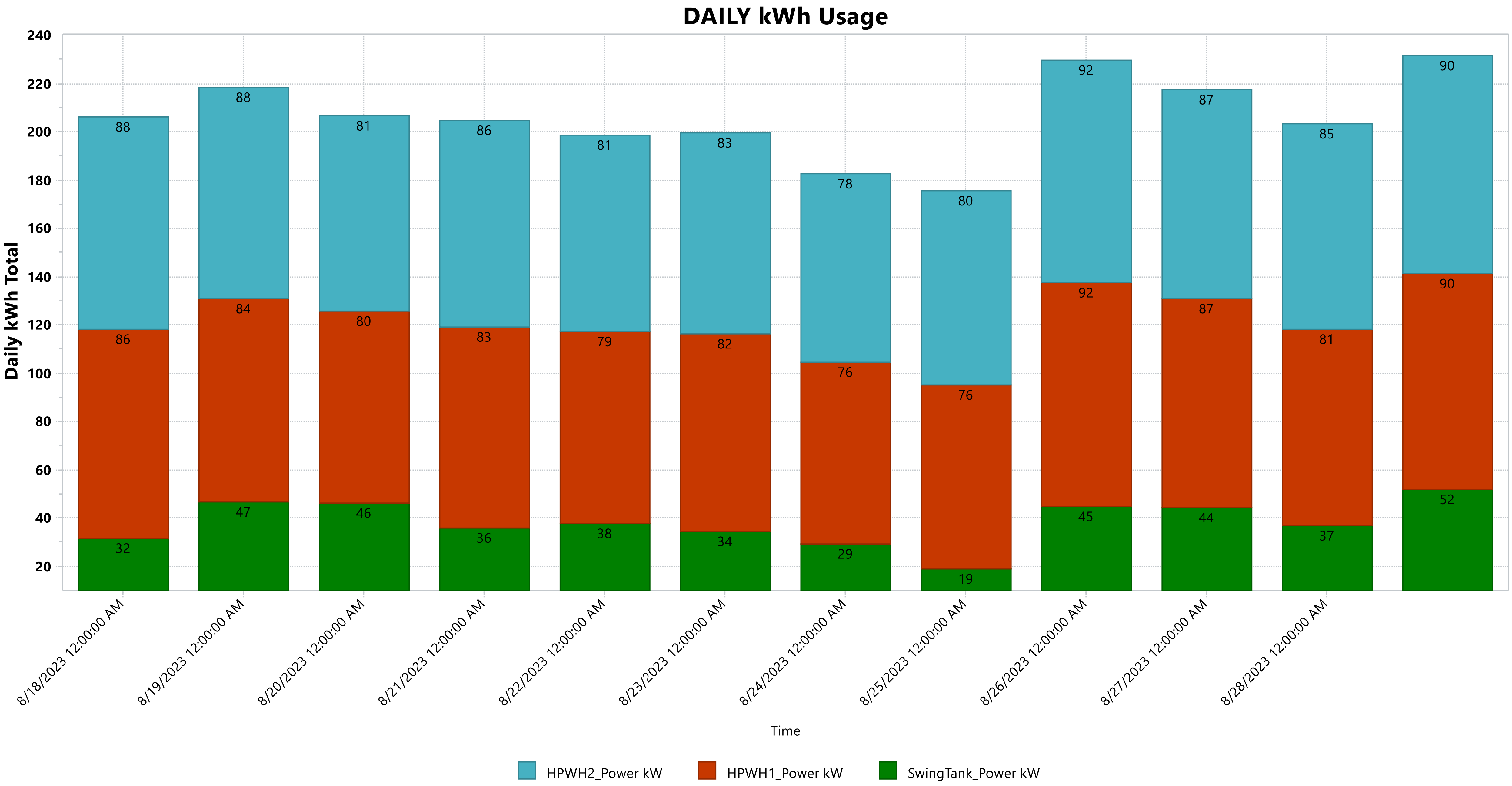
Nick Young
nyoung@aeacleanenergy.org

El Hadji Niang
eniang@aeacleanenergy.org

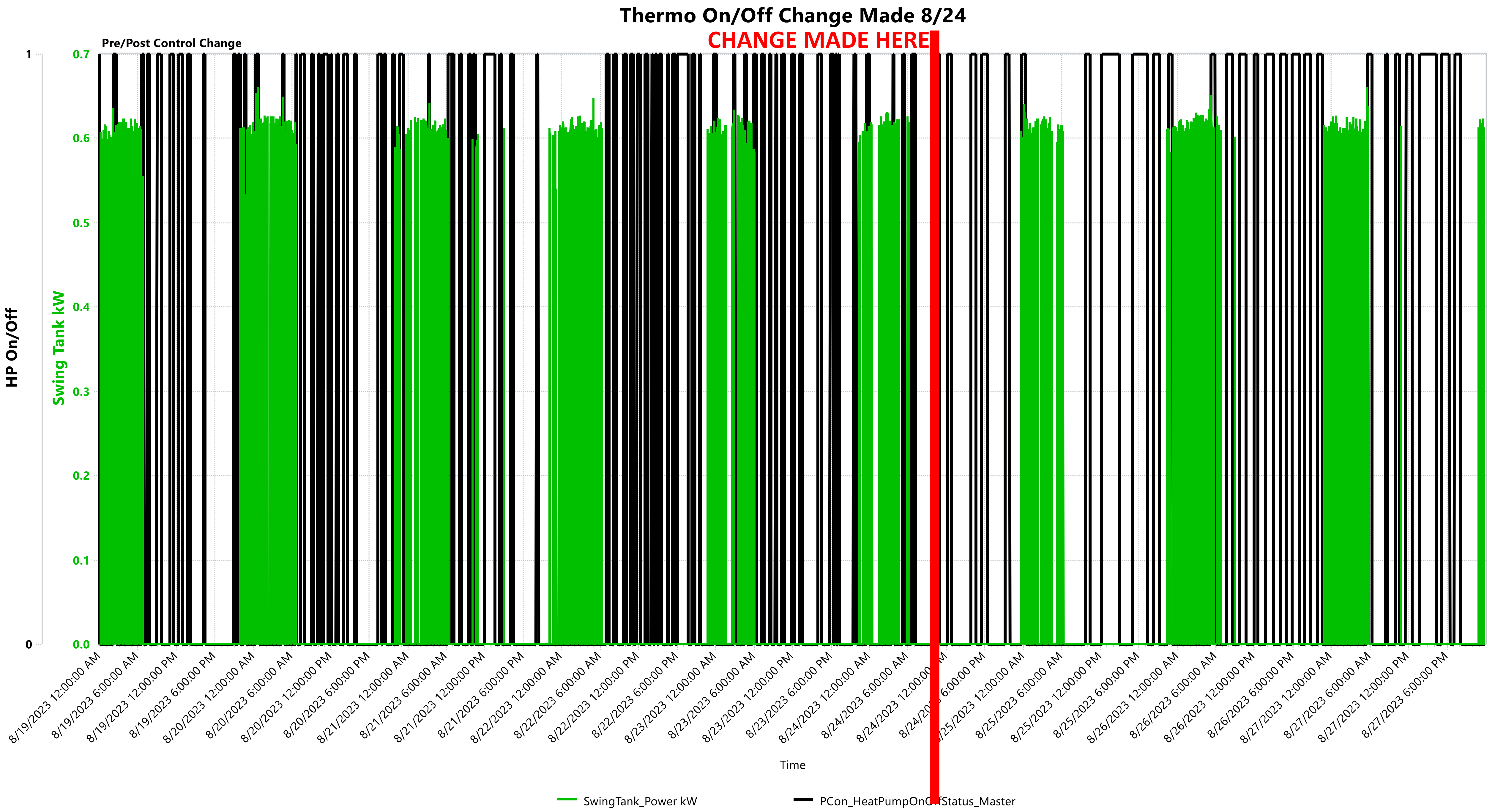
ASSOCIATION FOR ENERGY AFFORDABILITY INC.

Data Appendix

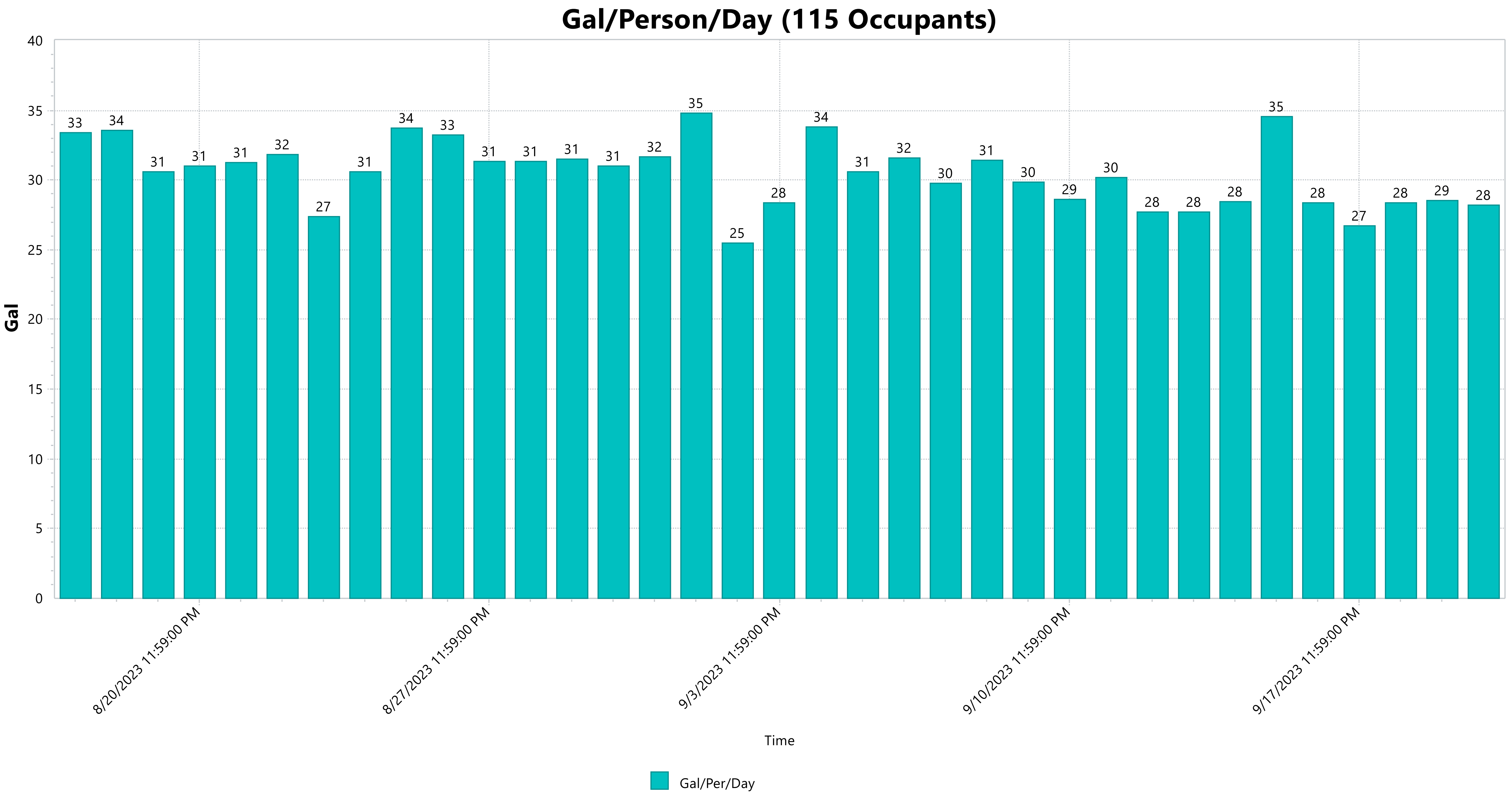

DAILY PLANT & MACHINE COP
COP
Outdoor Air Temp (°F)
Time
PLANT COP
MACHINE COP
OAT

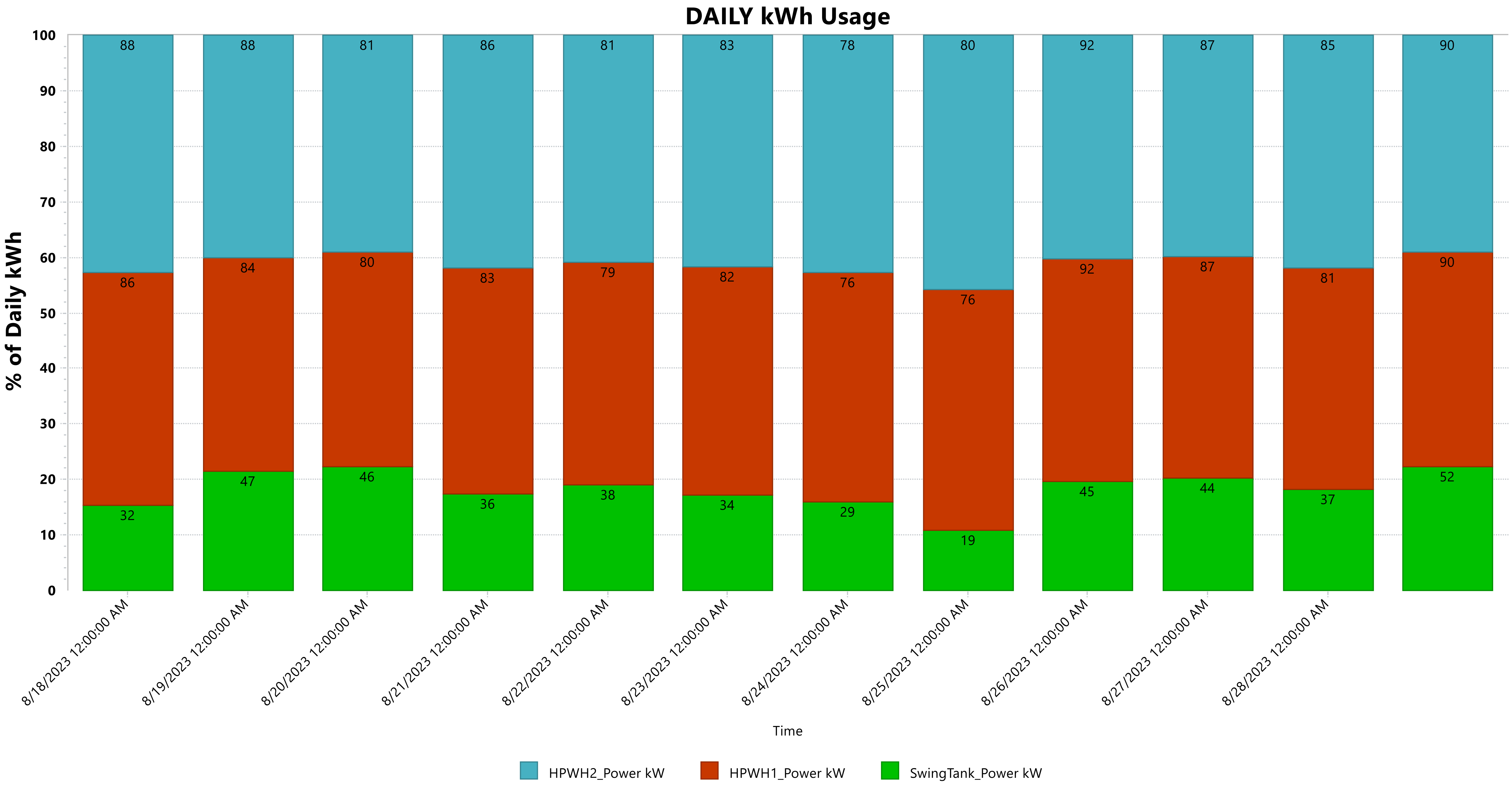


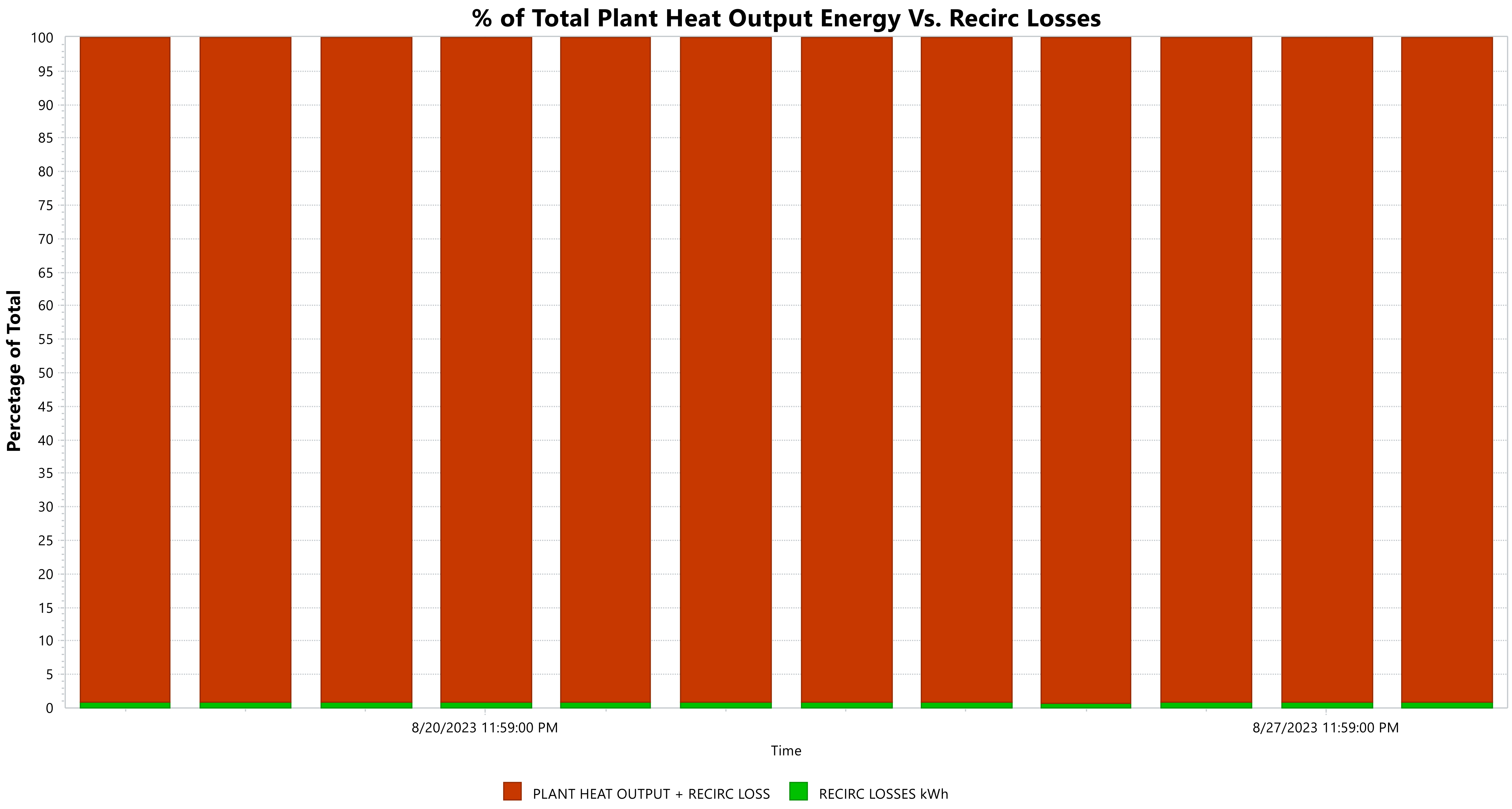
DAILY kWh Usage
Daily kWh Total
240
220
200
180
160
140
120
100
80
60
40
20
88
86
32
88
84
47
81
80
46
86
83
36
81
79
38
83
82
34
78
76
29
80
76
19
92
92
45
87
87
44
85
81
37
90
90
52
8/18/2023 12:00:00 AM
8/19/2023 12:00:00 AM
8/20/2023 12:00:00 AM
8/21/2023 12:00:00 AM
8/22/2023 12:00:00 AM
8/23/2023 12:00:00 AM
8/24/2023 12:00:00 AM
8/25/2023 12:00:00 AM
8/26/2023 12:00:00 AM
8/27/2023 12:00:00 AM
8/28/2023 12:00:00 AM
Time
HPWH2_Power kW
HPWH1_Power kW
SwingTank_Power kW



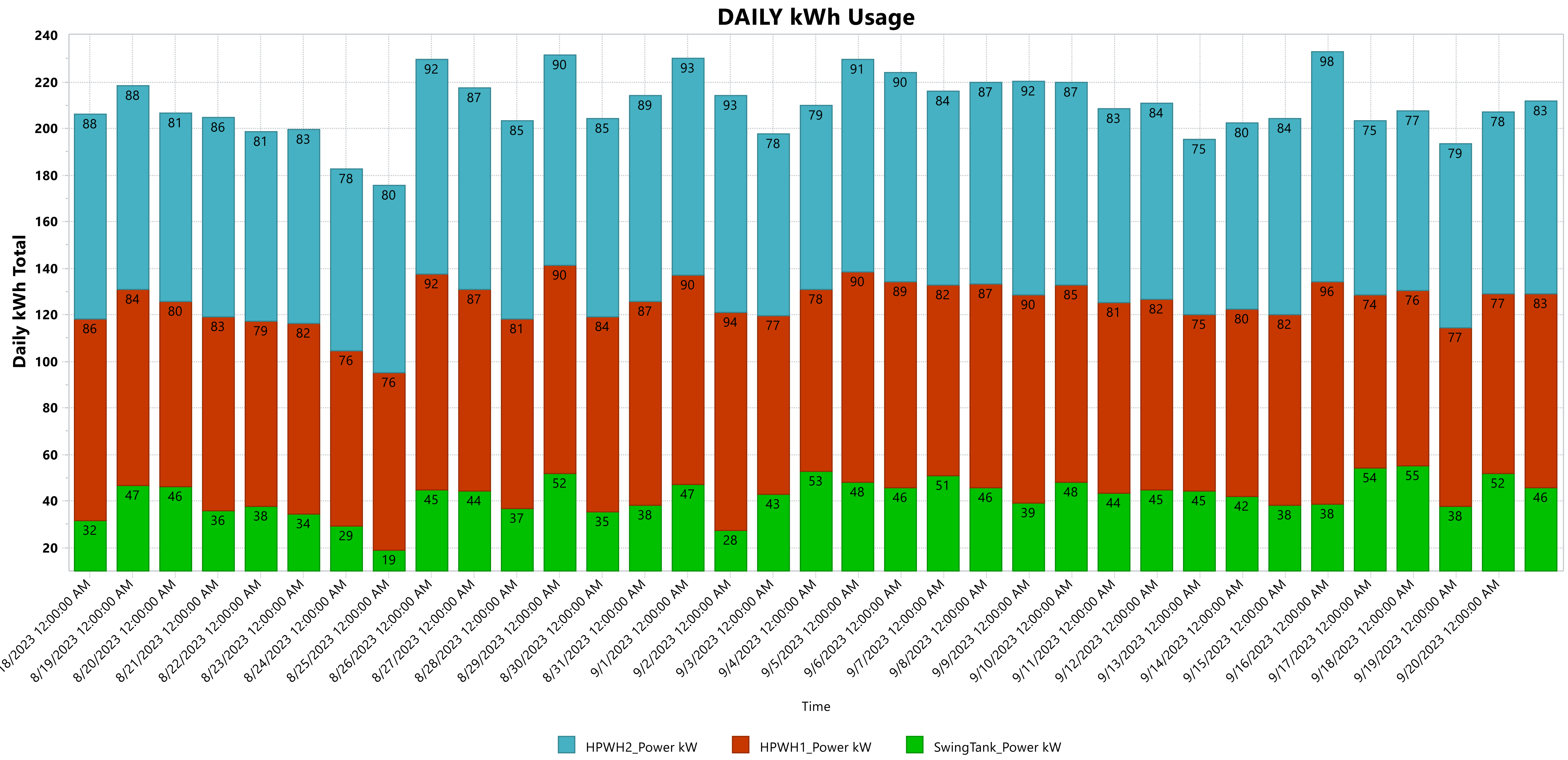
Thermo On/Off Change Made 8/24
CHANGE MADE HERE
Pre/Post Control Change
HP On/Off
Swing Tank kW
1
0
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
8/19/2023 12:00:00 AM
8/19/2023 6:00:00 AM
8/19/2023 12:00:00 PM
8/19/2023 6:00:00 PM
8/20/2023 12:00:00 AM
8/20/2023 6:00:00 AM
8/20/2023 12:00:00 PM
8/20/2023 6:00:00 PM
8/21/2023 12:00:00 AM
8/21/2023 6:00:00 AM
8/21/2023 12:00:00 PM
8/21/2023 6:00:00 PM
8/22/2023 12:00:00 AM
8/22/2023 6:00:00 AM
8/22/2023 12:00:00 PM
8/22/2023 6:00:00 PM
8/23/2023 12:00:00 AM
8/23/2023 6:00:00 AM
8/23/2023 12:00:00 PM
8/23/2023 6:00:00 PM
8/24/2023 12:00:00 AM
8/24/2023 6:00:00 AM
8/25/2023 12:00:00 AM
8/25/2023 6:00:00 AM
8/25/2023 12:00:00 PM
8/25/2023 6:00:00 PM
8/26/2023 12:00:00 AM
8/26/2023 6:00:00 AM
8/26/2023 12:00:00 PM
8/26/2023 6:00:00 PM
8/27/2023 12:00:00 AM
8/27/2023 6:00:00 AM
8/27/2023 12:00:00 PM
8/27/2023 6:00:00 PM
Time
SwingTank_Power kW

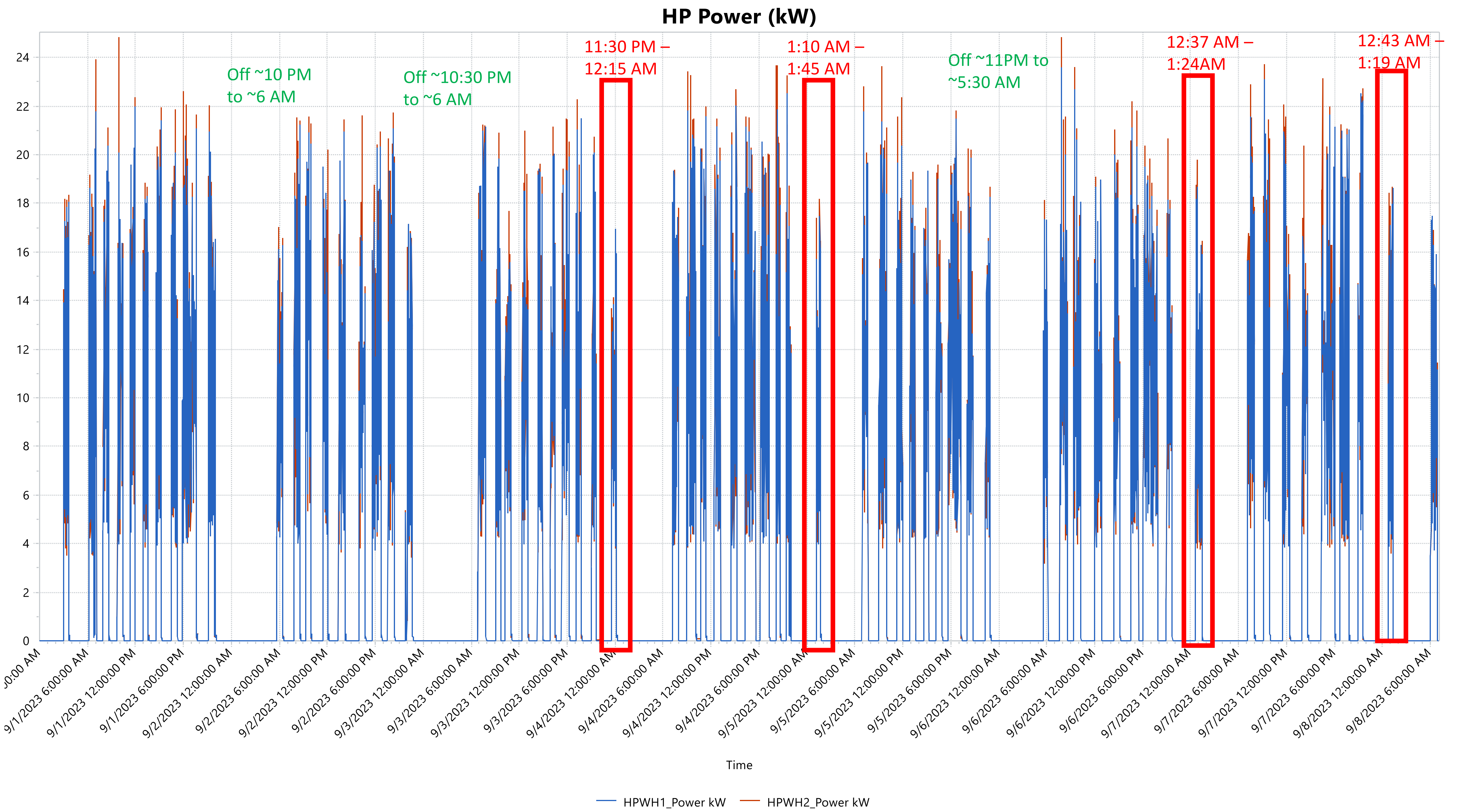

Gal/Person/Day (115 Occupants)
Gal
40
35
30
25
20
15
10
5
0
33
34
31
31
31
32
27
31
34
33
31
31
31
31
32
35
25
28
34
31
32
30
31
30
29
30
28
28
28
35
28
27
28
29
28
8/20/2023 11:59:00 PM
8/27/2023 11:59:00 PM
9/3/2023 11:59:00 PM
9/10/2023 11:59:00 PM
9/17/2023 11:59:00 PM
Time
Gal/Per/Day

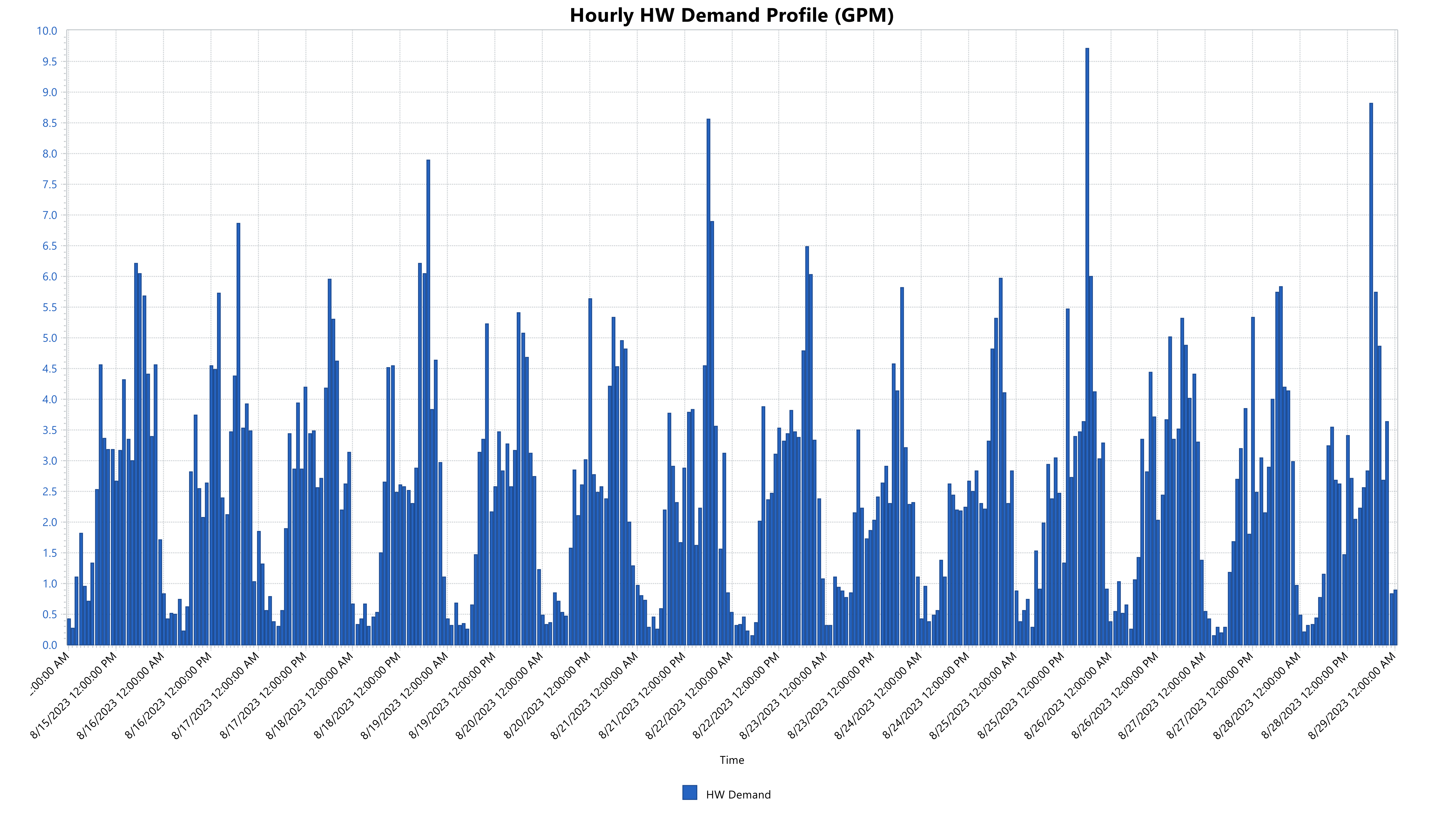

DAILY kWh Usage
% of Daily kWh
100
90
80
70
60
50
40
30
20
10
0
88
88
81
86
81
83
78
80
92
87
85
90
86
84
80
83
79
82
76
76
92
87
81
90
32
47
46
36
38
34
29
19
45
44
37
52
8/18/2023 12:00:00 AM
8/19/2023 12:00:00 AM
8/20/2023 12:00:00 AM
8/21/2023 12:00:00 AM
8/22/2023 12:00:00 AM
8/23/2023 12:00:00 AM
8/24/2023 12:00:00 AM
8/25/2023 12:00:00 AM
8/26/2023 12:00:00 AM
8/27/2023 12:00:00 AM
8/28/2023 12:00:00 AM
Time
HPWH2_Power kW
HPWH1_Power kW
SwingTank_Power kW



% of Total Plant Heat Output Energy Vs. Recirc Losses
Percetage of Total
100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0
8/20/2023 11:59:00 PM
8/27/2023 11:59:00 PM
Time
PLANT HEAT OUTPUT + RECIRC LOSS
RECIRC LOSSES kWh

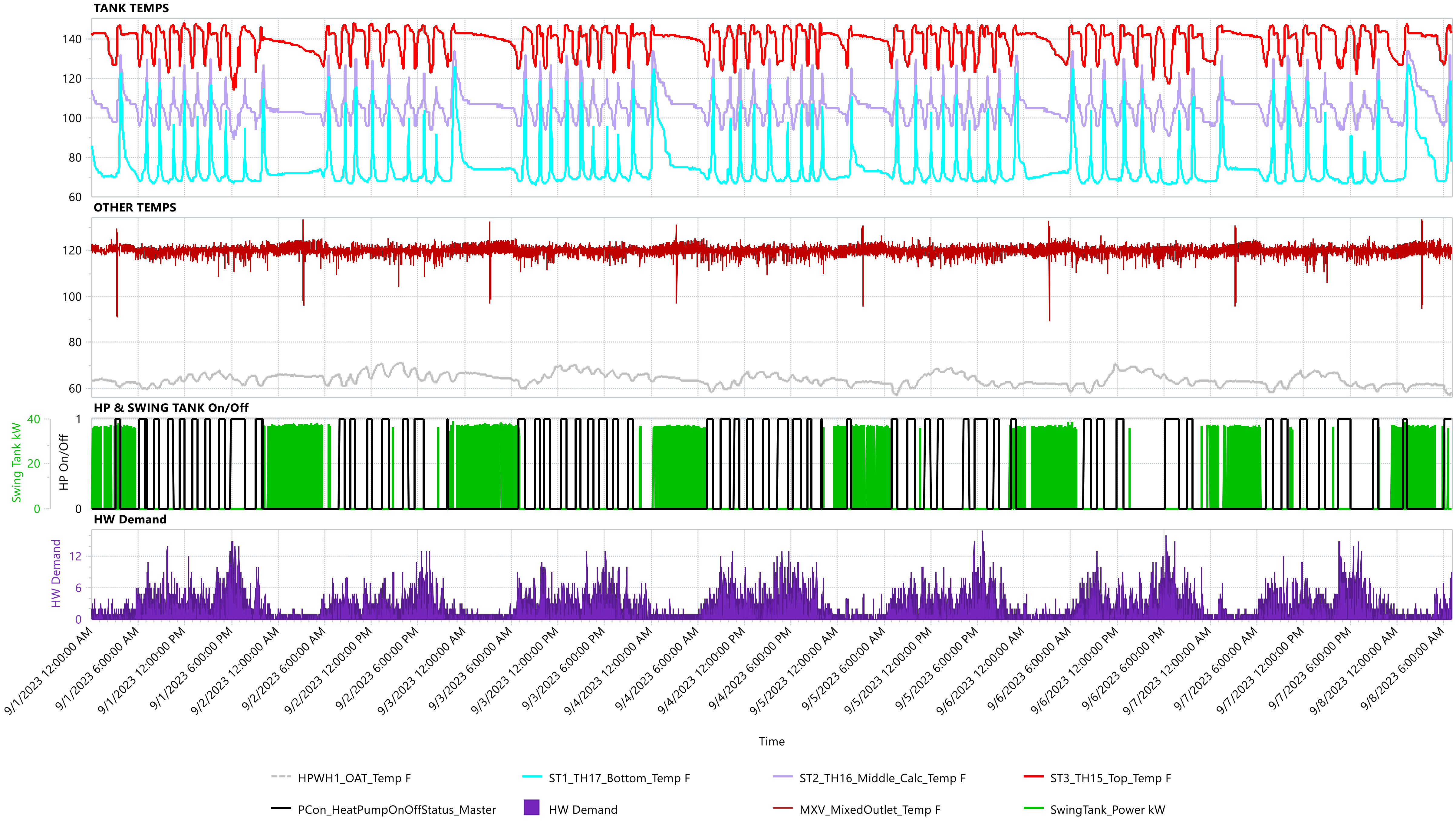

DAILY kWh Usage
Daily kWh Total
240
220
200
180
160
140
120
100
80
60
40
20
88 86 32
88 84 47
81 80 46
86 83 36
81 79 38
83 82 34
78 76 29
80 76 19
92 92 45
87 87 44
85 81 37
90 90 52
85 84 35
89 87 38
93 90 47
93 94 28
78 77 43
79 78 53
91 90 48
90 89 46
84 82 51
87 87 46
92 90 39
87 85 48
83 81 44
84 82 45
75 75 45
80 80 42
84 82 38
98 96 38
75 74 54
77 76 55
79 77 38
78 77 52
83 83 46
18/2023 12:00:00 AM
8/19/2023 12:00:00 AM
8/20/2023 12:00:00 AM
8/21/2023 12:00:00 AM
8/22/2023 12:00:00 AM
8/23/2023 12:00:00 AM
8/24/2023 12:00:00 AM
8/25/2023 12:00:00 AM
8/26/2023 12:00:00 AM
8/27/2023 12:00:00 AM
8/28/2023 12:00:00 AM
8/29/2023 12:00:00 AM
8/30/2023 12:00:00 AM
8/31/2023 12:00:00 AM
9/1/2023 12:00:00 AM
9/2/2023 12:00:00 AM
9/3/2023 12:00:00 AM
9/4/2023 12:00:00 AM
9/5/2023 12:00:00 AM
9/6/2023 12:00:00 AM
9/7/2023 12:00:00 AM
9/8/2023 12:00:00 AM
9/9/2023 12:00:00 AM
9/10/2023 12:00:00 AM
9/11/2023 12:00:00 AM
9/12/2023 12:00:00 AM
9/13/2023 12:00:00 AM
9/14/2023 12:00:00 AM
9/15/2023 12:00:00 AM
9/16/2023 12:00:00 AM
9/17/2023 12:00:00 AM
9/18/2023 12:00:00 AM
9/19/2023 12:00:00 AM
9/20/2023 12:00:00 AM
Time
HPWH2_Power kW
HPWH1_Power kW
SwingTank_Power kW


HP Power (kW)
Off ~10 PM
to ~6 AM
Off ~10:30 PM
to ~6 AM
11:30 PM –
12:15 AM
1:10 AM –
1:45 AM
Off ~11PM to
~5:30 AM
12:37 AM –
1:24AM
12:43 AM –
1:19 AM
0
2
4
6
8
10
12
14
16
18
20
22
24
Time
HPWH1_Power kW
HPWH2_Power kW



Hourly HW Demand Profile (GPM)
10.0
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
:00:00 AM
8/15/2023 12:00:00 PM
8/16/2023 12:00:00 AM
8/16/2023 12:00:00 PM
8/17/2023 12:00:00 AM
8/17/2023 12:00:00 PM
8/18/2023 12:00:00 AM
8/18/2023 12:00:00 PM
8/19/2023 12:00:00 AM
8/19/2023 12:00:00 PM
8/20/2023 12:00:00 AM
8/20/2023 12:00:00 PM
8/21/2023 12:00:00 AM
8/21/2023 12:00:00 PM
8/22/2023 12:00:00 AM
8/22/2023 12:00:00 PM
8/23/2023 12:00:00 AM
8/23/2023 12:00:00 PM
8/24/2023 12:00:00 AM
8/24/2023 12:00:00 PM
8/25/2023 12:00:00 AM
8/25/2023 12:00:00 PM
8/26/2023 12:00:00 AM
8/26/2023 12:00:00 PM
8/27/2023 12:00:00 AM
8/27/2023 12:00:00 PM
8/28/2023 12:00:00 AM
8/28/2023 12:00:00 PM
8/29/2023 12:00:00 AM
Time
HW Demand

PLANT OPERATION



Adjustment made to Sensor Strategy:

Mode-1:

- Thermo-On at sensor 1 (cold tank)
- Thermo-Off at sensor-2 (middle tank).

Mode-2:

- Thermo-On at Sensor-2
- Thermo-Off and Sensor-2.

Use Mode-2 as the load up and Mode-1 as Normal operation.

Looking at 3 days before and 3 days after

BEFORE

Runtime 0001

Channel Name: PCon_HeatPumpOnOffStatus_Master
Number of DataPoints: 2882
Minimum Value: 0
Maximum Value: 1
Average Value: 0.23

	Minimum	Maximum	Count	MinimumValue	MaximumValue	AverageValue	RunTimeHours	%RunTime	ActualEnergy	NumberOfCycles	AverageCyclesPerHour
OFF	-1	0	2223	0	0	0	37.05	77.13	0	0	0
ON	).1	1	659	1	1	1	10.98	22.87	10.98	28	2.55

AFTER

Runtime 0001

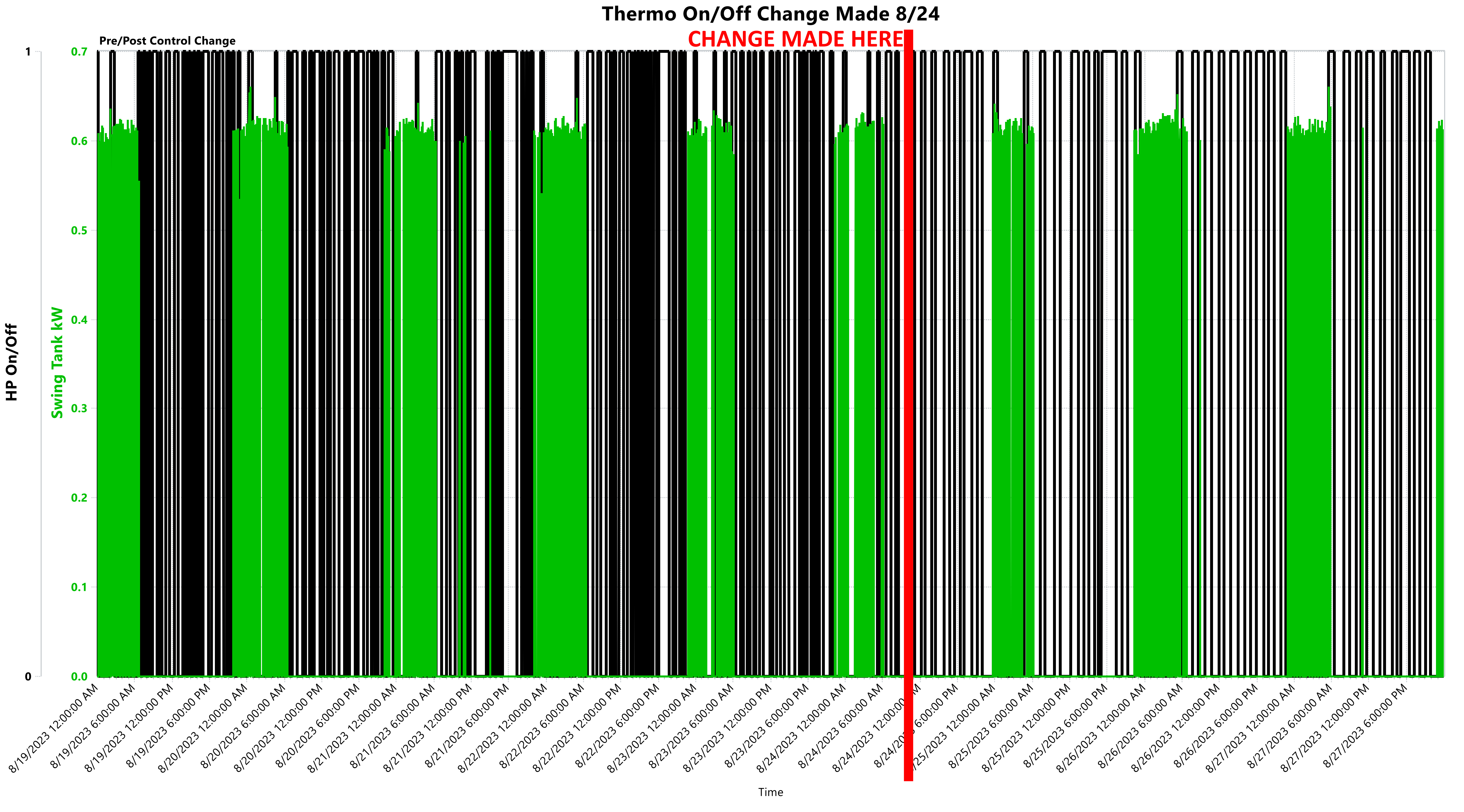
Channel Name: PCon_HeatPumpOnOffStatus_Master
Number of DataPoints: 4321
Minimum Value: 0
Maximum Value: 1
Average Value: 0.32

	Minimum	Maximum	Count	MinimumValue	MaximumValue	AverageValue	RunTimeHours	%RunTime	ActualEnergy	NumberOfCycles	AverageCyclesPerHour
OFF	1	0	2931	0	0	0	48.85	67.83	0	0	0
ON	.1	1	1390	1	1	1	23.17	32.17	23.17	21	0.91

Looking at singe day before and after:

8/19: Ran for 4.5 hours, cycled 12 times

8/27: Ran for 7.5 hours, cycled 7 times


Thermo On/Off Change Made 8/24
CHANGE MADE HERE
Pre/Post Control Change
HP On/Off
Swing Tank kW
1
0
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
8/19/2023 12:00:00 AM
8/19/2023 6:00:00 AM
8/19/2023 12:00:00 PM
8/19/2023 6:00:00 PM
8/20/2023 12:00:00 AM
8/20/2023 6:00:00 AM
8/20/2023 12:00:00 PM
8/20/2023 6:00:00 PM
8/21/2023 12:00:00 AM
8/21/2023 6:00:00 AM
8/21/2023 12:00:00 PM
8/21/2023 6:00:00 PM
8/22/2023 12:00:00 AM
8/22/2023 6:00:00 AM
8/22/2023 12:00:00 PM
8/22/2023 6:00:00 PM
8/23/2023 12:00:00 AM
8/23/2023 6:00:00 AM
8/23/2023 12:00:00 PM
8/23/2023 6:00:00 PM
8/24/2023 12:00:00 AM
8/24/2023 6:00:00 AM
8/25/2023 12:00:00 AM
8/25/2023 6:00:00 AM
8/25/2023 12:00:00 PM
8/25/2023 6:00:00 PM
8/26/2023 12:00:00 AM
8/26/2023 6:00:00 AM
8/26/2023 12:00:00 PM
8/26/2023 6:00:00 PM
8/27/2023 12:00:00 AM
8/27/2023 6:00:00 AM
8/27/2023 12:00:00 PM
8/27/2023 6:00:00 PM
Time

Primary Pump Vs. HP On/Off