Monitoring the Ground Source Heat Pump System at Zero Place – a Multifamily, Mixed-Use Building in New Paltz, NY

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Monitoring the Ground Source Heat Pump System at Zero Place - A Multifamily, Mixed-Use Building in New Paltz, New York

Final Report

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Acronyms and Abbreviations

AC	air conditioning
ASHP	air source heat pump (interchangeable with ccASHP)
ASHRAE	American Society of Heating, Refrigerating and Air-Conditioning Engineers
ccASHP	cold-climate air source heat pump
cDHW	centralized domestic hot water
Clg	cooling
COP	coefficient of performance
DHW	domestic hot water
ERV	energy recovery ventilator
EWT	entering water temperature (to the heat pump)
ft	feet
GSHP	ground-source heat pump
HPDE	high density polyethylene
Htg	heating
HP	heat pump or horsepower
HVAC	heating, ventilating and air conditioning
IAPMO	International Association of Plumbing and Mechanical Officials
kW	kilowatt
kWh	kilowatt hours
MWh	megawatt hours (1000 kWh)
NY	New York
NYS	New York State
NYSERDA	New York State Energy Research and Development Authority
PHIUS	Passive House Institute of United States
PTAC	packaged terminal air conditioner
PTHP	packaged terminal heat pump
PV	photovoltaic
sq	square
TLR	temperature loop return
TLS	temperature loop supply
TRM	technical resource manual
VRF	variable refrigerant flow
W	watts
WSHP	water source heat pump
WWHP	water-to-water heat pump

Executive Summary

A newly constructed four-story, mixed use multifamily building in the Hudson Valley was built to Passive House (PHIUS) standards. The building also used a ground source heat pump (GSHP) system to provide both space conditioning and domestic water heating (DHW) –eliminating the need for fossil fuels. A monitoring system was installed to collect detailed energy data at 5-minute intervals for more than a year to confirm the system performed as expected. The performance data showed that the GSHP system efficiently met both space conditioning and DHW loads with little to no impact on the electric grid. The GSHP system was more efficient and had lower peak demand impacts than other all-electric options typically used in multifamily building applications.

This report examines the performance of the installed GSHP system, however it does not evaluate the installed cost of the system to determine project economics compared to other HVAC and DHW design options.

S.1 Description of the Building and GSHP System

Zero Place is a 4-story, 63,320 sq ft building in New Paltz, NY with 46 apartments as well as 6 retail spaces totaling 7,540 sq ft on the first floor. Forty-one (41) apartments are market rate while five (5) apartments are affordable housing units. Twenty-one (21) of the apartments are one-bedroom units and twenty five (25) are two-bedroom units, for a total of 71 bedrooms. To make the building net zero, a 248 KW solar photovoltaic array was installed to offset building energy use on an annual basis. The building envelope was constructed to PHIUS standards with R-25 walls, air-tight construction, and triple pane windows, Separate energy recovery ventilators for each apartment provided ventilation as required by ASHRAE Standard 62.2.

A GSHP system was installed for heating and cooling the building. The ground loop heat exchanger included fifteen 400 ft deep vertical bores installed under the building footprint. Since the building envelope was very efficient, the apartment water source heat pumps (WSHPs) were mostly ¾-ton units with 1-ton units used on the 2-bedroom corner and top floor apartments. Common areas and retail spaces used slightly larger WSHP units. The DHW loads were also met by two 5-ton water-to-water heat pumps (WWHPs). Since the WWHP units extract heat year-round to provide DHW, they reduced summertime heat rejection loads and in turn reduced the required size of the ground loop heat exchanger from 18 to 15 vertical bores. There are a total of 62 heat pump units in the building with a total installed capacity of 87 tons.

S.2 Results and Findings

Measured data were collected at 5-minute intervals from the building starting in January 2022 and continuing through October 2023. The apartments were first occupied in April 2022 and full-occupancy started in June 2022. Retail spaces started to fill up in 2022 and 2023.

The highly efficient building envelope was successfully built to PHIUS standards. Total measured loads for multifamily portions of the building was 7.5 kBtu per sq ft per year for heating and 8.0 kBtu per sq ft per year for cooling – within 20% of the PHIUS targets and much lower than has typically been measured in other PHIUS buildings in New York State (BEX 2021).

The PV solar panels were able to meet 95% of the building's energy requirements on an annual basis. While PV panels provided most of the building's energy use, the solar output had very little impact on building's peak demand profile since the kW peaks were outside side of the solar production period.

The ground loop temperatures ranged from the high 70s in the summer to low 40s in the winter (degrees Fahrenheit). The energy use for the variable speed ground loop pumps was very low. The full load pumping power was 18 Watts per installed ton and pump energy use was 3% of total heat pump power across the year. Pumping energy was also low because the loop fluid was methanol and because no additional valves, circuit setters, etc. were installed to unnecessarily increase pressure requirements. The low-cost, sensorless pump controls modulated back the flow just as well as a traditional variable speed pumping systems with a remote pressure sensor. On an annual basis, heat pump energy use was about equal for space heating and space cooling. The transition between heating and cooling was about 60°F, though there were many hours below this temperature where simultaneous heating and cooling was required in the zones.

The overall system heating COP for space and water heating combined exceeded 3.6 even on the coldest day of the year, that dropped well below zero. In contrast, an air source heat pump would have operated at COP of 1 to 1.5 at these same conditions – and closer to a COP of 1 at coldest moments in the early morning hours. The peak demand of the WSHPs was highest on that cold morning when the ambient temperature dropped to -6°F. Neither the WSHP nor WWHP units set the building peak demand. The building’s peak was set later in the evening when occupants turned on their appliances in each apartment. On the hottest summer days, we also saw that the heat pumps did not drive the building’s peak demand.

Adding the WWHPs to the ground loop provided an average year-round heat extraction load of 0.7 MMBtu per day. This allowed the geothermal designer and contractor to provide the DHW system for “free” since the heat extraction decreased the peak summer load on the ground loop and reduced the number of vertical bores required for the cooling-driven design. The savings from removing three vertical bores saved about $45,000 and covered the cost the installing the WWHPs and tanks for the DHW system. The hot water loads in the building were close to predictions in the NYS TRM, using about 1,285 gallons per day, or about 18 gallons per bedroom per day. The WWHPs provided DHW with an annual average COP of 3.3. Air-source heat pump options to meet DHW loads are expected have annual COPs between 2 and 2.5.

Detailed measurements of hot water use and recirculation flows allowed us to show that recirculation losses accounted for about 30% of the thermal energy input, consistent with what we have measured at other multifamily buildings (Henderson 2023). At this building, we were able to reduce the recirculation flowrate from 10 gpm to 4 gpm and measure the energy impact. The lower flow reduced the disruption to the thermoclines in the final tank and reduced thermal recirculation losses by 25%. The lower recirculation flow also improved the system COP and reduced WWHP system energy use by 11%.

Hot water use flow data was collected at 1-minute intervals to understand what range of flow rates can be expected. Plumbing codes and ASHRAE handbooks often anticipate peak flow rates in multifamily buildings which exceed what is observed in practice. We measured peak hot water use rates of 6.1 gpm at the 99.9% occurrence level, similar values in other multifamily buildings (Henderson 2023). These observed peaks confirm that the 4-inch cold water inlet piping was much larger than needed. IAPMO and ASHRAE design guidance is currently being revised based on measured data from this site and other buildings to reduce pipe sizing requirements.

1 Introduction

This report evaluated the measured performance of the newly-constructed mixed use building in New Paltz, New York known as Zer0 Place. This section provides background on typical heating ventilation and air conditioning (HVAC) options in these types of buildings and describes the benefits of geothermal or ground source heat pump technologies. Then the goals of the field demonstration project are discussed.

1.1 Mechanical Options for Multifamily Buildings

Moderately-sized multifamily and mixed use buildings with 3 or more stories typically have very few energy-efficient options to meet space conditioning and centralized domestic hot water (cDHW) needs. Historically a fossil fuel boiler has been installed to meet both space and water heating loads. Using residential split system air conditioners in multi-story buildings can be cumbersome because some many individual outdoor units are required and must be located on the roof. Therefore multiple, thru-the-wall packaged terminal air conditioners (PTACs) or window ACs are often used.

All-electric space conditioning options to meet carbon reduction goals in NY State are even more limited. Heat pump versions of PTACs and window ACs are possible, but performance suffers due to space constraints on these systems. Variable Refrigerant Flow (VRF) units can have one outdoor unit serving one or more apartments but are expensive and are often less efficient than residential-scale cold climate air source heat pumps (ccASHPs). Even if space conditioning needs can be met with air source heat pumps, the significant DHW loads in the building still need be met with fossil fuel boiler since only limited heat pump options are available to electrify the cDHW system.

Geothermal or ground source heat pump systems are one of best alternatives for meeting space and water heating loads in this building application.

1.2 Benefits of GSHP Technology in Multifamily

Ground Source Heat Pump (GSHP) systems are a good fit for multifamily and mixed use buildings because an individual water source heat pump (WSHP) units can be installed to serve each apartment or retail space, or other zone. Each WSHP unit rejects or extracts heat from a ground loop as needed. The distribution piping within the building connects each unit to the shared ground loop heat exchanger. The electricity for each apartment's WSHP unit can either be on the tenant electric meter or on the master meter for the facility.

If cDHW is used for the apartments, then water-to-water heat pumps (WWHPs) can also be added to the ground loop. Since the need for DHW is year-round, the continuous heat extraction from the ground loop heat exchanger reduces both the seasonal and the peak heat rejection in the summer. Therefore, since ground loop heat exchangers for most multifamily buildings in New York are sized based on summertime peak heat rejection, the size of the ground loop can be smaller than if the system adds water heating.

Historically GSHP systems added on the order of $10 to 20 per sq ft of floor area to the mechanical systems costs. Now federal programs that are part of the Inflation Reduction Act (IRA) offer significant direct funding that can reduce or eliminate the cost premium for GSHP systems and even make GSHP systems the lowest cost HVAC option in Multifamily buildings.

1.3 Study Objectives

This study sought to add additional instrumentation to this high efficiency building to measure the detailed performance of the GSHP system in order prove performance. Sensors were added to the eGuage monitoring system and the collected monitored data are used to analyze the performance of this innovative system.

2 Description of Facility and Ground Source System

This section describes the facility and provides technical details about the ground source heat pump system.

2.1 Zero Place Facility

Zero Place is a 4-story, 63,320 sq ft building in New Paltz, New York with 46 apartments as well as 6 retail spaces totaling 7,540 sq ft on the first floor (one of the six retail spaces was converted into fitness center for the building occupants). Forty-one apartments are market rate while 5 apartments are affordable housing units. Twenty-one of the apartments are one-bedroom units and 25 are two-bedroom units, for a total of 71 bedrooms. This zero-energy building has a vertical ground loop under the building footprint and uses extended range geothermal water source heat pumps in each apartment, in the common areas, and in the retail spaces. Since the building envelope is very efficient, the apartment heat pump units are mostly ¾-ton units with 1-ton units on the 2-bedroom corner and top floor apartments. Separate ERVs for each apartment provide nominal ventilation required by ASHRAE Standard 62.2. Each ERV has an occupant-controlled boost mode when additional ventilation is required. There are a total of 62 heat pump units in the building with a total installed capacity of 87.25 tons as shown in Table 1.

The building envelope was built to Passive House Standards, with the following features:

- well-insulated concrete slab (R25)
- walls are insulated concrete form (ICF) construction (R22)
- triple-paned fenestration (0.17 U-Value)
- exterior air-tight construction with measured leakage of 0.6 to 1.0 ACH50
- internal apartment-to-apartment leakage 0f 0.07 to 0.18 CFM50 per sq ft of surface area

The performance predicted by the Passive House Institute US (PHIUS) building envelope metrics for annual loads were 6.2 kBtu per sq ft per year for heating and 6.5 kBtu er sq ft per year for cooling (12.7 kBtu/sq ft-yr total). Figure 1 and Figure 2 show photos of the facility.

Figure 1. Photos of the Front Door Zer0 Place

Figure 2. Photos of the Facility from the South

Table 1. Water Furnace Water Source Heat Pump Units Installed in the Building

	Location		HP Model
Retail Spaces	R1		NBV060
	R2		NBV060
	R3		NBV060
	R4		NBV060
	R5		NBV060
	R6		NBV060
1st Floor Apts	1	A	NBV012
	1	B	NBV009
	1	C	NBV009
	1	D	NBV009
2nd Floor Apts	2	A	NBV009
	2	B	NBV009
	2	C	NBV009
	2	D	NBV009
	2	E	NBV009
	2	F	NBV009
	2	G	NBV009
	2	H	NBV009
	2	I	NBV009
	2	J	NBV009
	2	K	NBV009
	2	L	NBV009
	2	M	NBV009
	2	N	NBV009
Hallway, Lobby, Atrium, Public Bathroom	1st Floor		NBV038
	1st Floor		NBV038
	2nd Floor		NBV009
	3rd Floor		NBV009
	4th Floor		NBV009
	5th Floor		NBV009
Stairway 1st Floor	North		NCS009
	South		NCS009

	Location		HP Model
3rd Floor Apts	3	A	NBV009
	3	B	NBV009
	3	C	NBV009
	3	D	NBV009
	3	E	NBV009
	3	F	NBV009
	3	G	NBV009
	3	H	NBV009
	3	I	NBV009
	3	J	NBV009
	3	K	NBV009
	3	L	NBV009
	3	M	NBV009
	3	N	NBV009
4th Floor Apts	4	A	NBV012
	4	B	NBV012
	4	C	NBV012
	4	D	NBV012
	4	E	NBV009
	4	F	NBV009
	4	G	NBV009
	4	H	NBV012
	4	I	NBV012
	4	J	NBV012
	4	K	NBV012
	4	L	NBV009
	4	M	NBV009
	4	N	NBV009
WWHPs for DHW			NEW066
			NEW066

Total Installed tons:	87.25
WSHP tons:	77.25
WWHP tons:	10
No of HPs:	62

The facility also installed an extensive solar photovoltaic (PV) array to offset electric consumption and make the building net zero. As shown in Figure 3, the solar panels cover most of the roof area and are installed to provide shading for the windows on the south side of the facility. The PV array has a rated output of 248 kW DC and was sized to offset building consumption on an annual basis.

Figure 3. Photos of 248 kW Solar Array on the Building Roof

2.2 Ground Source Heat Pump System

The modest heating and cooling loads in this facility reduced the necessary size of the ground heat exchanger and allowed the vertical bores to be installed under building foundation (see Figure 4). Buffalo Geothermal LLC (BG) was the design-build contractor for the space heating and water heating systems. BG installed a total of fifteen (15) 400 ft deep vertical bores before the building was built. Therefore, the limited size of this building lot was not an impediment to using geothermal at this facility. The designer claimed that the available building footprint could have still supported a geothermal field for an even larger building of more than 28 stories.

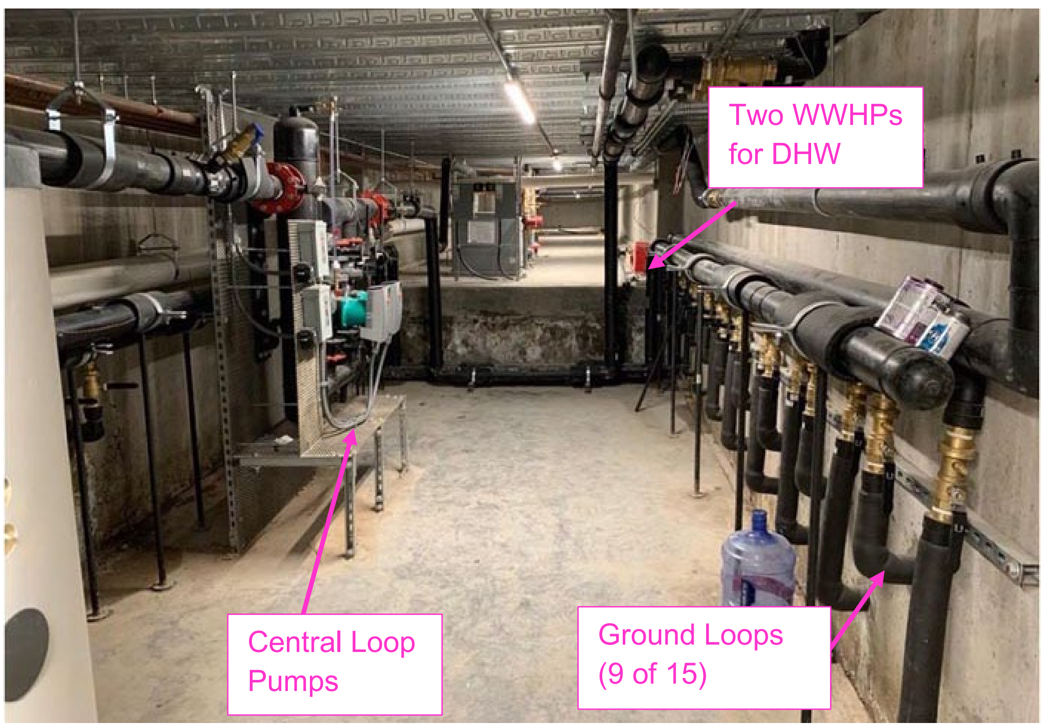
The ground loop field used 1-½ inch diameter high density polyethylene (HDPE) piping for each borehole, that came to headers inside the basement, as shown in Figure 5. HDPE piping was also used inside the building for the distribution piping to each heat pump unit. The system uses a central pumping station rated at 100 tons with two variable speed 2-HP pumps (only one pump operates at a time). Every heat pump has a motorized two-way valve that shuts off loop flow to the HP unit when it is off, thereby reducing the flow requirements of the overall system. The loop fluid was potable water and 12.5% Methanol (by weight). No other circuit setters or flow limiters were added to the ground loop circuits or to the HP units. Ball valves to each HP were used to provide minor flow balancing (i.e., reduction) on only a handful of HP units.

The pumping system was designed to use approximately 18 Watts of pumping power per installed ton of HP. The variable speed pumps use an internal, sensorless[1] control algorithm to modulate pump speed to maintain differential pressure as the number of operating HP units varies. The control method uses built-in "pump curves" to maintain the design pressure across the heat pumps near the design flowrate. As the loop flow rate modulates down – when two-way valves on the HPs close – the pump decreases speed to maintain the required pressure differential. In addition, the algorithm reduces the differential pressure setting to 50% of the design pressure at low flow rates. This control approach accounts for the fact that the pressure drop across the HPs in the building must remain constant and is still required at low flow (this is about half the total pressure drop). However, the pressure drop in the ground loop heat exchanger approaches zero at low flow.

[1] We use the term "sensorless" to contrast it with a traditional variable speed pumping system that uses a variable speed drive (VSD) with a remote differential pressure sensor located on the loop out at the far end of the building. The senseless approach uses built in pump curves in the controller to mimic the approximate the performance of a VSD-sensor control system.

Figure 4. Photo of the Vertical Bores Installed Before Building Construction (the bores used only 15% of the building footprint)

Figure 5. Photo of the Basement Showing Ground Loop and WWHP Details



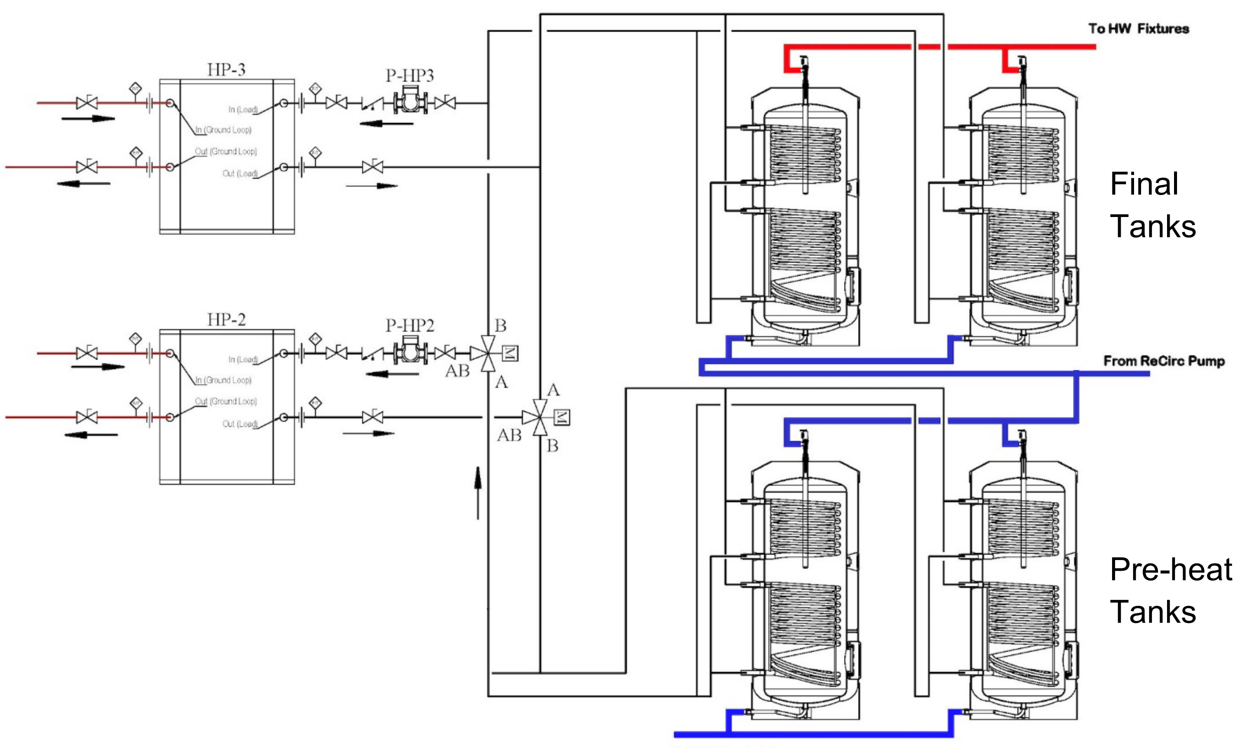
Two water-to-water 5-ton heat pumps (WWHPs) provide cDHW heating using the ground loop. The WaterFurnace model NEW066 WWHP units and four 162-gallon storage tanks, totaling 648 gallons, are located in the basement (see Figure 6). The storage volume is 14 gallons per apartment and 9 gallons per bedroom. Since the WWHPs are always extracting heat from the ground loop each day in all seasons, their year-round operation allowed the ground loop heat exchanger to be smaller. The designer reduced the number of vertical bores from 18 to 15 since the continuous heat extraction reduced the peak summer heat rejection load on the ground loop – and the summertime heat rejection due to cooling is what set the size of the ground loop heat exchanger.

The cDHW system is schematically shown in Figure 7. This central system includes a recirculation loop that circulates hot water through the hot water distribution piping so that all apartments quickly see hot water for each draw. Therefore, a system based around heat pumps significantly benefits from a two-stage arrangement. The first or pre-heat stage has one WWHP serving two tanks and takes in cold water and heats it to the near the desired temperature. Since average temperatures are lower in these tanks, the WWHP serving this pre-heating load has a higher heating COP. The final stage uses the other WWHP serving the two upper tanks in the schematic. Since the recirculation flow returns to the inlet for this set of tanks, the operating temperatures are much higher. The second or final stage WWHP still needs to operate to make up for recirculation thermal losses. As a result, the WWHP for final stage has a lower COP and cycles more frequently due to the nature of its loads. The 3-way valves allow the pre-heating WWHP unit to serve either stage of tanks for design redundancy.

At this facility the central DHW system does not use a mixing valve to temper outgoing hot water to the loads since the supply temperature is relatively modest. The recirculation pump, set to run continuously, ensures all apartments and retail spaces have hot water quickly available.

Figure 6. Photo of the DHW Tanks in Basement

Figure 7. Schematic of Water-to-Water Heat Pumps, Storage Tanks, and Distribution Piping



3 Monitoring Approach

The project planned to extensively measure or sub-meter electricity use in this new facility. While the building is master metered – with the landlord paying the utility bills and including estimated utility costs in the monthly rent – the building owners still planned to measure the electricity and water use for each apartment and various systems. The measured apartment level consumption was intended to confirm the building's overall energy efficiency and provide the option to potentially charge renters a fixed cost penalty each month if they significantly exceeded the expected energy consumption. The owner hired Integral Building + Design, Inc. (IPD) to install and operate an eGuage monitoring system to continuously collect all this data at regular intervals.

3.1 Overall Building Monitoring

An extensive eGuage power monitoring system was installed to measure power use throughout the building. Power measurements included:

- Total facility power use, power production by the solar array, and power import (or export) through the utility meter,
- Power use in each apartment including total apartment use, heat pump power, and power use for various other appliances and plug loads.
- Power use in each retail space.
- Power use in common areas

3.2 GSHP Space Heating and Water Heating System

NYSERDA provided funding for this project to install additional monitoring of flows and temperatures in the geothermal and DHW system. The geothermal system measured points are shown in Figure 8 and Table 2. The DHW points are shown in Figure 9. The goals of the overall monitoring effort were to:

- Quantify the energy use of the geothermal system by measuring power use for every heat pump unit in the facility as well as the power use of the central loop pumping system.
- Quantify the heat rejection/extraction rate for the ground heat exchanger across each day, month, and season (using installed BTU meters). Use the heat pump power data and loop heat rates to infer overall heating efficiency and cooling efficiency for the system.
- Confirm the central loop pumping system (with sensorless variable speed control) provides good flow modulation and low pumping energy use.
- Quantify the DHW water use and delivered heating energy for the entire building. Determine hot water use for the total building (as well as the apartments, commercial spaces, and public bathrooms).

- Measure DHW recirculation losses so that energy losses from distribution can be directly determined.
- Infer the heating output from the WWHPs using the measured power input and the expected heating COPs. Compare hot water use and losses to predicted WWHP heating output.

Fifteen (15) of the WaterFurnace heat pumps also had a Symphony monitoring system to measure various diagnostic points, power use, and flow/delta-T on the source side of the unit. The two WWHPs had the Symphony system installed. This Symphony data was mostly used by the designer to confirm the measurements listed in Table 2.

Figure 8. Schematic of Ground Source Heat Pump System with Monitoring Points Shown

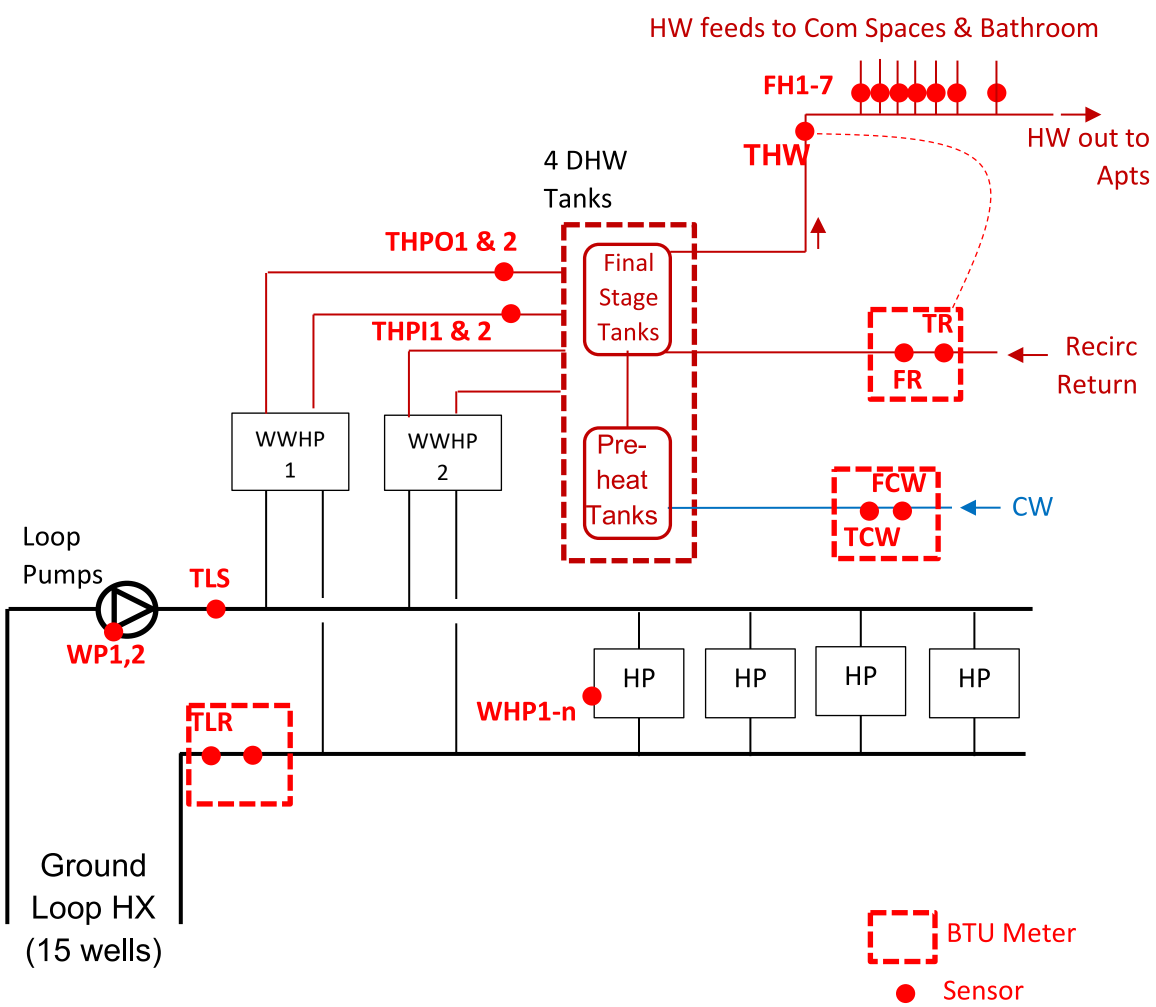
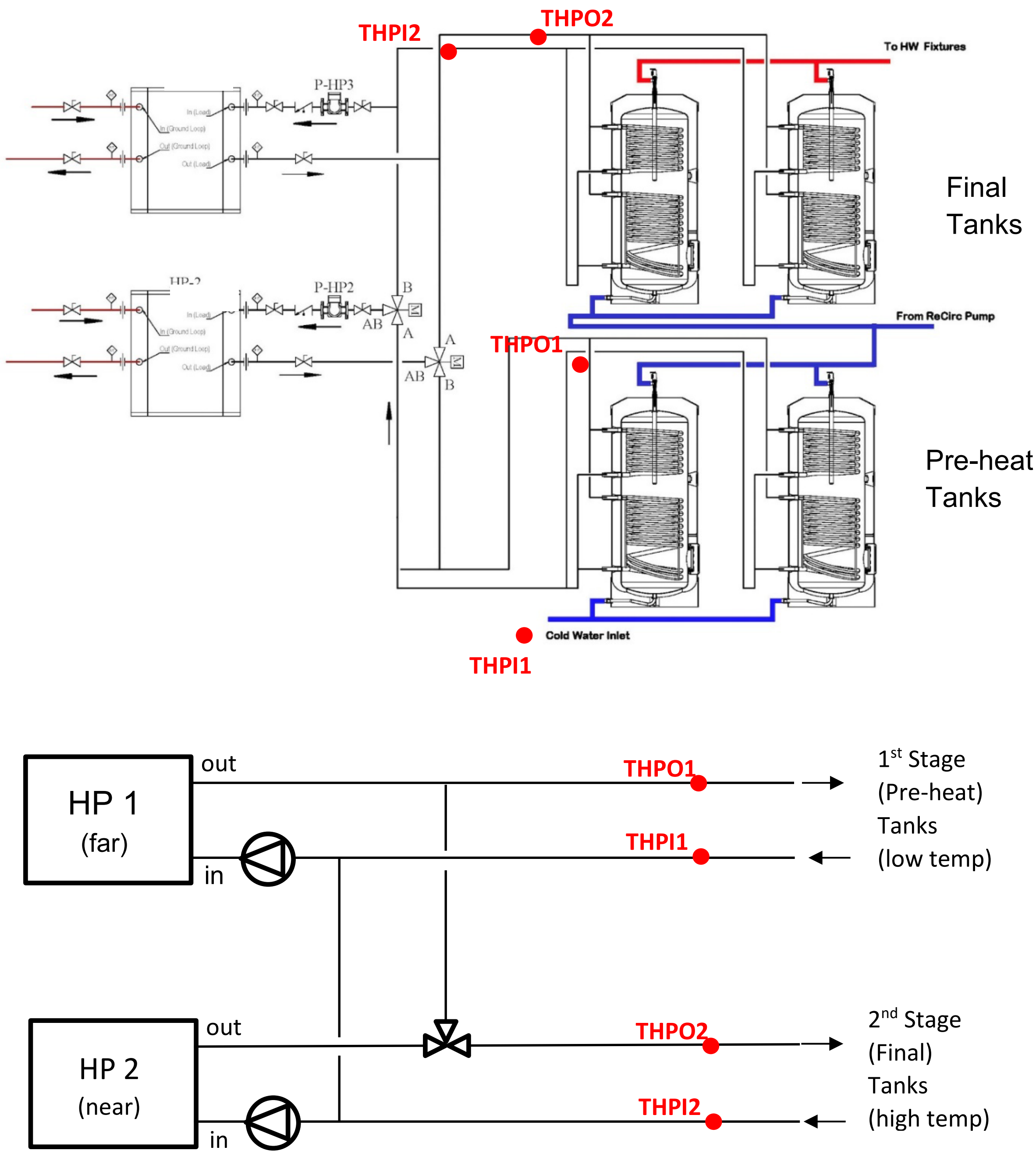


Table 2. Monitored Data Point

Name	Description	Eng Units	Instrument
WHPn	Heat Pump Power for Each WSHP (46 apts + retail + common areas)	kW/kWh	eG
TAO	Ambient Temperature (on roof)	°F	eG
RHO	Ambient Humidity (on roof)	%	eG
WWHP1	WWHP #1 Power	kW/kWh	eG
TLS1	WWHP #1 Supply Temp (source side)	°F	Symphony
TLR1	WWHP #1 Return Temp (source side)	°F	Symphony
FL1	WWHP #1 flow (source side)	gpm	Symphony
QL1	WWHP#1 Heat (source side)	BTU/h	Symphony
WWHP2	WWHP #2 Power	kW/kWh	Symphony
TLS2	WWHP #2 Supply Temp (source side)	°F	Symphony
TLR2	WWHP #2 Return Temp (source side)	°F	Symphony
FL2	WWHP #2 flow (source side)	gpm	Symphony
QL2	WWHP#2 Heat (source side)	BTU/h	Symphony
WP1	Loop Pump #1 Power	kW/kWh	eG
WP2	Loop Pump #2 Power	kW/kWh	eG
WRP	Recirc Loop Pump Power	kW/kWh	eG
TLS	**Ground Loop Supply Temp (to bldg)**	**°F**	**BTU Meter (System 10, F1200)**
TLR	**Ground Loop Return Temp (from bldg)**	**°F**	
FL	**Ground Loop Flow**	**gpm**	
QL	**Ground Loop Heat**	**BTU/h**	
THW	**DHW HW Temp Supply to Bldg**	**°F**	**BTU Meter (System 40, 2.5 inch)**
TCW	**DHW CS Inlet Temp**	**°F**	
FCW	**DHW CW Flow in**	**gpm**	
QHW	**DHW Delivered Heat**	**BTU/h**	
THW	**HW Supply Temp to Bldg Loop (2nd sensor)**	**°F**	**BTU Meter (System 40, 1 inch)**
TR	**Recirc Temp Back from BLDG**	**°F**	
FR	**Recirculation Flow**	**gpm**	
QR	**Recirculation Loop Heat Losses**	**BTU/h**	
THPO1	**Outlet Temperature from WWHP1 (load)**	**°F**	**Temp Sensor**
THPI1	**Inlet Temperature to WWHP1 (load)**	**°F**	**Temp Sensor**
THPO2	**Outlet Temperature from WWHP2 (load)**	**°F**	**Temp Sensor**
THPI2	**Inlet Temperature to WWHP2 (load)**	**°F**	**Temp Sensor**

Note: Sensors in Bold installed with NYSERDA Funding

Figure 9. Schematic of WWHP and Storage Tanks with Monitoring Points Shown



4 Results

This section presents the results of monitoring effort that started in early 2022 and continued through October 2023.

4.1 Timeline of Events During the Monitoring Period

Data collection at the building first started in January 2022. The first apartment tenants moved in on April 1, 2022. All the apartments were fully occupied by June 1, 2022. The table below delineates the major events during the monitoring period.

Table 3. Events and Milestones During the Monitoring Period

Date	Event or Milestone
Jan-8-2022	Data collection starts for loop temperatures
Feb-14-2022	Data collection starts for BTU meters and flow meters (egauge: loop)
Feb-23-2022	Buffalo Geothermal control changes: The loop pump controls changed to reduce loop flow and increase the loop delta-T The WWHP controls changed so that one WWHP served the pre-heat DHW tank at a lower temperature (~105°F) and the other WWHP maintains the final tank at a hotter temperature (~130°F)
Mar-1-2022	Occupancy begins
Mar-14-2022	Data collection begins for pump and WWHP power (egauge: Main 2)
Mar-26-2022	Loop flow meter has one turbine stop (measured flow is ½)
Apr-1-2022	Full building occupancy expected.
Apr-29-2022	Open House / Grand Opening at Zero Place
May-2022	Loop flow meter failed and returned to the factory for repair
Jun-1-2022	ACTUAL Full Occupancy begins (affordable apartments fully occupied)
Jun-13-2022	Flow Meter replaced
Jan-5-2023	TLR sensor moved into flow stream for a better reading Loop pump control setting changed to 26.1 ft of head, constant pressure Recirculation flow reduced from 10 to under 4 gpm
Jan-24-2023	Recirculation loop extended to 1st floor Café

4.2 Monthly Building and HVAC Energy Use

Monthly energy use for the entire building is given in Table 4. Total use for July 2022 through June 2023 was 279.2 MWh for entire building or 4.4 kWh per sq ft. The solar output was 265.2 MWh for the year, showing the building is nearly net zero across the year. On a monthly basis the building is a net exporter in the summer months and net importer in the winter months. The net utility purchases were 14 MWh across the year. Dividing the total solar production by the nominal array size of 248 kWdc, the full load hours of production across the year was 1,069, typical of most solar systems

There was very little activity in the commercial spaces, so if we assign all the energy use to the apartments and common areas (55,780 sq ft of floor area) the usage becomes 5.0 kWh per sq ft, or 17.1 kBtu per sq ft. This is very close to the Passive House site energy use design target of 17 kBtu per sq ft (BEX 2021).

Table 4. Total Building Electricity Use, Solar Product and NET Utility Purchases

Month	Outdoor Temperature (F)	Total Building (MWh)	Solar Production (MWh)	Utility NET Meter (MWh)
Jun-22	50.7	13.8	21.0	-7.2
Jul-22	80.4	25.7	35.9	-10.2
Aug-22	79.7	25.4	32.4	-7.0
Sep-22	70.4	21.5	24.4	-2.9
Oct-22	58.5	20.6	19.0	1.6
Nov-22	51.5	22.6	13.9	8.6
Dec-22	38.9	28.0	8.0	20.0
Jan-23	43.0	27.0	7.5	19.6
Feb-23	40.7	24.3	14.5	9.8
Mar-23	44.3	23.5	20.2	3.3
Apr-23	56.2	19.9	25.7	-5.8
May-23	63.1	19.9	36.9	-17.0
Jun-23	69.9	20.8	26.8	-6.1
Jul-23	79.7	25.5	29.6	-4.1
Annual	July-June	279.2	265.2	14.0

Table 5 breaks out the power use for the WSHPs in various sections of the building. The annual data are for July 2022 through June 2023. The summer totals correspond to May through September while winter totals are October through April. In general, about half of the WSHP energy is used in the summer months and half in the winter months. The last column in the table breaks out the energy use for the multifamily section of the building.

Table 6 compares the multifamily energy use (WSHPs and loop pumps) to the original PHIUS predictions or targets of annual heating and cooling load normalized by floor area. We assumed seasonal COPs of 3.3

for heating and 3.6 for cooling to convert the input electric use into the delivered heating and cooling loads. Overall, the measured heating and cooling loads are about 20% greater than the PHIUS targets. The relatively modest PHIUS assumptions about internal loads and heat gains probably explains most of the differences.

Table 5. Space Conditioning Heat Pump Energy Use by Area

Month	Avg Outdoor (F)	[1] Loop Pumps (kWh)	[2] All WSHPs (kWh)	[3] Apartment WSHPs (kWh)	[4] Retail WSHPs (kWh)	= [1]+[2]-[4] MulitFamily WSHP+Pumps (kWh)
Apr-22	51.7	249	3,425	2,908	73	3,601
May-22	63.4	276	4,442	3,651	234	4,484
Jun-22	71.9	300	6,121	4,681	253	6,168
Jul-22	80.4	373	9,751	7,477	553	9,571
Aug-22	79.7	389	9,484	7,591	721	9,152
Sep-22	70.4	311	5,652	4,413	630	5,334
Oct-22	58.5	267	3,730	3,128	383	3,614
Nov-22	51.5	291	5,207	4,340	505	4,993
Dec-22	38.9	369	9,227	7,130	980	8,616
Jan-23	43.0	276	8,297	6,473	957	7,617
Feb-23	40.7	247	7,636	6,079	926	6,958
Mar-23	44.3	272	6,288	5,099	874	5,686
Apr-23	56.2	236	3,950	2,968	805	3,382
May-23	63.1	244	3,955	2,909	750	3,449
Jun-23	69.9	265	6,072	4,265	1,074	5,263
Jul-23	79.7	355	10,983	7,508	1,792	9,545
Annual		3,541	79,250	61,872	9,158	73,633
Summer	May-Sep	1849	38,645	29,783	4,111	36,383
Winter	Oct-Apr	1692	40,605	32,089	5,046	37,251

Table 6. Comparing Measured Space Conditioning Loads to Passive House (PHIUS) Targets

	PHIUS Metrics	Measured Values	Difference		Assumed COP(-)	Measured MF Use (kWh/yr)
Total Heating (kBtu/sq ft-yr)	6.2	7.5	21%		3.3	37,251
Total Cooling (kBtu/sq ft-yr)	6.5	8.0	23%		3.6	36,383

Note: Multifamily floor area is 55,780 sq ft

Table 7 shows the monthly energy use for the mechanical systems that provide space conditioning and DHW across the monitoring period. We selected July 2022 through June 2023 as the annual period when the building was fully occupied. The table also shows hot water consumption for each month as well as the ground loop supply temperature (TLS) and the outdoor temperature. On an annual basis, total mechanical electricity use was 113,626 kWh, with WSHPs for space conditioning using 79.250 kWh, the WWHPs for hot water using 30,835 kWh, and loop pumps using 3,541 kWh. Across the year, the loop pumps were only 3.2% of heat pump energy use. Similar tables with daily values are also available in Appendix B.

Table 7. Heat Pump System Energy Use, Hot Water Use, and Operating Temperatures

Month	Avg Outdoor (F)	Avg TLS (F)	Avg HW Use (gal/day)	Space WSHPs (kWh)	DHW WWHPs (kWh)	Loop Pumps (kWh)	Pumping (%)
Apr-22	51.7	49.1	1,061	3,425	2,408	249	4.3%
May-22	63.4	54.8	1,203	4,442	2,349	276	4.1%
Jun-22	71.9	60.6	1,318	6,121	2,096	300	3.6%
Jul-22	80.4	68.0	1,233	9,751	1,834	373	3.2%
Aug-22	79.7	70.0	1,319	9,484	1,932	389	3.4%
Sep-22	70.4	64.1	1,347	5,652	2,030	311	4.1%
Oct-22	58.5	56.5	1,284	3,730	2,364	267	4.4%
Nov-22	51.5	53.4	1,331	5,207	2,590	291	3.7%
Dec-22	38.9	47.5	1,238	9,227	3,193	369	3.0%
Jan-23	43.0	47.1	1,395	8,297	3,357	276	2.4%
Feb-23	40.7	46.1	1,339	7,636	3,065	247	2.3%
Mar-23	44.3	47.1	1,281	6,288	3,149	272	2.9%
Apr-23	56.2	52.2	1,281	3,950	2,701	236	3.6%
May-23	63.1	55.1	1,222	3,955	2,519	244	3.8%
Jun-23	69.9	61.3	1,151	6,072	2,102	265	3.2%
Jul-23	79.7	70.8	1,146	10,983	1,903	355	2.8%
Annual July-June			1,285	79,250	30,835	3,541	3.2%

Figure 10 graphically shows the monthly energy use breakdown for the entire period. The total monthly use is similar in peak summer and peak winter months. July 2023 was an especially warm month and was even slightly higher than December 2022, which had been the peak month up to that point.

Figure 11 shows how hot water use varied across the period. The graph confirms occupancy stabilized starting in June 2023. The average use has been 1,285 gallons per day over the year. As expected, hot water use is slightly lower in summer months, because occupants blend in less hot water at the shower control since the incoming water from the city main is not as cold in this period.

Figure 10. Monthly Electric Use Breakdown for Mechanical Systems

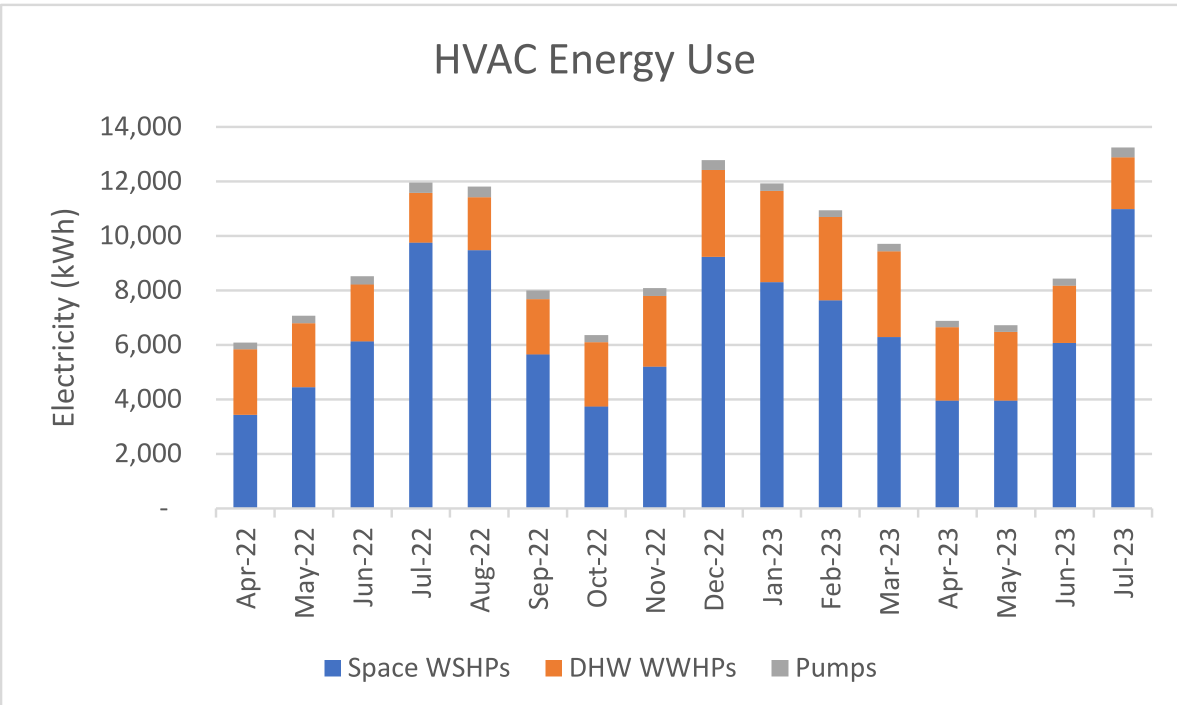
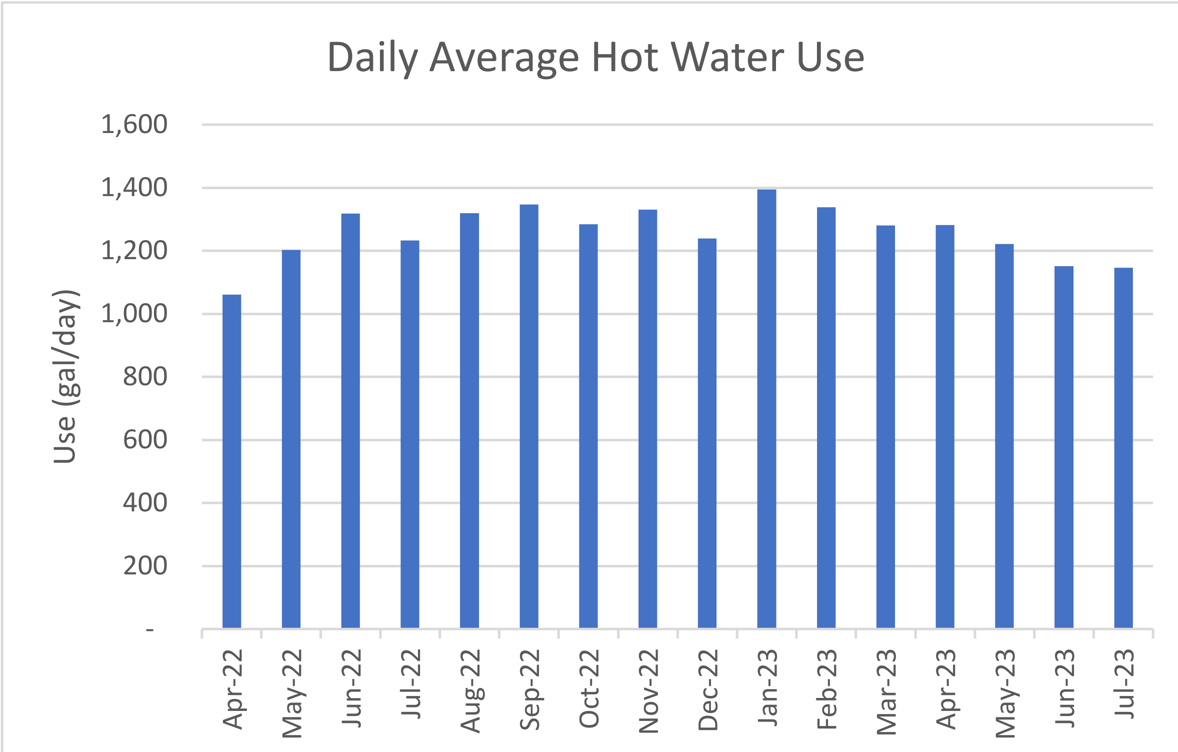


Figure 11. Monthly Average Hot Water Use



4.3 Ground Loop Temperatures

The fluid temperatures from the ground loop over the monitoring period are shown in the top of Figure 12. Temperatures ranged from the high 70s in the summer to the 40s in the winter. Summer 2023 did have higher cooling loads that pushed up the loop temperatures slightly compared to Summer 2022. As expected, the loop started out in January 2022 close to the expected undisturbed ground temperature of 50°F for the Hudson Valley.

The middle of Figure 12 shows the loop flow rates across the year. After a flow meter failure in early 2022 and some pump control adjustments in January 2023, the flows show some variation with loading.

The bottom of Figure 12 shows that the loop temperature difference (TLS-TLR) is positive in the winter when heat is being extracted and negative in the summer when heat is being rejected. The winter delta-T reached as high as 6°F and the summer delta-T reached -11°F. These values indicate that the flow was close to 3 gpm per nominal ton (3 gpm per ton would result in 6°F in the winter and 10°F in the summer).

Figure 12. Trend of Ground Loop Supply Temperatures (TLS), Loop Flows, and Loop Delta-T Over the Monitoring Period

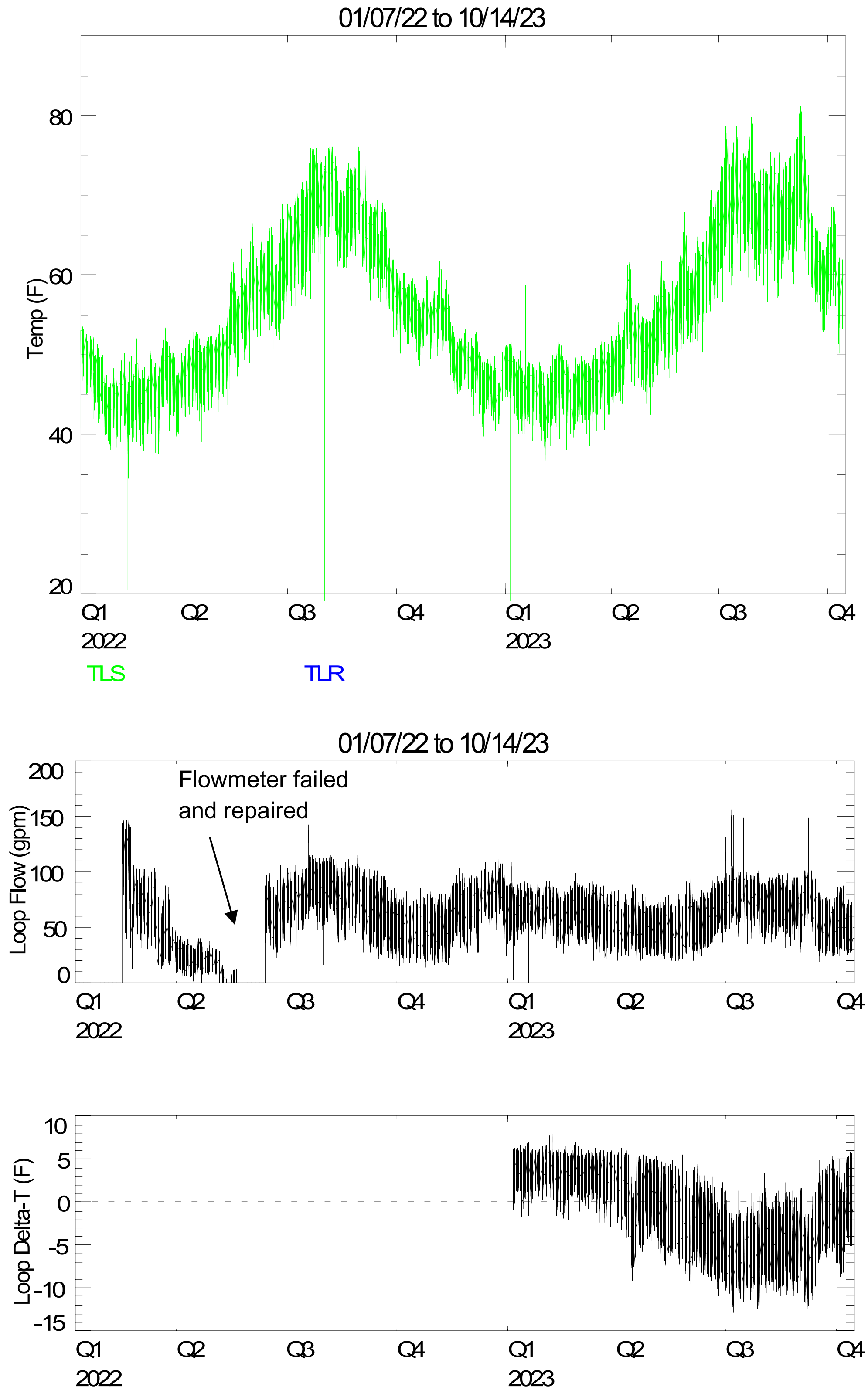
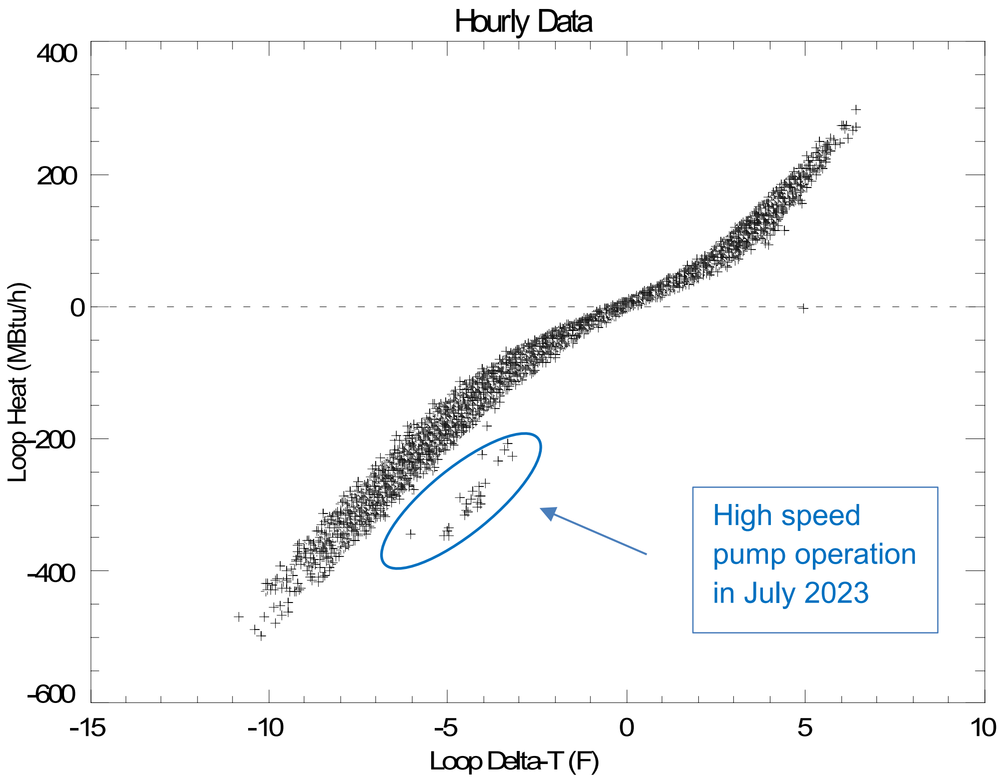


Figure 13 shows how the ground loop heat transfer varies with the loop delta-T, based on hourly averages. The non-linearity of the trend indicates that the flow per active ton varies slightly. The peak hourly heat transfer approaches 300 MBtu/h in the winter when delta-T exceeds 6°F. In the summer, the heat rejection exceeded 500 MBtu/h when the delta-T was -11°F. The only data that deviated from the trend corresponded to higher loop flows for a few days in July 2023, which is discussed further in the pumping section below.

Figure 13. Trend of Ground Loop Heat Transfer versus Loop Delta-T (starting January 2023)



4.4 Observations of Mixed Heating and Cooling in the Winter

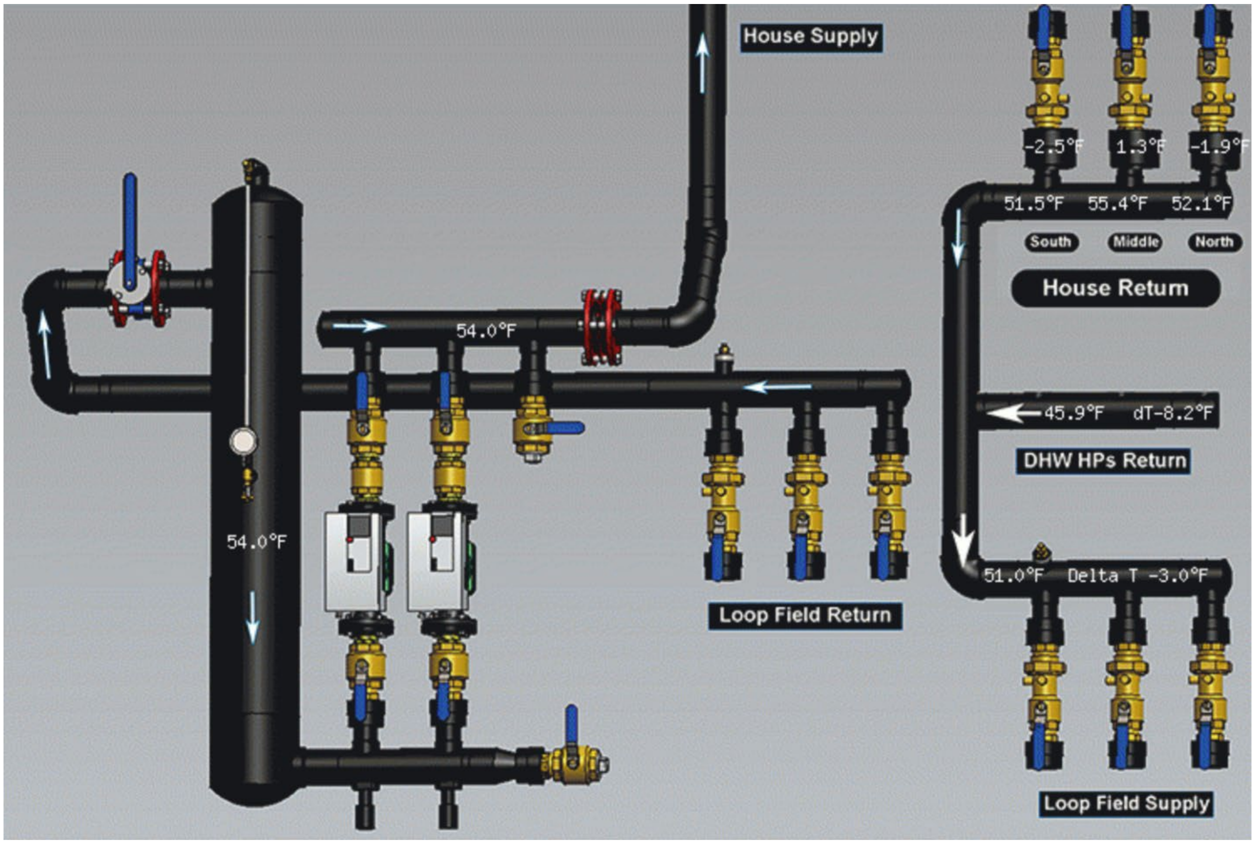
Figure 14 is a graphic from the geothermal monitoring system showing the return temperatures from the various parts of the building. It shows that return temperatures are quite different in different areas and indicate that a mixture of heating and cooling occur in the building. The snapshot is from December 18, 2023, around midnight when ambient was near 39°F. The supply temperature to the building is 54.0°F and the combined return header from the building is 51.0°F, resulting in an overall ΔT of -3.0°F.

However, the return temperatures from various parts of the building are quite different:

- the return from the DHW WWHPs is 45.9°F (ΔT = -8.2°F)
- the return from the South riser is 51.5°F (ΔT = -2.5°F)
- the return from the Middle riser is 55.4°F (ΔT = +1.3°F)
- the return from the North riser is 52.1°F (ΔT = -1.9°F)

Even when outdoor temperatures are 39°F, the WSHPs in the middle of the building have a positive temperature difference, indicating they are mostly in the cooling mode even though the outdoor temperature is 39°F.

Figure 14. Graphic Showing Different Return Temperatures with Ambient Temperatures at 39°F

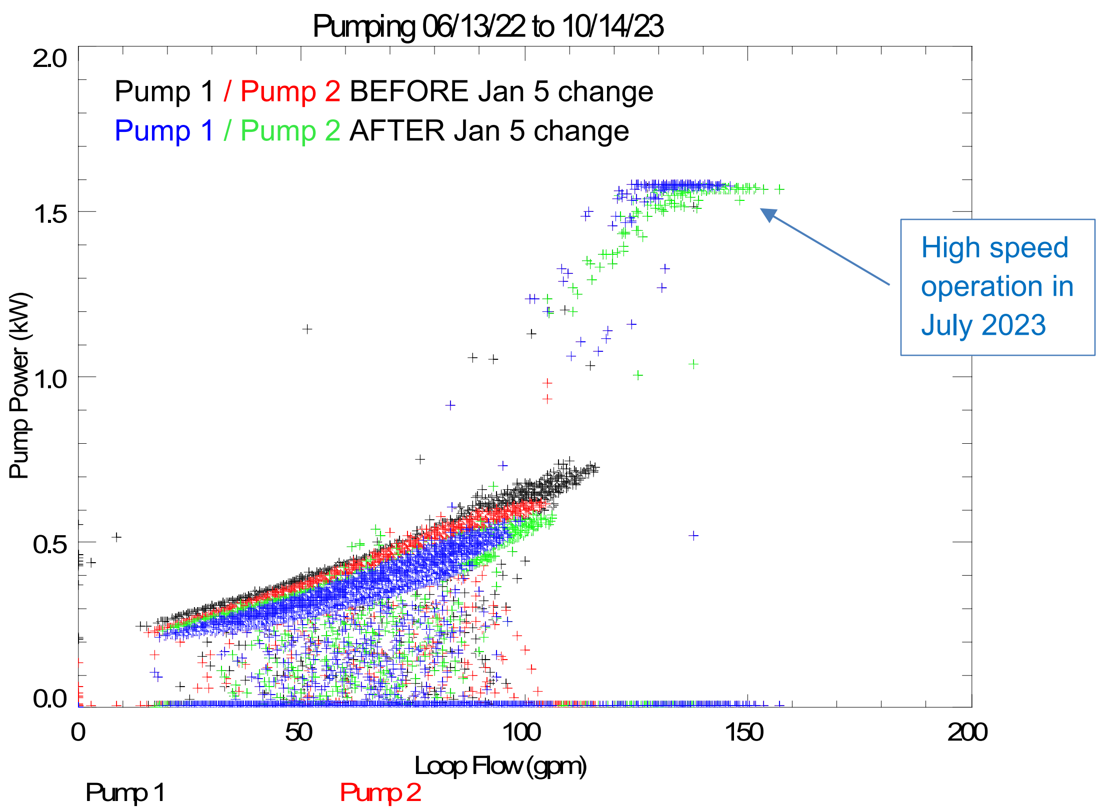


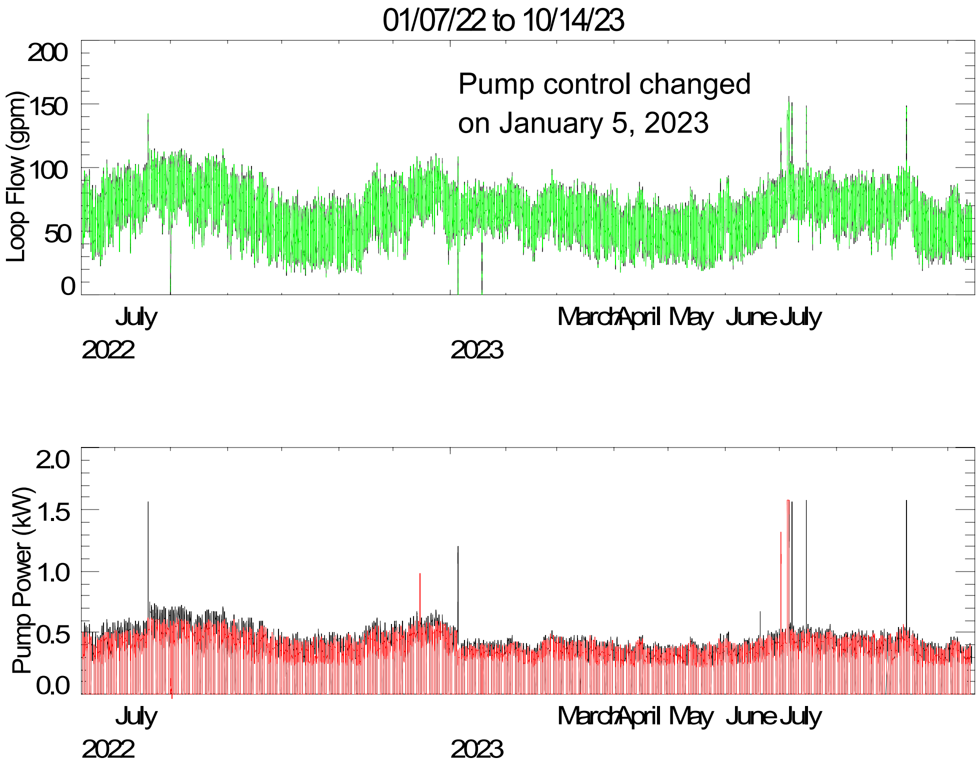
4.5 Ground Loop Pumping

The overall pumping power was shown to be about 3% of total heat pump power in Table 7, which is much lower than is typically observed for GSHP systems. Even the full load power of 1550 Watts is relatively small given the installed capacity of 87.25 tons; the full load value of 18 Watts per installed ton is also much lower than is typically observed for centrally-pumped systems. If the pump had run at full speed (1550 Watts) throughout the year it would have consumed 13,578 kWh. The actual annual pumping power from Table 7 is 26% of that hypothetical full load consumption.

The top of Figure 15 shows how pumping power varies with flow. A control change on January 5, 2023, further reduced the pumping power by changing the full load pumping pressure set point to 26.1 ft. The time series plot at the bottom of Figure 15 also shows that the power was typically lower after January 5, 2023. In summer 2023 the pumps were unexpectedly put into high speed.

Figure 15. Trends of Pumping Power and Ground Loop Flow



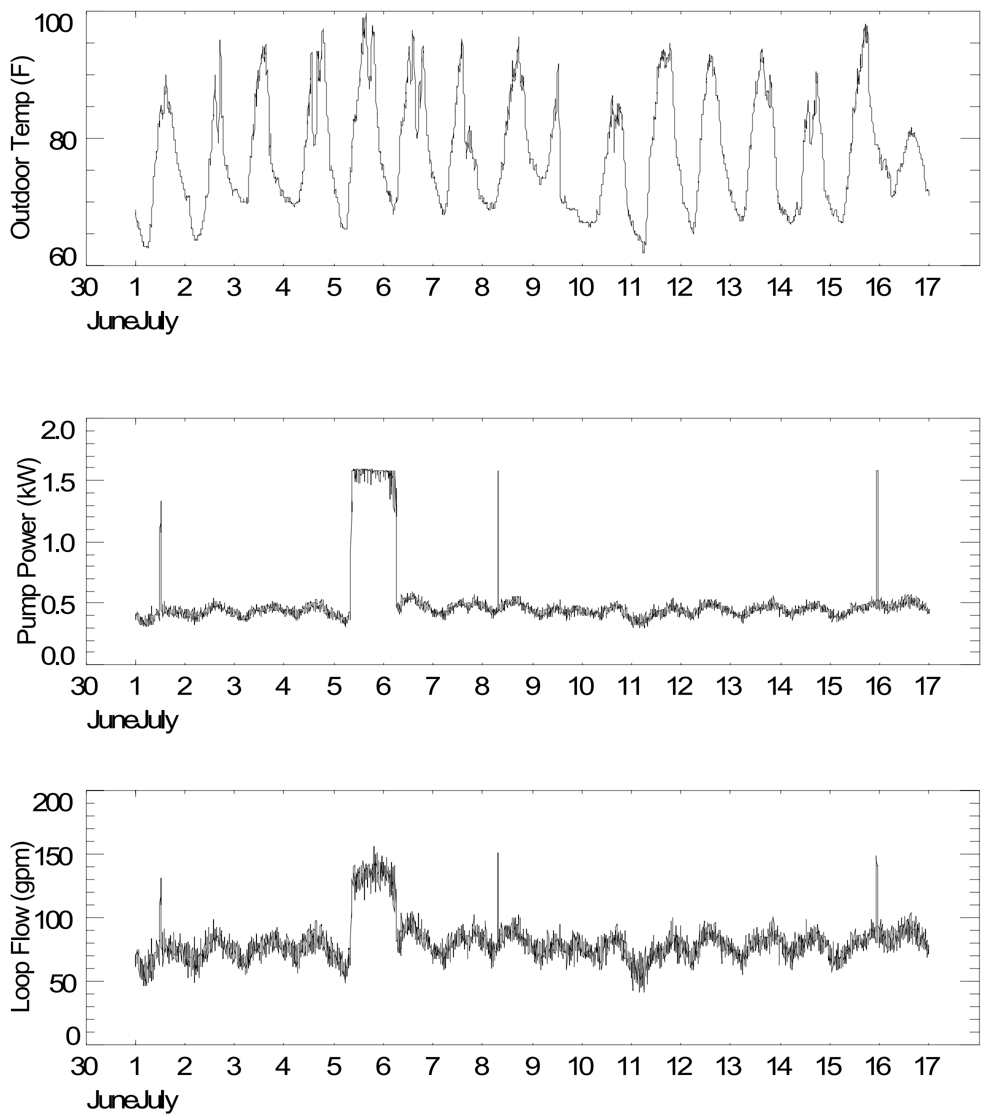


Several other practical features of the system helped to keep to pumping power low, including:

- Using Methanol as the loop fluid lowered pumping power.
- The variable speed pumping system reduces speed to maintain pressure as two-way valves on each HPs closed, thereby reducing pump energy use. In addition, the sensorless pump controls has a built-in "pressure reset strategy" that seeks to provide the design pressure difference at the design flow rate but lets the pressure differential decrease to 50% of design pressure as the flow approaches zero.
- The system contains no balancing valves, circuit setters, or other hydronic components to increase the pump head requirements; any flow limiting for the WSHP units at balancing was achieved by closing ball valves and removing handles.

Figure 16 shows the pumping power and loop flow along with the outdoor temperature in early July 2023 when the loop pumps unexpectedly went to high speed for few periods (on July 1, 5-6, 15). These periods corresponded to cooling operation though typically not a peak cooling period – as also corroborated by the circled data in Figure 13. It is unclear what caused these high-speed spikes.

Figure 16. Trend of Pumping Power and Ground Loop Flow in July 2023



4.6 Trends of Daily Energy Use and Heat Transfer

The following plots show the trends of daily energy use and daily heat transfer versus outdoor temperature. Each symbol represents a day and the associated month is indicated with different colors. Further the year is indicated by the type of symbol (+ indicates Jan to Jun 2022; * indicates Jul to Dec 2022; ◊ indicates Jan to Jun 2023; Δ indicates Jul to Dec 2023).

Figure 17 shows the trend of energy use for the all the WSHPs serving both apartments, common areas, and retail areas. Daily energy use is linear with outdoor temperature as expected, with distinct summer and winter trends. The minimum energy use is about 100 kWh per day and occurs with the outdoor temperatures around 50-60°F. This implies the building has a mix of heating and cooling happening at these temperatures. The daily peak for heating is just slightly higher than the daily peak for heating. The consistently high use for several days in July 2023 (Δ) and September 2023 (Δ) are apparent, as are the coldest days in December 2022 (*) and February 2023 (◊).

Figure 17. Daily Average Electricity Use for All WSHPs versus Daily Outdoor Temperature

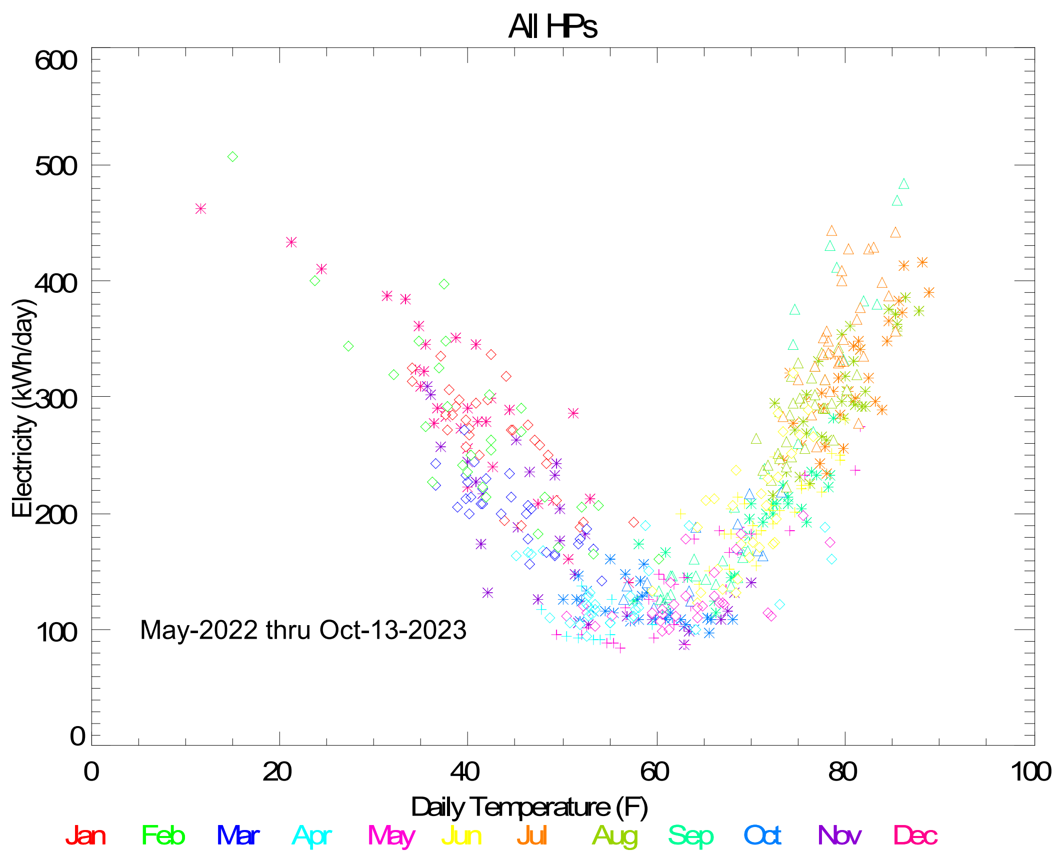


Figure 18 shows the trend daily heat transfer with ground loop heat exchanger versus outdoor temperature. Positive values indicate heat extraction from the loop while negative values indicate heat rejection to the loop. Note that this data did not start until January 2023 when the return temperature sensor was fixed and provided an accurate reading. The WWHPs that provide DHW have an average level of heat extraction near about 0.7 MMBtu/day. Note that the heat extraction equals this value at about 55°F, indicating that this is the approximate point where space heating and space cooling cancel out and have no net impact on the ground loop (i.e., consistent with the changeover temperature range shown by Figure 17).

Figure 18. Daily Ground Loop Loading versus Daily Outdoor Temperature

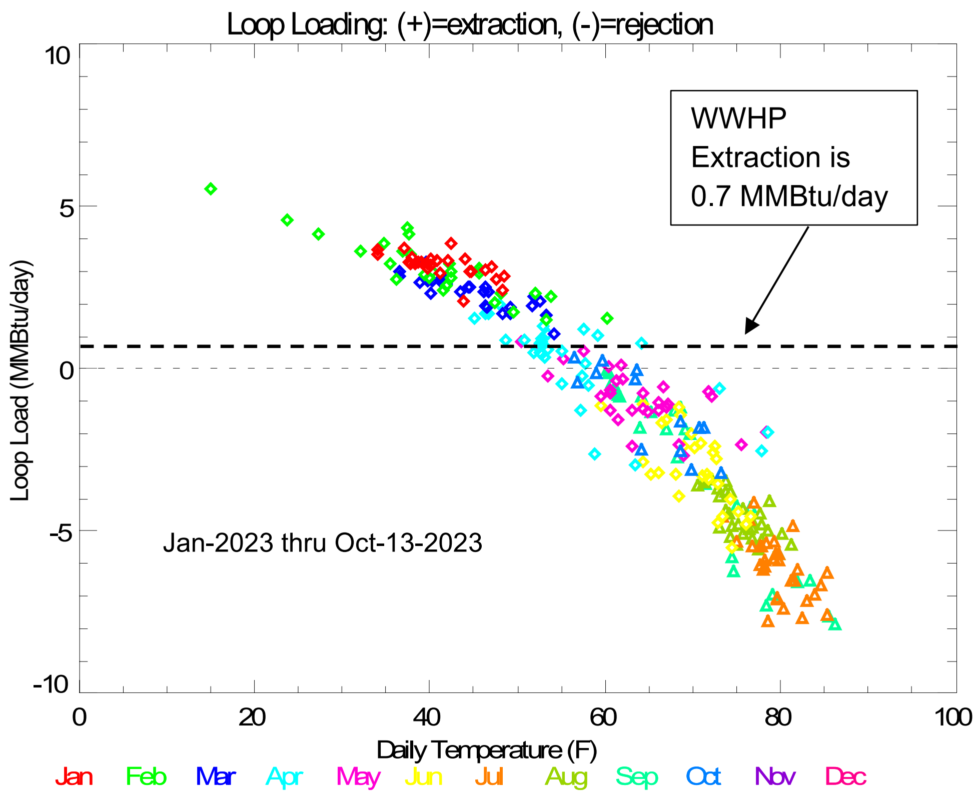
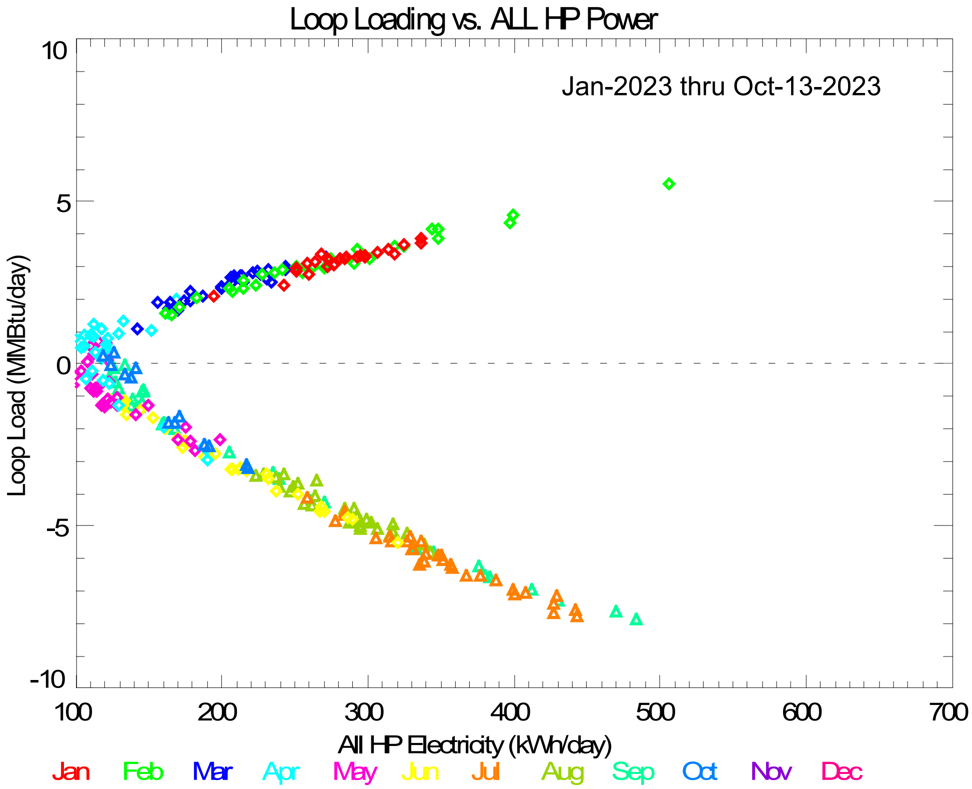


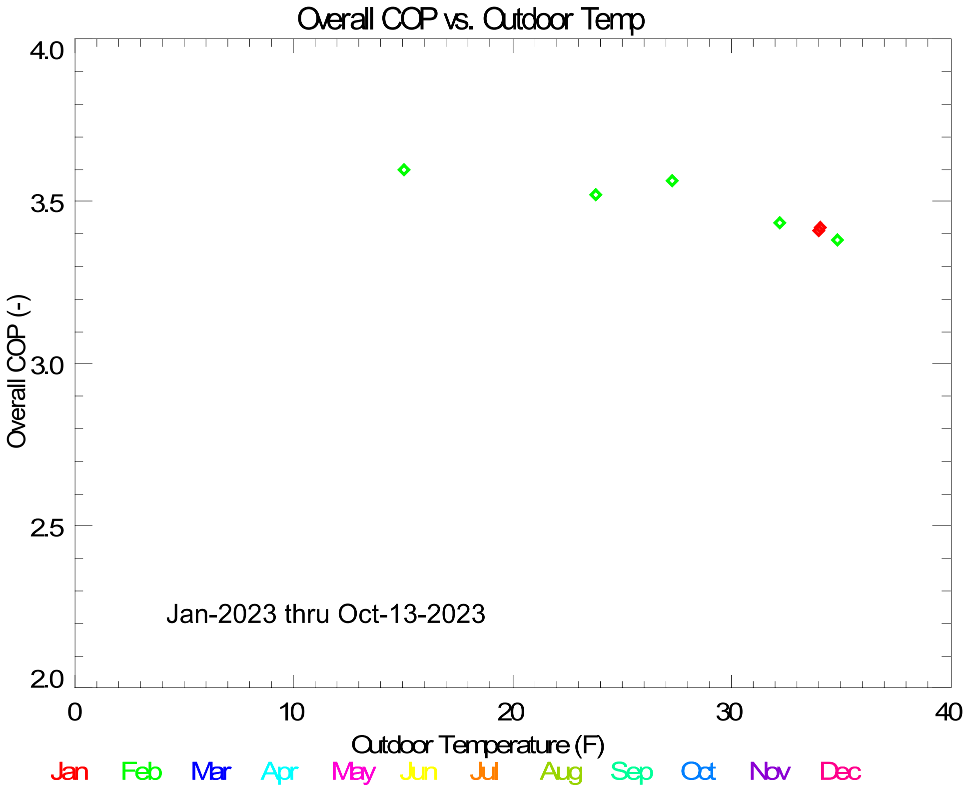
Figure 19 compares the ground heat transfer to the energy use of both the WSHPs for space conditioning and the WWHPs for DHW. The data shows a forked pattern corresponding to heating and cooling as expected, with a very tight trend. The heat transfer is strongly linked to the energy use of the heat pumps.

Figure 19. Daily Ground Loop Loading versus HP Energy Use (both WSHPs and WWHPs)



Using the daily ground loop heat transfer, the daily power for all the heat pumps, and the daily loop pump power, we can calculate the daily average heating COP for the entire system. Figure 20 shows daily average heating COP versus the daily average ambient temperature, with different months highlighted with different colors as for plots above (in this case only January and February 2023 are shown). The calculation is only valid when we are sure all heat pumps are only in the heating mode – therefore we only show COPs when the daily average ambient temperatures are below 35°F to ensure minimal or no cooling operation. Perhaps the most interesting aspect of this plot is that it confirms that the daily average COP remained high even on the coldest days of the year. The overall COP for space and water heating together remained above 3.6 even on the coldest day in February 2023 when the average ambient temperature was 15°F and the overnight temperature had dropped well below zero.

Figure 20. Daily Heating COP versus Outdoor Temperature



4.7 Performance of the DHW System

4.7.1 WWHP Operation and Performance

Figure 21 shows the temperatures in the DHW systems starting in January 2022. **THW** is the hot water temperature supplied to the building. **THPI1** and **THPO1** are the temperatures in and out of WWHP1 and **THPI2** and **THPO2** are the temperatures in and out of WWHP2. WWHP2 was changed to serve the pre-heat tank on February 23, 2022, so the temperatures for that unit decreased. Figure 22 shows the same data for the day on February 23 when the controls were changed.

Figure 21. Initial Operating Temperatures for the DHW System in Eary 2022

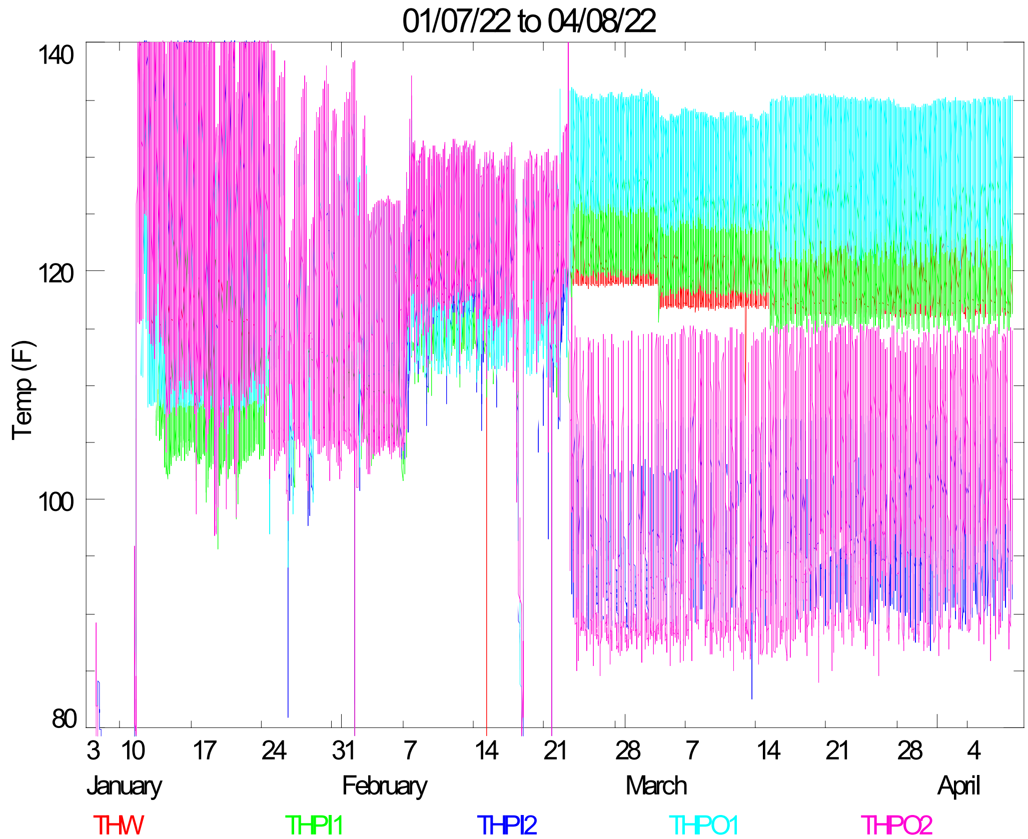


Figure 22. Operating Temperatures for the DHW System on February 23, 2022

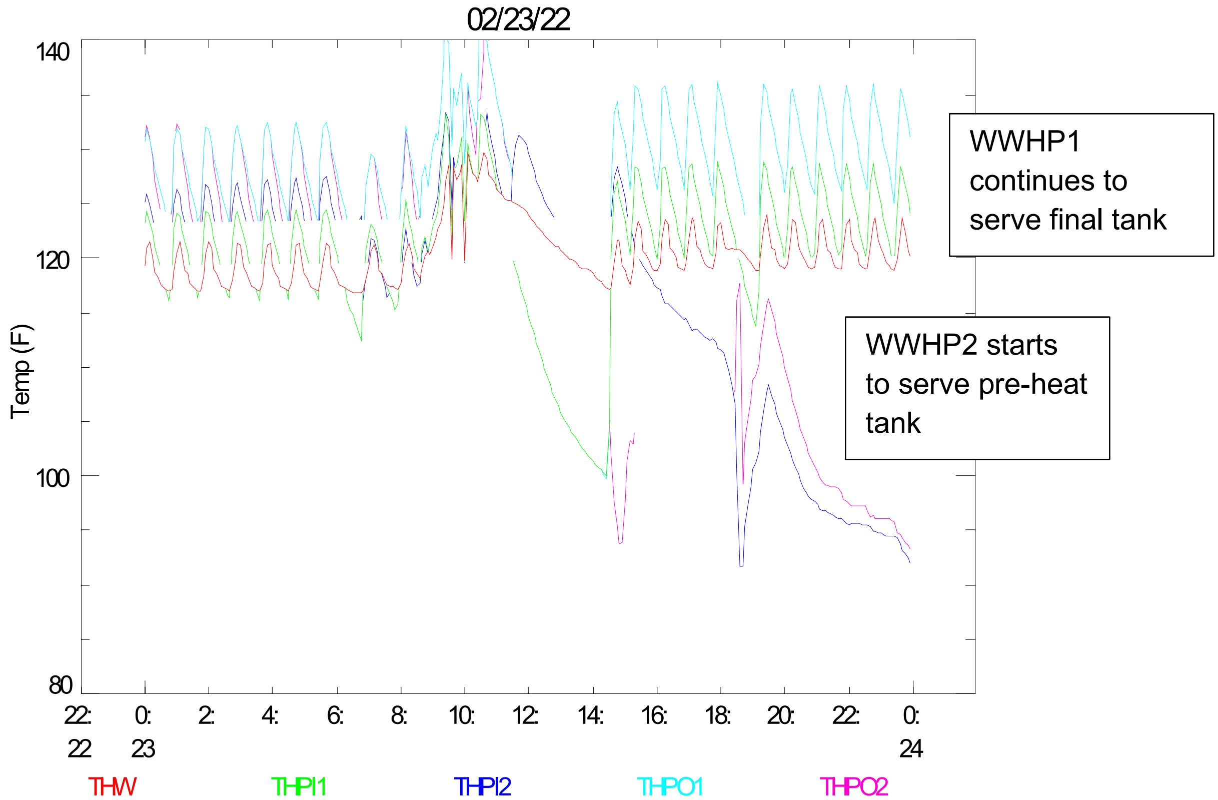


Figure 23 shows the same temperature data for February 1, 2023, a day when the DHW system was operating normally. The plots also include the status of the two WWHPs. WWHP2 still serves the pre-heat tank and therefore has a lower inlet temperature of 90-105°F. It runs longer and cycles less often. WWHP1 serves final stage tanks and has an inlet temperature near 120°F. It cycles frequently to hold the final tank at the 125°F set point (cutout). Figure 24 shows the water use profile for the same day (the square bars represent the hour average flow rates). Total use was 1,189 gallons per day, near the annual average value of 1,285 gallons per day.

Figure 23. Temperatures and WWHP Operation on February 1, 2023 – A Typical Day

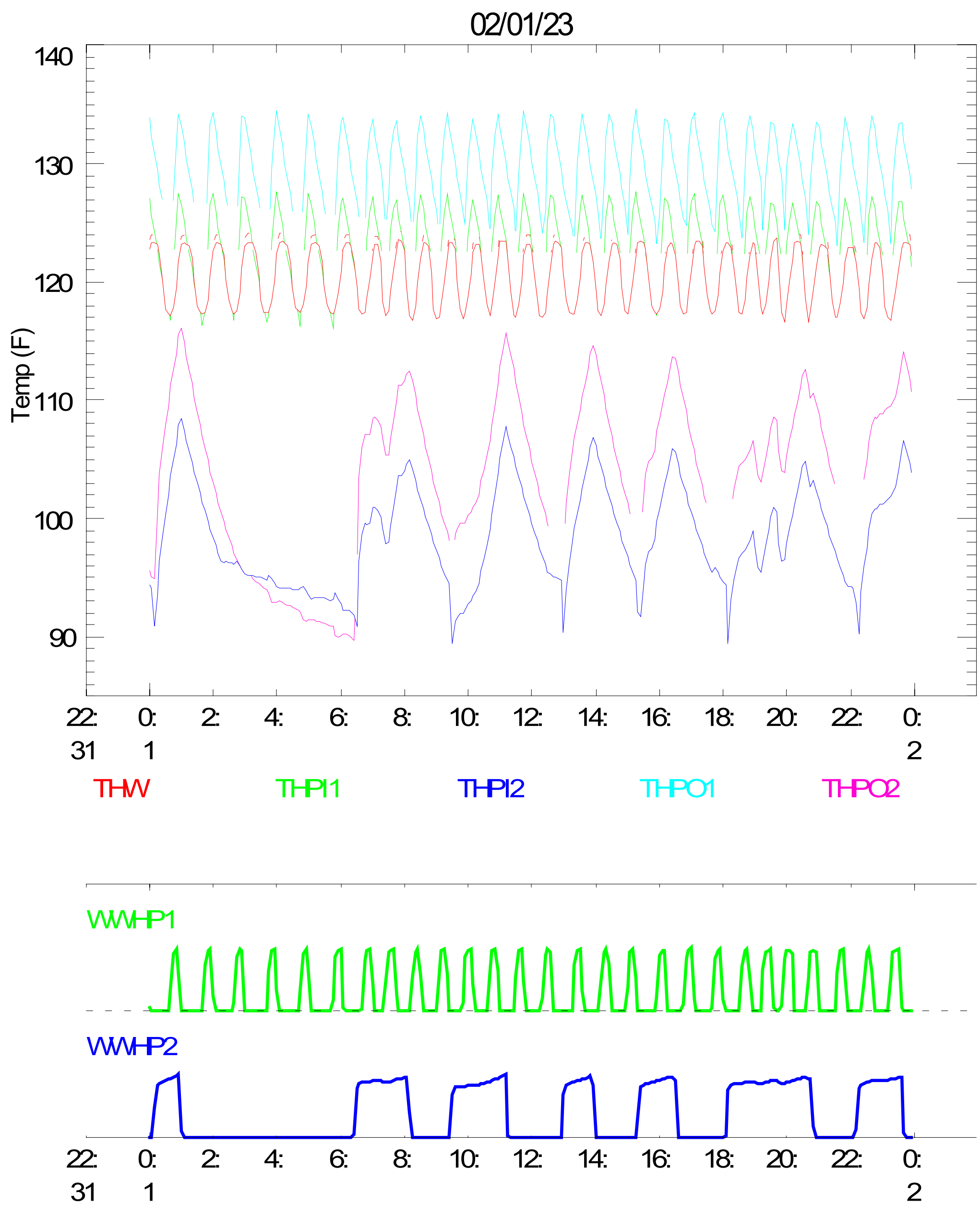
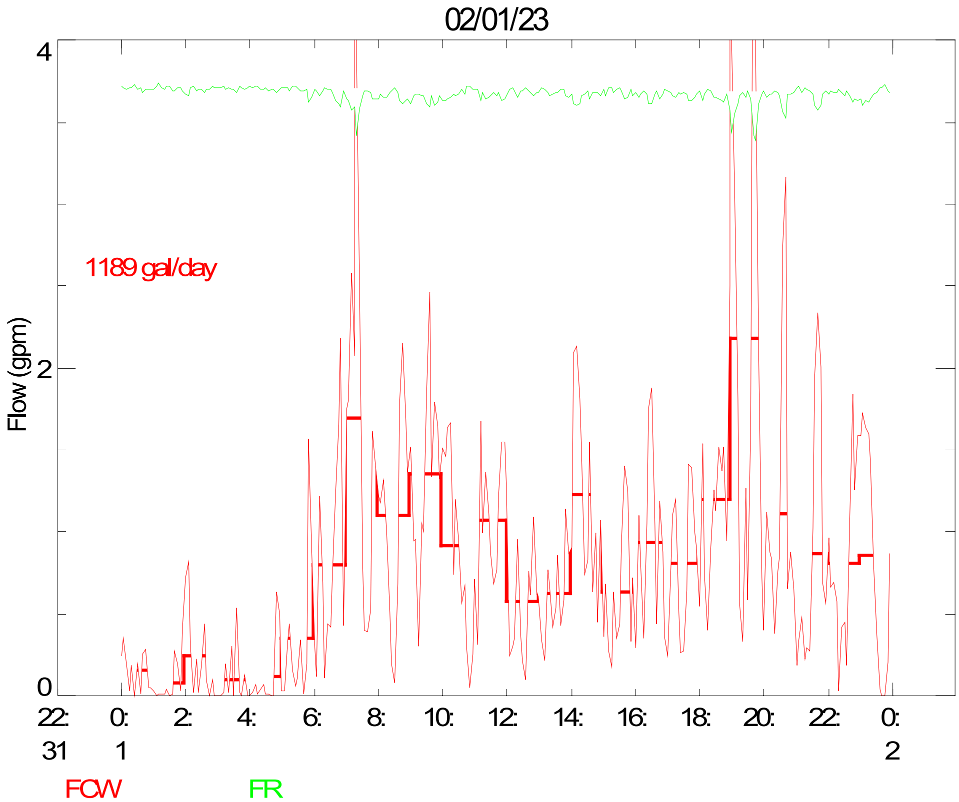


Table 8 summarizes the daily performance of the DHW System (tables for other periods are available in Appendix B). The measured heat delivered (QHW) is shown along with the measured heat loss from the recirculation loop (QR). The percent recirculation losses, or QR /(QHW+QR), are typically 30%, or an average of about 10-15 MBtu/h – consistent with losses measured at other multifamily sites (Henderson 2023). The overall measured COP based on the net delivered heat (QHW / HP Power) is shown as well as the measured COP based on delivered heat and losses i.e., Gross COP = (QHW + QR) / HP Power.

Figure 24. Daily Hot Water Use Profile on February 1, 2023 – A Typical Day



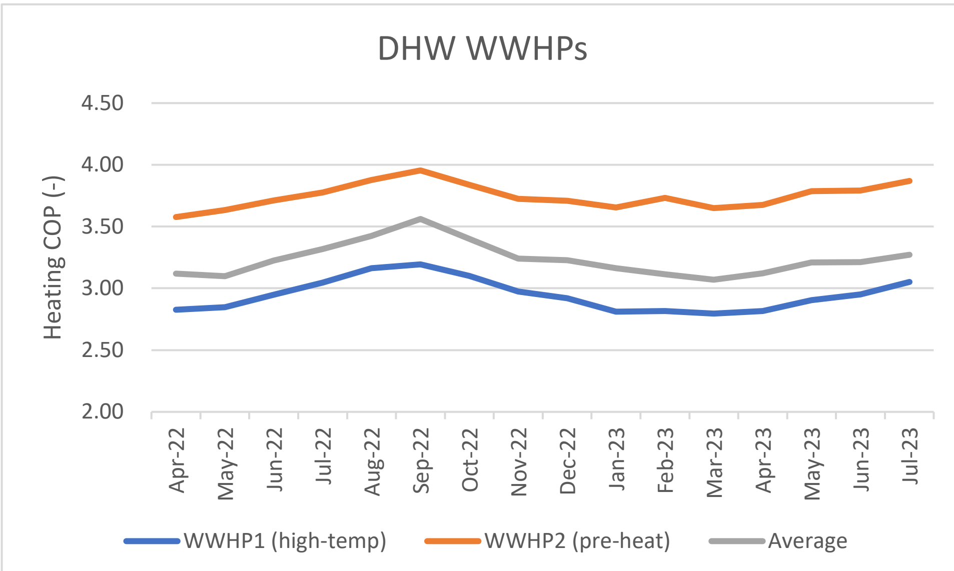
The predicted COP for each Waterfurnace NEW066 heat pump is a function of the operating conditions (TLS and THPI). The predicted COP is calculated using the regression model of manufacturers data for each unit (from Appendix A). The WWHP2 unit that serves the preheat tank has a COP near 3.6 and the WWHP1 unit has a COP near 2.8. We use the predicted COPs with the measured power to predict the total daily heat output from the WWHPs. Comparing the total measured heat (QHW + QR) with the predicted heat output for the WWHPs, we get a heat balance percentage of 95-100%. The slightly higher predicted heat output may be explained by HP cycling losses as well as unmeasured heat losses from the tank and piping systems. The heat balance check provides confidence in the measured data. The row corresponding to January 5, 2023, when the recirculation flow was changed, is highlighted in bold.

Table 8. Daily DHW System Performance in Early 2023

		Daily Energy (MBtu/day)					Predicted WWHP COP (-)		Predicted WWHP	
Date	HW Use (gal/day)	QHW	QR	Recirc Losses (%)	Gross COP (-)	Net COP (-)	HP1 (final)	HP2 (pre-heat)	Output (MBtu/day)	Heat Balance (%)
1/1/2023	977.3	594.4	373.9	39%	3.08	1.89	2.85	3.68	999.9	97%
1/2/2023	1,163.8	708.5	313.2	31%	3.25	2.26	2.85	3.71	1,011.7	101%
1/3/2023	1,168.0	707.6	324.3	31%	3.20	2.19	2.85	3.66	1,037.1	100%
1/4/2023	1,279.4	775.8	331.9	30%	3.27	2.29	2.85	3.70	1,093.2	101%
1/5/2023	**1,323.0**	**809.5**	**293.1**	**27%**	**3.22**	**2.36**	**2.83**	**3.75**	**1,115.6**	**99%**
1/6/2023	1,397.1	858.6	256.0	23%	3.21	2.47	2.87	3.82	1,157.8	96%
1/7/2023	1,491.8	925.6	259.5	22%	3.18	2.48	2.85	3.97	1,293.0	92%
1/8/2023	1,523.0	983.9	275.7	22%	3.08	2.40	2.85	4.91	1,733.1	73%
1/9/2023	1,437.9	886.1	258.7	23%	2.91	2.25	2.82	4.03	1,389.8	82%
1/10/2023	1,380.9	845.3	260.7	24%	3.08	2.35	2.81	3.56	1,152.9	96%
1/11/2023	1,456.4	897.0	255.4	22%	3.10	2.41	2.79	3.53	1,187.7	97%
1/12/2023	1,202.2	740.0	253.2	25%	2.93	2.19	2.80	3.53	1,075.2	92%
1/13/2023	1,227.6	756.5	271.0	26%	3.15	2.32	2.83	3.56	1,043.9	98%
1/14/2023	1,289.7	812.0	275.7	25%	3.06	2.29	2.81	3.81	1,205.8	90%
1/15/2023	1,506.9	931.5	256.2	22%	3.11	2.44	2.80	3.56	1,226.9	97%
1/16/2023	1,497.0	943.0	259.1	22%	3.10	2.43	2.79	3.71	1,295.5	93%
1/17/2023	1,659.6	1,044.3	260.8	20%	3.10	2.48	2.78	3.62	1,384.0	94%
1/18/2023	1,471.7	940.4	264.4	22%	3.16	2.47	2.82	3.98	1,343.0	90%
1/19/2023	1,436.5	899.4	272.0	23%	3.00	2.30	2.80	3.66	1,292.5	91%
1/20/2023	1,374.8	859.1	268.9	24%	3.09	2.35	2.81	3.54	1,166.6	97%
1/21/2023	1,482.2	931.8	263.1	22%	3.17	2.47	2.80	3.65	1,235.8	97%
1/22/2023	1,427.7	891.5	253.2	22%	3.07	2.39	2.80	3.59	1,209.0	95%
1/23/2023	1,604.0	1,003.8	251.7	20%	3.18	2.54	2.80	3.62	1,280.6	98%
1/24/2023	1,485.4	942.9	231.5	20%	3.16	2.54	2.81	3.83	1,270.1	92%
1/25/2023	1,370.9	859.7	267.9	24%	3.13	2.39	2.80	3.55	1,149.0	98%
1/26/2023	1,426.0	894.2	288.2	24%	3.02	2.29	2.80	3.54	1,250.9	95%
1/27/2023	1,515.2	977.9	308.2	24%	3.04	2.31	2.80	4.03	1,514.8	85%
1/28/2023	1,562.8	989.2	299.6	23%	3.17	2.43	2.80	3.70	1,342.7	96%
1/29/2023	1,500.6	953.4	295.0	24%	3.05	2.33	2.80	3.73	1,358.8	92%
1/30/2023	1,314.1	819.1	300.9	27%	3.07	2.24	2.81	3.57	1,165.4	96%
1/31/2023	1,287.4	804.0	309.9	28%	3.17	2.29	2.80	3.59	1,114.3	100%
2/1/2023	1,188.5	741.3	304.0	29%	2.93	2.08	2.78	3.49	1,119.1	93%
2/2/2023	1,422.3	921.3	315.1	25%	3.09	2.30	2.77	4.06	1,426.4	87%
2/3/2023	1,260.3	816.2	319.2	28%	2.79	2.01	2.76	3.96	1,464.2	78%
2/4/2023	1,288.9	810.4	304.5	27%	3.04	2.21	2.72	3.48	1,132.3	98%

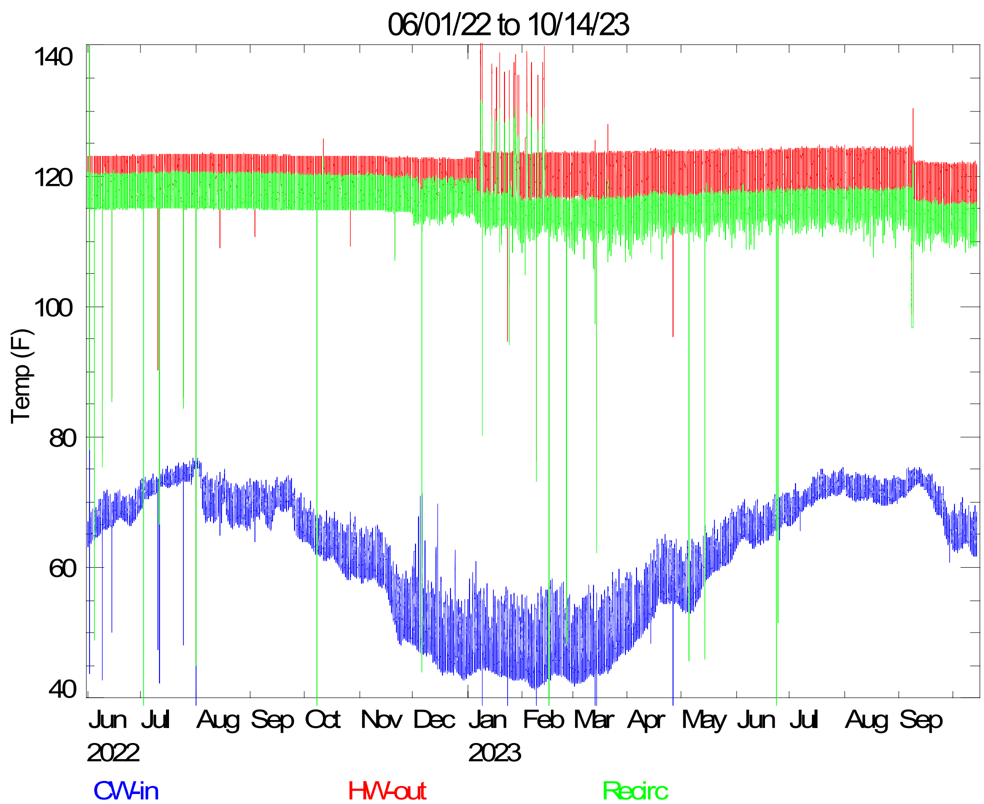
Figure 25 compares the monthly predicted COPs for WWHP1 and WWHP2 to the measured average (gross) COP over the entire period. All the COPs fluctuate seasonally as the ground loop temperature (TLS) changes. The average annual COP is 3.7 for WWHP2 on pre-heat tank and 3.0 for WWHP1 on the final tank. The annual average COP for both units is 3.3, based on measured data.

Figure 25. Monthly Predicted COPs for WWHP1 and WWHP2 Compared to the Measured Average (Gross) COP



The entering city (cold) water temperature varies substantially across the year, reaching the mid-70s in the summer and dropping to the low-40s in the winter. In August 2022 that cold water temperature suddenly dropped a few degrees, perhaps indicating that the city periodically flushes the lines to keep water temperatures lower. City water temperature temperatures started to drop in October (in both years) as would be expected in the fall.

Figure 26. Long-term Trends of Hot Water, Recirculation Water, and City Water Temperature



4.7.2 Peak Hot Water Use and Implications for Pipe Sizing

The project team used the 1-minute data at Zero Place primarily to look at the peak hot water use rates in the building (see Figure 27). These values are useful for understanding how HW piping should be sized. Other field measurements of peak flow from other multifamily buildings have shown that past ASHRAE and IAPMO design guidance is much higher than is typically observed in the field. The hot water supply piping was sized to be 4 inches at zero place – several times larger than necessary given the measured peak flows.

Table 9 summarizes the peak hot water flowrates for various periods with different occupancy. Hot water use stabilized in June 2022 when all the 46 apartments were fully occupied. The table below compares the overall peak usage rates from the beginning to the values since the building has been fully occupied in after June 2022. The maximum occurrence had been about 9 gpm while the systems operated normally. The observed peak flow of 21.5 gpm on January 24, 2023, occurred when the recirculation piping was expanded to coffee shop. The high flow appears to have occurred when the piping was drained and then refilled. Figure 28 graphically shows the cumulative occurrences of hot water flow for the Full Occupancy Period from June 2022 through August 2023.

Table 9. Cumulative Occurrences of Hot Water Flow for Different Periods

Cumulative Occurrence	PARTIAL OCCUPANCY Jan to May 2022 Flows (gpm)	FULL OCCUPANCY Jun to Oct 2022 Flows (gpm)	FULL OCCUPANCY Jun 2022 to Oct 2023 Flows (gpm)
90%	1.5	2.3	2.3
99%	3.7	4.5	4.3
99.9%	5.4	6.2	6.1
99.99%	7.1	8.0	7.7
Maximum recorded	30.4	9.1	21.5

The peak rate of 6.1 gpm at the 99.9% occurrence level equates to 0.13 gpm per apartment. This normalized flow is similar to the peak flowrates measured at five other multifamily sites (Henderson 2023) where the average observed 99.9% peak flow was 0.10 gpm per apartment. The apartment with the highest peak from Henderson (2023) was the Solara apartment complex near Schenectady, New York, where maximum flow was 0.18 gpm per apartment at the 99.9% level.

The percentage of occurrences with zero flow was about 60% from January through May 2022, but has stabilized near 28% since occupancy has stabilized with all apartments fully occupied.

Figure 27. Long-Term Trend of 1-Minute Readings for Recirculation Flows and How Water Use

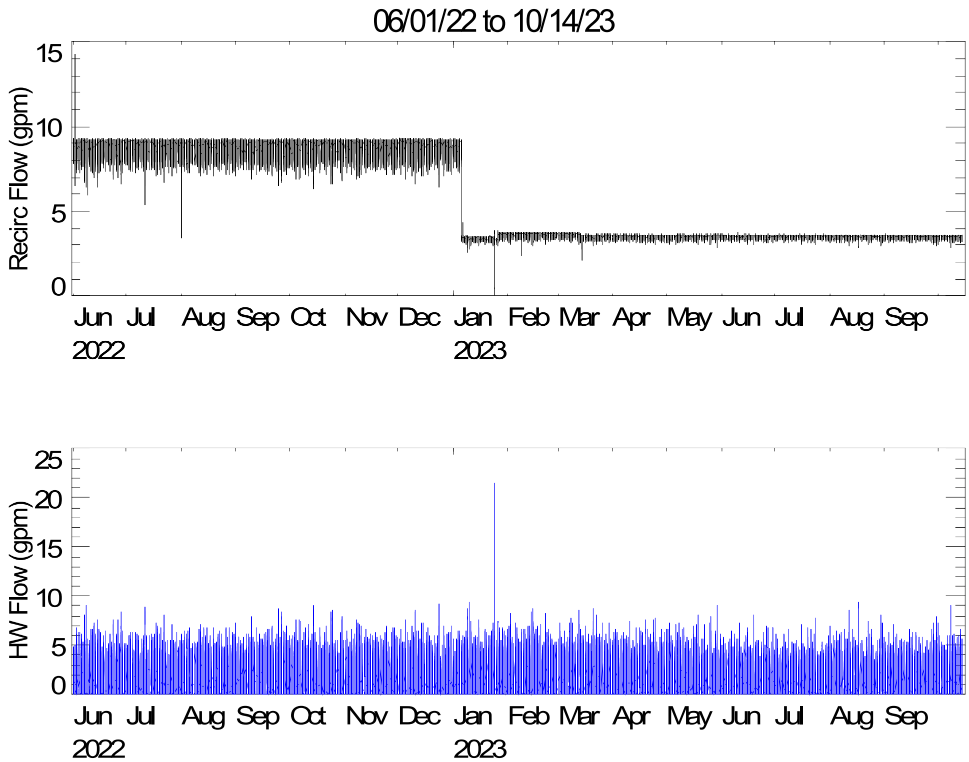
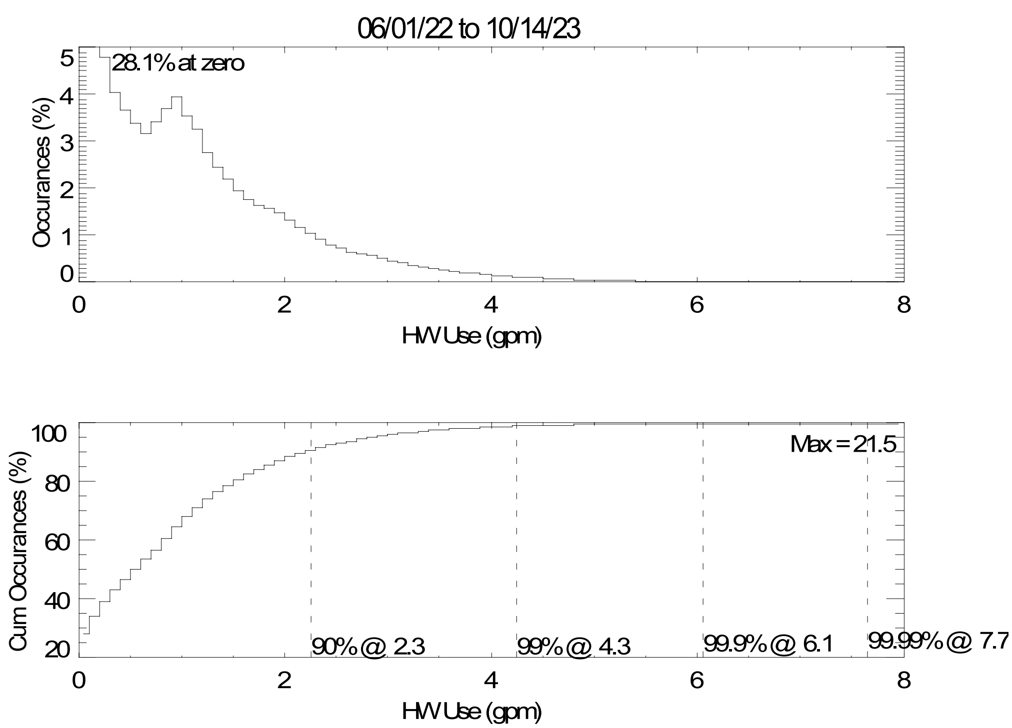


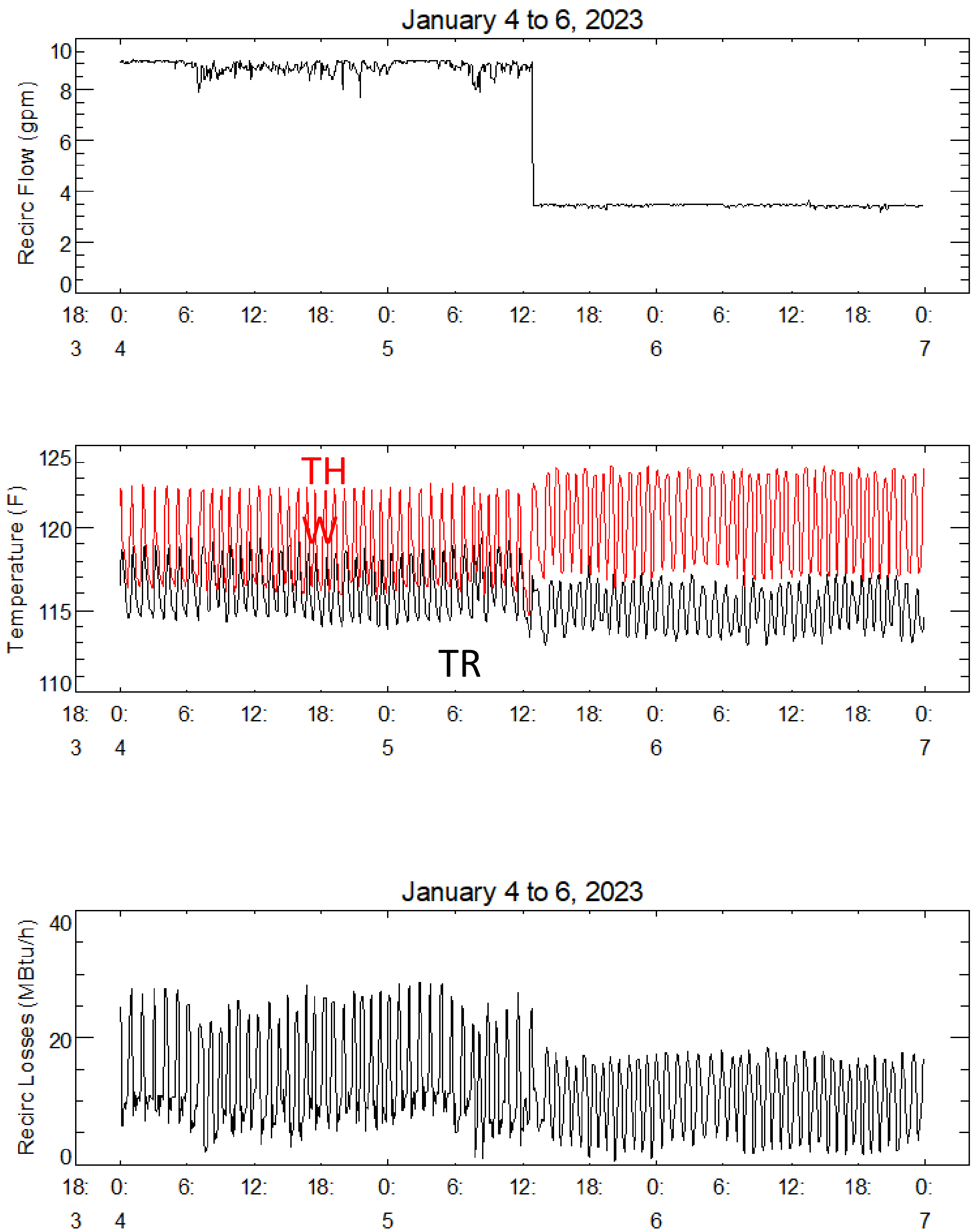
Figure 28. Cumulative Occurrences of Hot Water Use for FULL OCCUPANCY Period (from Table 9)



4.7.3 Performance of the Recirculation Loop and Impact of Lower Flows

As shown above in Figure 27, the recirculation flow rate was reduced on January 5, 2023, when a ball valve on the recirculation line was partially closed. Figure 29 shows the impact of this change on the delivered hot water temperature (THW) and the recirculation temperature (TR) for the hours before and after the change was made. When the recirculation flow dropped under 4 gpm, THW – which oscillates with every operating cycle of WHHP1 – increases by about 1°F. TR also decreased by about 1°F after the change. The thermal losses from the recirculation loop which are product of the recirculation flowrate back to the tank and the temperature difference (THW-TR) decreased from 331.9 MBtu/day on January 4 to 256 MBtu/day on January 6, or by about 23%.

Figure 29. Impact of Reduced Recirculation Flow on January 5, 2023



Using the data in Table 8, the longer-term performance impact of reducing the recirculation flowrate was evaluated in Table 10. The average recirculation losses before the recirculation flow change (Dec 1 to Jan 4) were 350 MBtu/day. After the flow was lowered (Jan 6 to 23), the average dropped to 262 MBtu/day. After the recirculation loop was extended/expanded to reach the Café (Jan 25 to Feb 29) the average recirculation losses increased up to 300 MBtu/day. Figure 30 shows the variation of daily recirculation losses across these three periods. The overall impact of lower recirculation flow was 25% lower thermal losses.

In addition to reduced thermal losses from the piping, the lower recirculation flow also resulted in less temperature disruption in the storage tanks. The reduced tank mixing and disruption increased the overall delivered thermal efficiency of the system. Table 10 also shows the impact on the net or delivered COP of the system (or delivered heating divided by WWHP input). The Net COP increased from 2.15 to 2.39 when the recirculation flow was reduced, an efficiency gain of 11%. The Gross COP was essentially similar across all periods, with only a small reduction as ground loop temperatures dropped later in the winter. Figure 31 shows the variation of daily Net COPs across these three periods.

Table 10. Impact of Recirculation Loop Changes on System Performance

Period	Recirc Flow	Recirc Losses	Recirc Losses (MBtu/h)	Net COP (-)	Gross COP (-)
Before Change (Dec 1 to Jan 4)	10 gpm	32%	350	2.15	3.16
After Change (Jan 6 to Jan 23)	4 gpm	23%	262	2.39	3.09
Café Recirc Changes (Jan 25 to Feb 28)	4 gpm	26%	300	2.28	3.07
Impact of Lower Recirc (Before-After)			-25%	+11%	-2%

Figure 30. Change in Recirculation Losses Between Periods Listed in Table 10

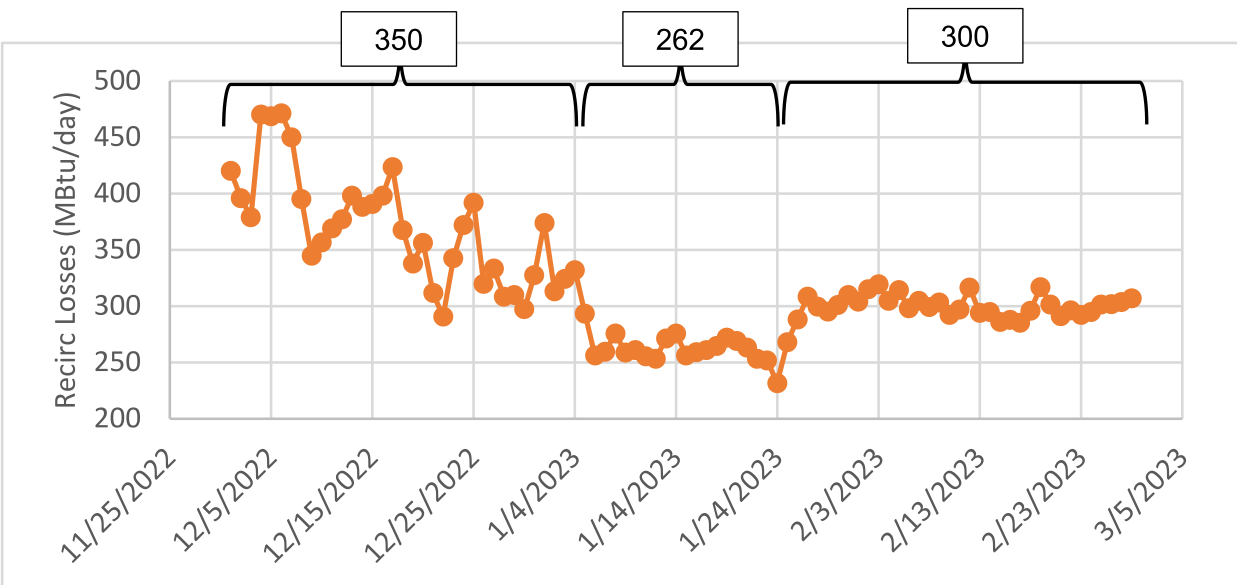
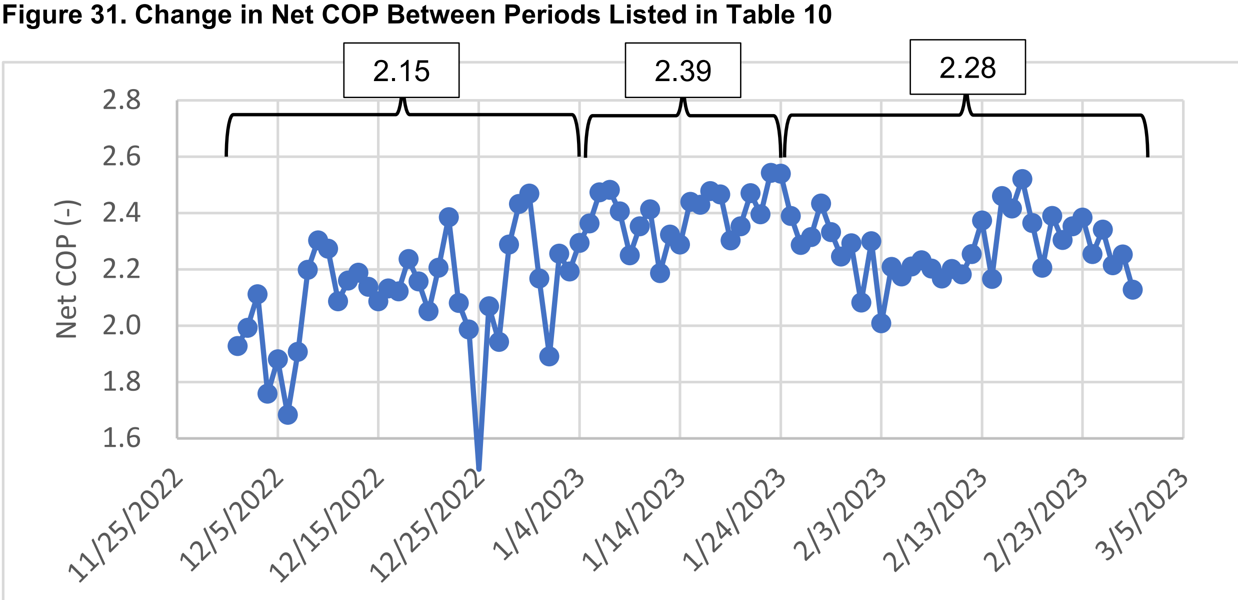


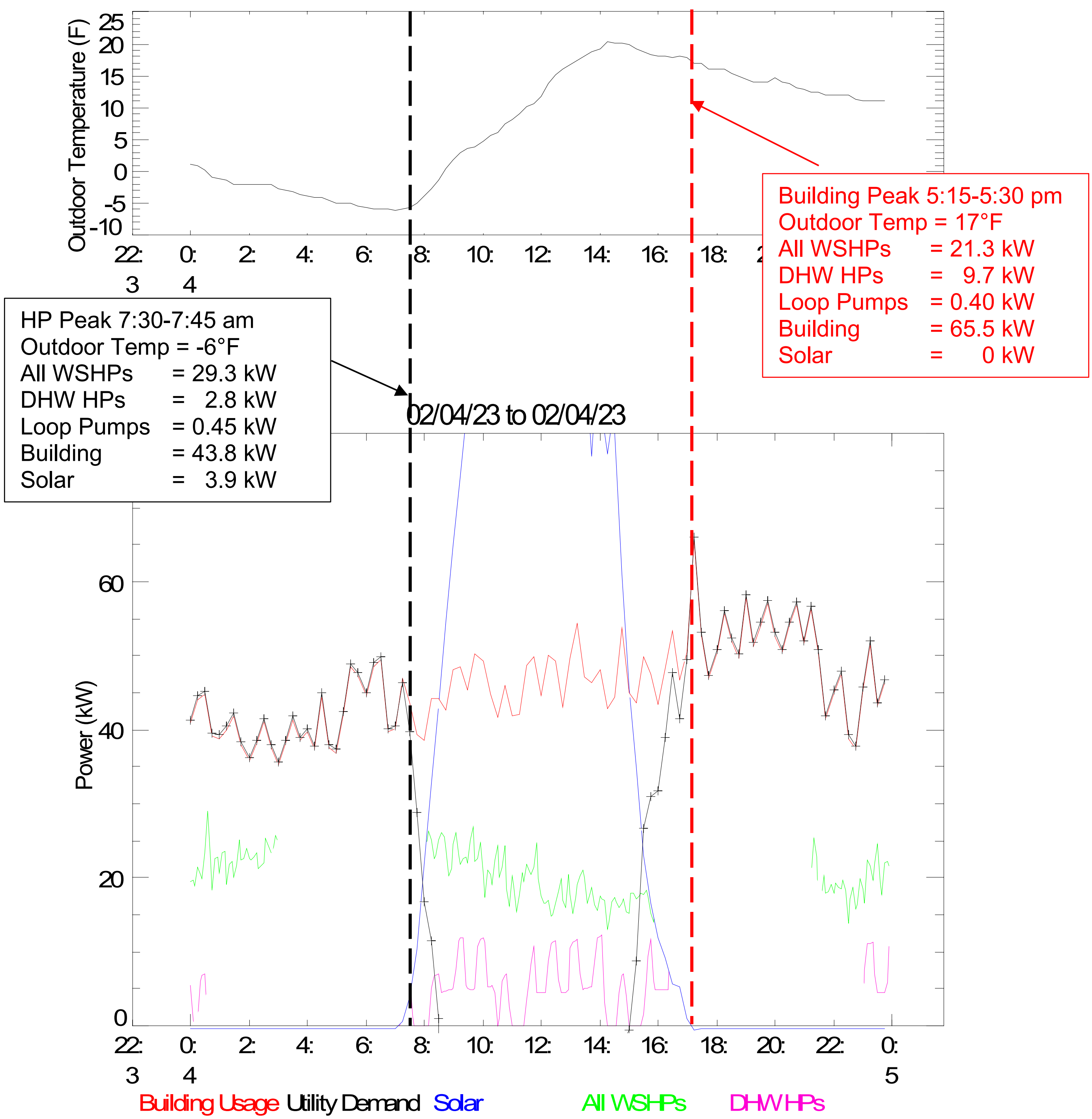
Figure 31. Change in Net COP Between Periods Listed in Table 10



4.8 Performance on Peak Heating and Cooling Days

The coldest winter day was February 4, 2023. Figure 32 shows the trend of ambient temperature for that day at the top of the plot. The bottom plot shows the 15-minute power use across the day for the building, including the solar production and utility-supplied energy as well as the power use for the space heating heat pumps (WSHPs) and the WWHPs. The peak power use for the WSHPs was 29.3 kW for the 7:30-7:45 am interval when ambient temperatures were near -6°F. The peak demand of the building was only 43.8 kW at that moment. The building peaked later in the day at 65.5 kW in the 5:15-5:530 pm interval when the ambient temperature had warmed to 17°F. The WSHP demand at that moment was only 21.3 kW with an additional 9.7 kW added by the WWHPs for DHW.

Figure 32. Building and HVAC Demand on the Coldest Day – February 4, 2023



The hottest summer day was July 19, 2023. Figure 33 shows the trend of ambient temperature for that day at the top of the plot. The bottom plot shows the 15-minute power use across the day for the building, including the solar production and utility-supplied energy as well as the power use for the space cooling heat pumps (WSHPs) and the WWHPs. The peak power use for the WSHPs was 22 kW for the 7:45-8:00 pm interval when ambient temperatures were near 96°F. This interval had the highest building peak demand for the summer of 71 kW.

July 28, 2023, is another hot day when the power use for the WSHPs were at the highest level. Figure 34 shows that the WSHP power peaked at 28.5 kW in the 5:00-5:15 pm interval on that day when the ambient temperature was 95°F. The peak demand for the building was relatively low at the moment and the building peak occurred slightly later at 8:30-8:45 pm at 54.7 kW. The WSHP power was only 19.3 kW in that later interval.

Several key findings are apparent from both the summer and the winter peak demand data:

- The WSHPs for space conditioning were not the primary driver of peak building demand for either the peak summer or peak winter day. The timing of the peak space heating and cooling loads was not well aligned with the building peak demand times.
- In some cases, the 8-10 kW associated with the WWHPs turning on to meet DHW loads did increase the building peak demand. However, the WWHPs alone did not fully explain all the observed building power peaks. The majority of the building peak demand events were driven by occupants coming home at the end of the day and turning on the appliances in their apartments.
- The large solar array did not significantly change the peak demand of the building, since the peaks usually occurred outside the solar production period – even in the summer. So, while the PV array offsets much of the building's energy use, it does not significantly change the peak demands used for utility billing purposes.

Figure 33. Building and HVAC Demand on the Hottest Day – July 19, 2023

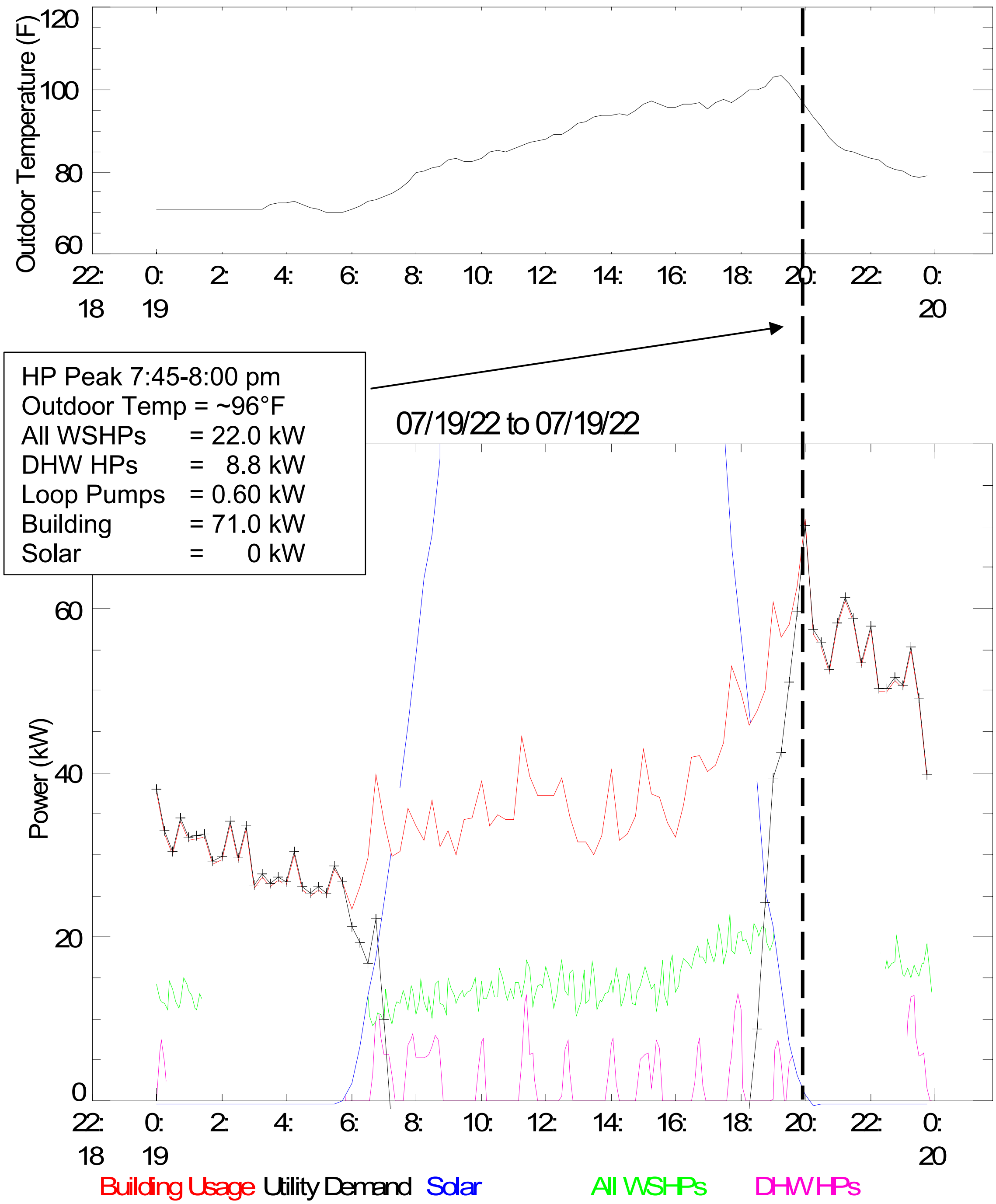
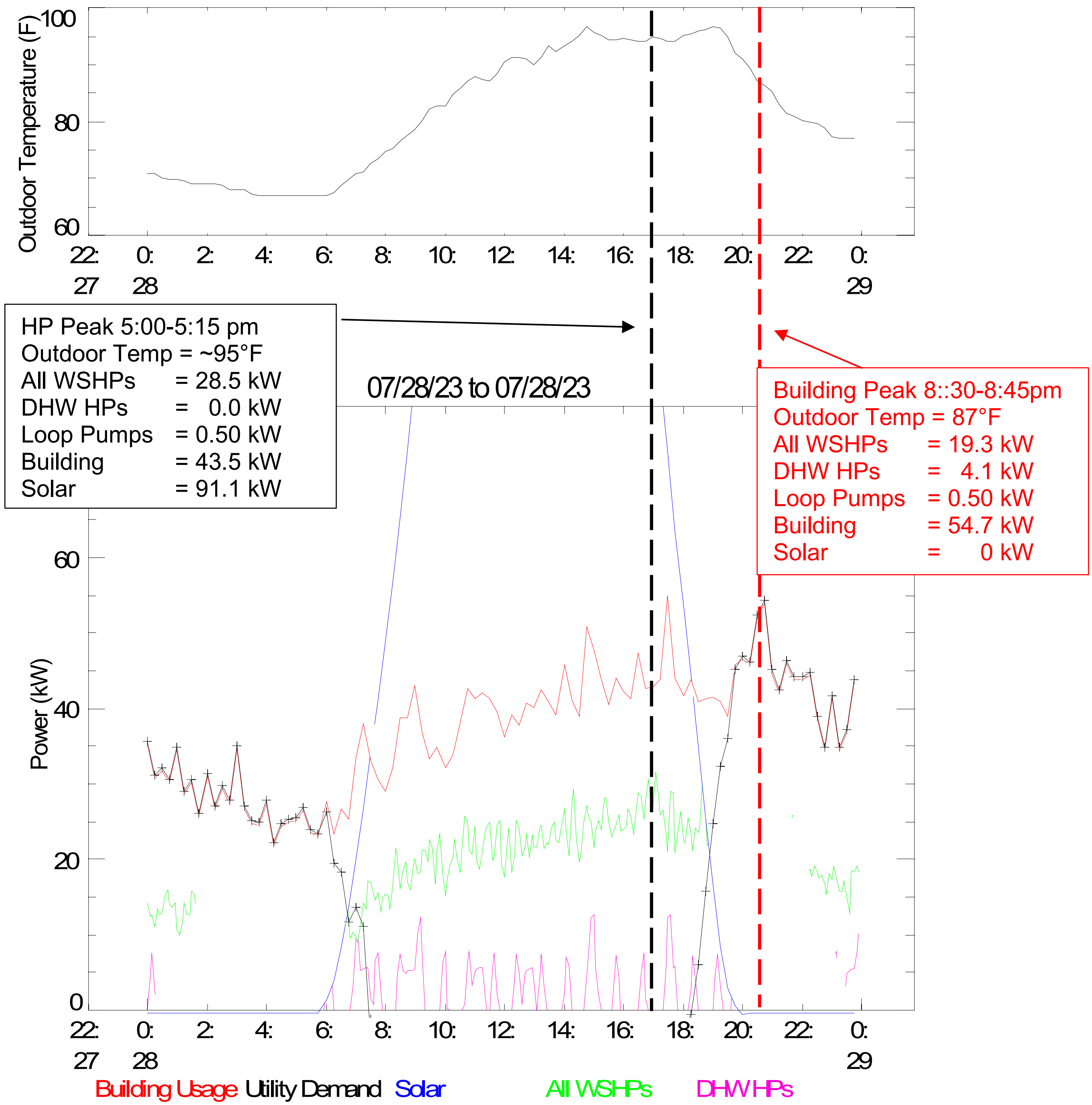


Figure 34. Building and HVAC Demand on the Hot Summer Day – July 28, 2023



5 Lessons Learned

The results from this field monitoring and demonstration project show that geothermal heat pumps can efficiently meet all the space conditioning and water loads in a newly constructed, mixed-use. multi-family building in New York. Some key take aways from the results are:

5.1 Building Efficiency and Solar Integration

- The highly efficient building envelope was successfully built to PHIUS standards. The PHIUS calculations for the annual loads on the space conditioning equipment in the multifamily section of the building were predicted to be 6.2 kBtu per sq ft per year for heating and 6.5 kBtu per sq ft per year for cooling. The measured load was 7.5 kBtu per sq ft per year for heating and 8.0 kBtu per sq ft per year for cooling – much closer than has typically been measured in other PHIUS buildings in New York State (BEX 2021).
- The PV solar panels were able to meet 95% of the building's energy requirements on an annual basis. Solar production was higher than use in the summer months and lower than use in the winter months. Overall, the full load hours of production for the solar array was 1,069 (based on DC output), which is typical of systems in this size range.
- While PV panels provided most of the building's energy use, the solar output had very little impact on the building's peak demand profile. Since building demand peaks are outside side of the solar production period, both summer and winter peak demand for billing purposes did not appreciably change by adding the solar array.

5.2 Geothermal System Performance

- The ground loop temperatures ranged from the high 70s in the summer to low 40s in the winter. Loop temperatures were slightly higher in the second summer season, which was also slightly warmer.
- The energy use for the variable speed ground loop pumps was very low. The full load pumping power was 18 Watts per installed ton and pump energy use was 3% of total heat pump power across the year. Pumping energy was also low because the loop fluid was methanol and because no additional valves, circuit setters, and flow limiters were installed to unnecessarily increase pressure requirements. The low-cost, sensorless pump controls modulated back the flow when WSHPs turned off and closed their two-way valves. Annual pumping power was 26% of what it would have been with continuous, full speed pumping across the year.
- On an annual basis, heat pump energy use was about equal for space heating and space cooling. The transition between heating and cooling was about 60°F, however there were many hours above and below this temperature where simultaneous heating and cooling occurred in the zones. The coldest days had the highest heat pump energy use.
- The overall system heating COP for space and water heating combined exceeded 3.6 on the coldest day of the year (average temperature of 15°F; low of -6°F). In contrast, an air source heat pump would have operated at COP of 1 to 1.5 at these same conditions –and closer to a COP of 1 at below zero conditions.

- The peak demand of the WSHPs was highest on a cold morning when the ambient temperature dropped to -6°F. Neither the WSHPs, nor WWHPs used to meet DHW loads, set the building peak demand. The building's peak was set later that day in the evening when occupants turned on their appliances. On the hottest summer days, we also saw that the heat pumps did not drive the building's peak demand – again appliances in the apartments were the key driver.

5.3 Geothermal Water Heating Performance

- Adding the WWHPs to the ground loop provided an average year-round heat extraction load of 0.7 MMBtu per day. This allowed the geothermal contractor to offer to provide the DHW system for "free" since the heat extraction decreased the peak summer load on the ground loop and reduced the number of vertical bores required for the cooling-driven design. The savings from dropping three vertical bores saved about $45,000 and reportedly covered the cost the installing the WWHPs and tanks for the DHW system.
- The hot water loads in the building were close to predictions in the NYS TRM, using about 1,285 gallons per day, or about 18 gallons per bedroom per day.
- The DHW load was met by the WWHPs with an annual average COP of 3.3 based on energy production. The COP of the WWHP serving the cooler preheat tank was about 3.7 annually while the COP of the WWHP on final stage was closer to 3.0. Higher COPs were observed in the summer when ground loop temperatures were higher.
- Detailed measurements of hot water use and recirculation flows allowed us to show that recirculation losses accounted for about 30% of the thermal energy input, consistent with what we have measured at other multifamily buildings (Henderson 2023). At this building, we were able to reduce the recirculation flowrate from 10 gpm to 4 gpm and measure the energy savings. The lower flow reduced the disruption to the thermoclines in the final tank and reduced thermal recirculation losses by 25%. The lower recirculation flow also increased the Net COP of the WWHP system by 11% -- reducing energy use by the same amount. This result demonstrates that small tweaks to the recirculation system can have big impacts on DHW performance.
- Hot water use flow data were collected at 1-minute intervals to understand what range of flow rates can be expected. Plumbing codes and ASHRAE handbooks often anticipate peak flow rates in multifamily buildings which exceed what is observed in practice. We measured peak hot water use rates of 6.1 gpm at the 99.9% occurrence level and 7.7 gpm at the 99.99% occurrence level. We have measured similar values in other multifamily buildings (Henderson 2023). These observed peaks confirm that the 4-inch cold water inlet line was much larger than needed. IAPMO and ASHRAE design guidance is currently being revised based on measured data from this site and other buildings.

6 References

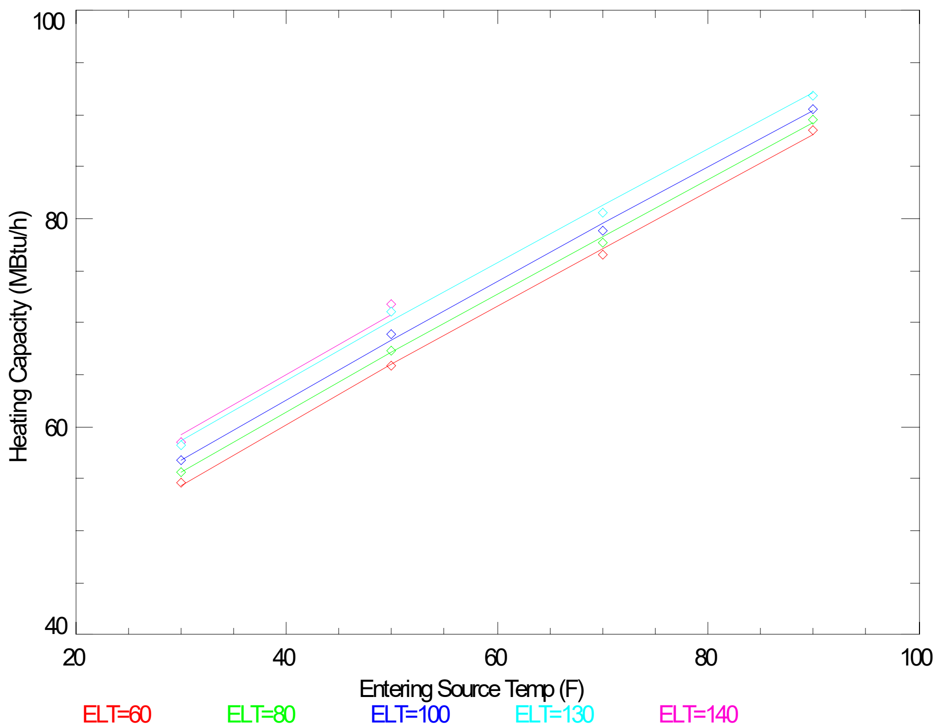
BEX. 2021. Multifamily Passive House: Connecting Performance to Financing. Building Energy Exchange. March 18. https://be-exchange.org/multifamily-passive-house-performance/

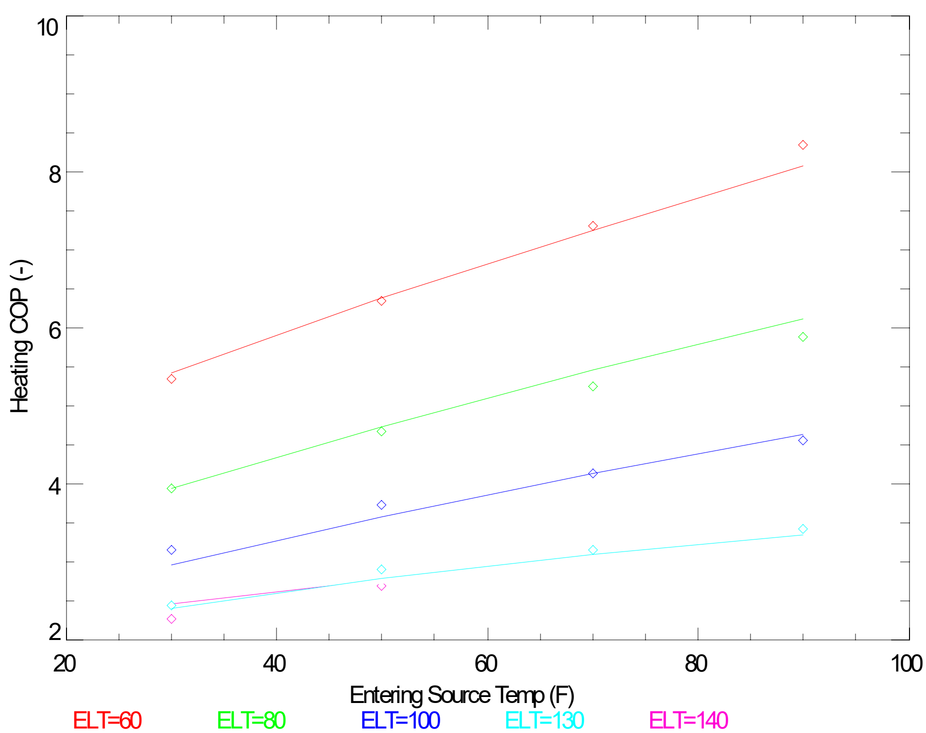
Henderson, H. 2023. Recommended DHW Use in Multifamily and Other Commercial Applications. White Paper prepared by Owahgena Consulting, Inc. August. https://cleanheat.ny.gov/contractor-resources

Appendix A. Performance Curves for WWHPs

The published performance data for the Waterfurnace NEW066 water-to-water heat pump are fit to a multilinear regression model (with cross terms) as shown in Figure A-1. The symbols represent the actual published data from WaterFurnance and line is the best-fit regression model. The regression model is used in the analysis above in Section 4.6 to predict the COP and Capacity of the WWHP to achieve a heat balance.

Figure A-1. Performance Data for Waterfurnace NEW066 WWHP NEW066 (lines = regression model; symbols = data)





Appendix B. Monthly Tables of Daily Data

The appendix has tables of daily average or daily totals.

The first set of monthly tables (B-1 to B16) includes daily averages for ambient temperatures, ground loop temperatures, and loop flow rates. The table also includes total daily loop heat extraction (+) and heat rejection (-) as well as daily energy use for the loop pumps and the WWHPs. The loop heat is only shown after January 6, 2023, when a measurement issue with the loop return temperature was fixed.

The second set of monthly tables (B-17 to B-36) focuses on the DHW system and lists the daily average values of hot water use (gal/day), delivered hot water energy (QHW, MBtu/day), and recirculation losses (QR, MBtu/day). The COPs use these values with the WWHP energy use from the other tables. The gross COP includes delivered heat and recirculation losses (QHW+QR) while the net COP is based on only delivered energy (QHW). The predicted COPs are determined using the operating temperatures of the system with the performance curves from Appendix A. The percentage recirculation losses is QR divided by total energy (QHW+QR). The predicted Q is determined using the predicted COPs for each WWHP unit along with the measured electricity input. The heat balance percentage compares the predicted Q to the total measured heat (QHW+QR).

Table B-1. Daily Ground Loop Data and Loop Pump and WWHP Energy Use – April 2022

Date	TAO (F)	Avg TLS (F)	Avg TLR (F)	Avg Loop Flow (gpm)	Loop Heat (MBtu/day)	Pump 1 (kWh/day)	Pump 2 (kWh/day)	WWHP 1 (kWh/day)	WWHP 2 (kWh/day)
3/15/2022	54.4	47.0	44.7	55.5	-	6.8	2.8	39.5	16.8
3/16/2022	55.1	48.3	46.3	46.4	-	2.7	5.9	37.6	13.9
3/17/2022	47.2	48.5	46.4	49.3	-	6.2	2.7	39.9	21.7
3/18/2022	56.9	49.2	47.6	37.1	-	2.6	5.1	38.6	20.5
3/19/2022	57.2	50.5	49.3	30.7	-	5.1	2.2	37.1	16.7
3/20/2022	54.7	49.7	47.9	37.6	-	2.9	4.7	39.1	25.8
3/21/2022	52.1	49.3	47.3	43.2	-	5.7	2.6	39.3	25.3
3/22/2022	50.5	49.1	47.0	46.5	-	3.0	5.4	38.4	22.7
3/23/2022	43.1	48.4	46.0	58.9	-	6.7	3.1	41.1	24.5
3/24/2022	43.0	48.2	45.7	57.8	-	3.4	6.2	39.3	23.8
3/25/2022	51.2	48.3	45.9	54.5	-	6.4	2.9	42.3	29.8
3/26/2022	49.2	48.5	46.2	54.2	-	3.4	5.8	41.7	30.5
3/27/2022	40.7	47.8	45.1	63.2	-	6.7	3.6	42.5	29.0
3/28/2022	27.7	45.3	41.7	77.6	-	4.4	7.4	45.4	34.5
3/29/2022	31.6	44.9	41.6	76.6	-	8.1	3.7	45.1	33.7
3/30/2022	38.8	45.3	42.0	73.1	-	4.0	7.3	43.7	29.8
3/31/2022	53.5	46.3	43.7	60.4	-	7.4	2.7	44.9	33.4
4/1/2022	52.3	48.1	45.9	49.0	-	3.4	5.4	43.8	33.3
4/2/2022	45.5	47.5	45.0	57.2	-	6.8	2.8	41.5	32.1
4/3/2022	44.2	47.6	44.9	57.2	-	3.4	6.1	44.7	33.4
4/4/2022	46.8	47.8	45.4	53.3	-	6.5	2.8	43.5	35.4
4/5/2022	49.4	48.1	45.7	46.6	-	2.8	5.7	43.3	38.6
4/6/2022	47.5	48.6	46.6	45.7	-	5.8	2.8	45.0	35.1
4/7/2022	49.4	48.6	46.4	47.1	-	3.1	5.5	43.9	40.0
4/8/2022	55.4	49.2	47.3	39.8	-	5.5	2.5	43.5	33.5
4/9/2022	51.5	48.6	46.2	45.2	-	3.0	5.4	44.4	41.4
4/10/2022	46.5	48.2	45.7	55.5	-	6.4	3.1	42.1	29.6
4/11/2022	48.9	48.0	45.6	49.0	-	2.7	6.1	42.0	33.8
4/12/2022	59.1	49.4	47.8	35.0	-	5.3	2.3	42.0	36.1
4/13/2022	59.5	49.8	48.9	35.2	-	2.6	4.9	40.5	30.8
4/14/2022	60.8	50.8	50.6	37.5	-	5.2	2.6	42.5	45.8
4/15/2022	59.7	50.6	49.5	34.1	-	2.7	4.7	41.1	33.4
4/16/2022	57.8	50.5	49.3	33.8	-	5.0	2.5	41.6	32.1
4/17/2022	46.1	49.7	47.5	39.9	-	2.9	5.0	41.5	36.9
4/18/2022	45.9	49.0	46.6	47.1	-	5.9	2.8	46.0	37.6
4/19/2022	45.7	48.4	45.8	51.4	-	3.2	5.8	44.1	37.9
4/20/2022	49.7	48.3	45.9	50.9	-	6.2	2.8	44.1	38.7
4/21/2022	51.5	48.7	46.3	45.2	-	2.8	5.5	43.2	37.1
4/22/2022	59.5	49.5	47.8	38.5	-	5.5	2.4	45.8	34.8
4/23/2022	55.0	49.7	47.9	35.0	-	2.6	4.9	41.7	36.9
4/24/2022	54.0	49.9	48.4	36.1	-	5.2	2.5	44.4	45.9
4/25/2022	51.6	50.3	49.0	35.4	-	2.6	4.8	43.6	36.3
4/26/2022	53.3	50.2	48.7	35.6	-	5.1	2.5	42.3	38.3
4/27/2022	50.4	50.2	48.2	35.5	-	2.9	4.6	43.0	45.1
4/28/2022	47.8	49.6	47.4	41.9	-	5.5	2.7	43.7	38.1
4/29/2022	52.0	49.4	47.2	45.6	-	3.0	5.4	44.8	37.1
4/30/2022	55.3	49.6	62.5	45.0	-	5.9	2.6	45.9	43.9

Table B-2. Daily Ground Loop Data and Loop Pump and WWHP Energy Use – May 2022

Date	TAO (F)	Avg TLS (F)	Avg TLR (F)	Avg Loop Flow (gpm)	Loop Heat (MBtu/day)	Pump 1 (kWh/day)	Pump 2 (kWh/day)	WWHP 1 (kWh/day)	WWHP 2 (kWh/day)
5/1/2022	56.6	50.1	63.1	41.8	-	2.8	5.2	43.5	40.3
5/2/2022	52.6	50.6	63.5	37.9	-	5.3	2.6	41.3	37.5
5/3/2022	54.7	50.8	63.7	32.9	-	2.7	4.6	43.2	34.5
5/4/2022	55.4	50.9	64.1	36.6	-	5.2	2.5	43.3	39.1
5/5/2022	63.1	51.9	64.8	36.5	-	2.7	4.9	41.9	39.6
5/6/2022	56.1	51.7	64.6	34.0	-	5.1	2.4	40.6	32.5
5/7/2022	49.4	50.9	62.3	36.2	-	2.8	4.8	44.6	43.8
5/8/2022	52.0	50.6	59.4	37.9	-	5.5	2.4	43.9	36.6
5/9/2022	57.3	50.6	63.5	40.5	-	2.7	5.2	44.3	44.5
5/10/2022	59.7	51.1	64.2	37.0	-	5.2	2.6	44.0	35.8
5/11/2022	61.9	51.5	64.4	40.2	-	2.9	5.0	47.1	37.5
5/12/2022	63.3	53.1	65.3	47.2	-	5.7	3.0	38.9	32.9
5/13/2022	60.2	55.0	66.9	52.4	-	3.5	5.5	38.3	33.2
5/14/2022	64.0	57.2	68.2	63.0	-	7.0	3.3	41.6	42.8
5/15/2022	66.7	57.9	68.8	61.1	-	3.6	6.3	38.0	35.3
5/16/2022	69.0	57.4	69.1	58.3	-	6.5	3.3	36.1	32.9
5/17/2022	67.3	56.3	68.2	49.0	-	3.2	5.5	38.1	35.0
5/18/2022	63.6	54.9	67.3	43.9	-	5.5	2.9	38.3	30.4
5/19/2022	59.2	54.5	67.1	43.6	-	3.0	5.2	36.7	29.5
5/20/2022	60.0	54.7	67.6	44.7	-	5.6	2.9	37.6	32.0
5/21/2022	74.1	57.0	68.4	59.3	-	3.8	5.9	39.5	39.8
5/22/2022	81.0	59.8	69.9	70.4	-	7.4	3.6	37.0	36.3
5/23/2022	67.7	57.8	68.9	56.2	-	3.4	6.0	35.4	30.9
5/24/2022	61.8	56.6	68.5	51.5	-	5.9	3.2	37.7	33.2
5/25/2022	60.8	56.2	68.1	52.0	-	3.4	5.6	40.0	37.3
5/26/2022	62.9	55.9	68.1	54.2	-	6.2	3.2	42.0	42.7
5/27/2022	68.5	57.5	69.0	58.7	-	3.6	6.1	38.1	32.5
5/28/2022	68.8	58.6	69.9	63.0	-	7.0	3.3	36.4	31.8
5/29/2022	70.0	57.9	69.3	59.2	-	3.7	6.1	37.4	30.9
5/30/2022	75.8	59.6	70.2	68.3	-	7.2	3.7	39.0	37.8
5/31/2022	81.6	62.1	71.4	73.1	-	4.3	7.0	35.5	31.0

Table B-3. Daily Ground Loop Data and Loop Pump and WWHP Energy Use – June 2022

Date	TAO (F)	Avg TLS (F)	Avg TLR (F)	Avg Loop Flow (gpm)	Loop Heat (MBtu/day)	Pump 1 (kWh/day)	Pump 2 (kWh/day)	WWHP 1 (kWh/day)	WWHP 2 (kWh/day)
6/1/2022	62.5	60.7	71.1	65.4	-	7.1	3.4	36.5	35.0
6/2/2022	69.3	60.3	70.9	64.2	-	3.9	6.4	38.7	33.3
6/3/2022	67.8	60.6	71.1	64.8	-	7.1	3.4	37.7	37.7
6/4/2022	71.1	59.4	70.6	57.6	-	3.5	6.1	38.4	36.0
6/5/2022	67.9	58.6	70.3	57.9	-	6.5	3.3	37.4	33.6
6/6/2022	73.0	59.1	70.4	61.3	-	3.9	6.1	40.4	43.8
6/7/2022	70.5	59.2	70.7	59.8	-	6.7	3.3	38.8	31.9
6/8/2022	76.0	60.3	70.8	65.1	-	3.9	6.5	36.4	32.5
6/9/2022	75.4	60.8	71.5	66.7	-	7.2	3.4	36.5	33.2
6/10/2022	72.0	60.4	71.4	61.2	-	3.6	6.3	37.0	32.4
6/11/2022	70.3	60.2	71.5	61.2	-	6.8	3.3	36.1	36.6
6/12/2022	68.9	59.5	71.1	56.7	-	3.7	5.8	42.1	38.5
6/13/2022	77.4	60.9	71.7	66.8	-	7.0	3.5	35.0	31.5
6/14/2022	74.6	60.4	71.4	65.2	-	3.9	6.0	36.7	29.4
6/15/2022	72.4	62.0	72.1	75.1	-	7.4	3.6	38.0	39.8
6/16/2022	68.7	61.3	71.8	68.0	-	3.7	6.4	34.5	29.5
6/17/2022	79.4	62.6	72.4	73.6	-	7.3	3.5	33.4	27.3
6/18/2022	67.2	60.8	72.0	60.2	-	3.2	6.1	35.0	31.0
6/19/2022	64.4	58.7	71.0	50.6	-	5.7	2.8	36.1	29.5
6/20/2022	70.6	58.4	70.6	53.9	-	3.4	5.3	35.6	28.3
6/21/2022	70.2	58.3	70.6	56.2	-	5.9	3.2	35.6	29.4
6/22/2022	65.5	58.6	70.7	55.0	-	3.1	5.6	37.8	34.6
6/23/2022	67.6	58.3	70.3	55.8	-	5.9	3.2	38.1	31.9
6/24/2022	72.3	59.7	70.9	63.1	-	3.8	5.8	36.5	36.4
6/25/2022	79.5	62.2	72.0	74.1	-	7.3	3.6	39.3	36.8
6/26/2022	80.0	63.9	72.9	74.9	-	4.2	6.7	33.8	30.2
6/27/2022	74.8	63.7	72.8	75.5	-	7.4	3.6	36.5	33.6
6/28/2022	72.2	62.3	72.5	66.6	-	3.8	6.2	35.5	30.4
6/29/2022	75.4	62.1	72.5	70.0	-	6.9	3.5	36.4	32.5
6/30/2022	78.6	63.5	73.3	71.8	-	4.0	6.5	33.3	27.0

Table B-4. Daily Ground Loop Data and Loop Pump and WWHP Energy Use – July 2022

Date	TAO (F)	Avg TLS (F)	Avg TLR (F)	Avg Loop Flow (gpm)	Loop Heat (MBtu/day)	Pump 1 (kWh/day)	Pump 2 (kWh/day)	WWHP 1 (kWh/day)	WWHP 2 (kWh/day)
7/1/2022	83.9	65.2	74.0	78.6	-	7.7	3.7	33.3	26.5
7/2/2022	83.3	66.1	74.6	78.1	-	4.1	7.1	33.6	28.4
7/3/2022	79.9	65.0	74.0	74.9	-	7.7	3.4	33.1	25.9
7/4/2022	78.0	63.6	73.4	68.9	-	3.9	6.3	33.4	27.2
7/5/2022	77.4	64.1	73.6	73.7	-	7.3	3.6	33.5	27.7
7/6/2022	79.5	65.5	74.2	76.6	-	4.1	7.0	33.1	30.2
7/7/2022	74.4	65.0	73.9	76.2	-	7.4	3.7	34.6	27.4
7/8/2022	74.0	66.7	74.8	79.7	-	4.2	7.2	33.3	29.6
7/9/2022	77.1	66.5	74.8	78.5	-	7.8	3.6	32.7	27.2
7/10/2022	73.4	64.7	73.9	71.2	-	4.0	6.5	35.2	28.7
7/11/2022	75.4	65.0	74.1	74.0	-	7.2	3.6	34.2	30.6
7/12/2022	81.1	66.2	74.5	76.7	-	4.2	6.9	32.9	26.4
7/13/2022	82.4	67.3	75.0	80.2	-	7.8	3.8	31.3	26.1
7/14/2022	80.3	67.7	75.5	78.4	-	4.1	7.2	35.8	33.4
7/15/2022	77.8	65.6	74.4	72.6	-	7.1	3.6	33.5	25.5
7/16/2022	75.6	66.2	74.6	75.9	-	4.1	6.9	32.5	26.4
7/17/2022	78.9	67.8	75.4	81.8	-	8.0	3.8	30.9	24.9
7/18/2022	79.3	67.9	75.4	79.6	-	4.2	7.2	34.7	32.1
7/19/2022	84.4	69.0	76.0	84.4	-	8.3	4.4	32.4	26.2
7/20/2022	88.1	71.4	77.9	90.5	-	5.2	8.7	31.3	25.7
7/21/2022	86.1	72.0	78.2	93.6	-	10.0	4.5	31.8	28.0
7/22/2022	85.7	71.5	77.6	88.5	-	5.0	8.5	30.1	21.2
7/23/2022	86.0	71.4	77.1	90.1	-	9.6	4.3	30.3	27.0
7/24/2022	88.9	71.7	77.9	88.3	-	4.9	8.5	30.2	22.6
7/25/2022	84.6	72.0	77.8	89.6	-	9.4	4.4	29.7	23.1
7/26/2022	77.4	70.1	75.0	83.3	-	4.7	8.0	32.0	28.1
7/27/2022	77.7	69.0	73.6	82.3	-	8.6	4.1	32.0	23.7
7/28/2022	81.6	70.5	76.1	85.3	-	4.9	8.1	31.4	26.7
7/29/2022	81.4	71.5	77.0	89.3	-	9.4	4.2	30.3	25.2
7/30/2022	80.8	71.3	76.9	86.4	-	4.6	8.4	29.6	21.8
7/31/2022	78.8	69.6	74.3	84.2	-	8.7	4.2	32.2	26.0

Table B-5. Daily Ground Loop Data and Loop Pump and WWHP Energy Use – Aug 2022

Date	TAO (F)	Avg TLS (F)	Avg TLR (F)	Avg Loop Flow (gpm)	Loop Heat (MBtu/day)	Pump 1 (kWh/day)	Pump 2 (kWh/day)	WWHP 1 (kWh/day)	WWHP 2 (kWh/day)
8/1/2022	72.5	65.3	70.1	78.7	-	4.7	7.0	30.6	22.2
8/2/2022	81.6	71.2	76.7	87.4	-	9.0	4.3	32.3	24.5
8/3/2022	80.9	71.0	76.4	85.2	-	4.7	8.1	31.8	29.1
8/4/2022	85.3	71.9	77.9	89.5	-	9.2	4.4	32.2	30.9
8/5/2022	84.7	72.9	79.0	89.1	-	4.8	8.5	31.1	28.5
8/6/2022	85.6	72.5	78.9	90.0	-	9.3	4.3	30.6	31.3
8/7/2022	85.5	72.6	78.2	88.4	-	4.7	8.5	32.7	33.1
8/8/2022	86.5	73.3	79.7	91.1	-	9.4	4.3	29.6	27.8
8/9/2022	87.8	73.3	79.0	88.7	-	4.8	8.4	31.1	29.4
8/10/2022	80.0	71.5	77.8	86.1	-	8.9	4.1	32.6	27.2
8/11/2022	80.1	70.5	77.5	83.1	-	4.6	7.9	33.5	32.0
8/12/2022	77.4	69.2	76.9	79.9	-	8.4	3.8	32.6	32.7
8/13/2022	72.3	67.1	76.1	71.0	-	3.8	7.2	32.8	27.8
8/14/2022	75.2	66.7	75.5	72.7	-	7.4	4.0	31.8	25.1
8/15/2022	75.9	68.2	76.3	78.8	-	4.4	7.6	32.4	30.5
8/16/2022	74.6	68.3	76.2	79.8	-	8.2	4.0	32.6	29.1
8/17/2022	73.8	67.3	76.0	74.9	-	4.1	7.4	33.7	27.4
8/18/2022	76.2	66.7	75.5	74.8	-	7.9	3.7	32.6	30.5
8/19/2022	79.9	67.9	76.0	78.6	-	4.6	7.4	33.7	34.9
8/20/2022	82.1	69.6	76.8	85.7	-	8.8	4.2	32.5	33.8
8/21/2022	77.2	70.5	77.1	85.5	-	4.7	8.1	35.5	35.2
8/22/2022	75.9	70.0	76.9	85.9	-	8.8	4.1	35.5	35.4
8/23/2022	79.7	70.0	76.9	83.4	-	4.6	7.9	32.0	32.0
8/24/2022	81.1	70.0	76.9	83.6	-	8.7	4.0	31.5	28.2
8/25/2022	82.1	69.5	76.6	80.9	-	4.5	7.7	31.7	28.5
8/26/2022	81.7	69.8	76.9	83.0	-	8.5	4.1	31.9	27.6
8/27/2022	80.9	70.0	76.8	82.0	-	4.3	8.0	31.7	33.6
8/28/2022	75.5	69.3	76.5	81.2	-	8.2	4.2	32.5	30.2
8/29/2022	79.7	71.5	77.5	86.4	-	4.8	8.2	33.2	31.9
8/30/2022	80.5	72.3	77.8	89.2	-	9.2	4.2	30.7	29.5
8/31/2022	78.1	69.6	76.8	78.1	-	4.1	7.8	34.1	29.3

Table B-6. Daily Ground Loop Data and Loop Pump and WWHP Energy Use – Sep 2022

Date	TAO (F)	Avg TLS (F)	Avg TLR (F)	Avg Loop Flow (gpm)	Loop Heat (MBtu/day)	Pump 1 (kWh/day)	Pump 2 (kWh/day)	WWHP 1 (kWh/day)	WWHP 2 (kWh/day)
9/1/2022	78.2	67.2	75.7	72.5	-	7.5	3.8	30.9	28.7
9/2/2022	70.0	66.3	75.4	69.2	-	3.9	6.9	34.1	28.5
9/3/2022	73.9	66.5	75.5	71.3	-	7.5	3.7	32.9	30.6
9/4/2022	78.8	68.6	76.3	78.8	-	4.3	7.6	32.2	31.2
9/5/2022	78.3	67.4	75.7	75.0	-	7.9	3.7	33.4	31.4
9/6/2022	72.3	66.1	75.1	68.5	-	3.8	6.9	34.5	30.3
9/7/2022	69.8	65.5	74.9	68.3	-	7.3	3.5	33.9	30.2
9/8/2022	71.3	65.2	74.4	66.6	-	3.9	6.6	33.1	31.2
9/9/2022	71.6	65.1	74.2	68.3	-	7.2	3.7	35.8	31.9
9/10/2022	75.4	65.5	74.5	67.8	-	3.9	6.7	34.0	28.8
9/11/2022	72.3	65.7	74.5	71.9	-	7.5	3.7	33.5	33.0
9/12/2022	73.9	65.9	74.6	70.4	-	4.1	6.9	35.8	29.2
9/13/2022	76.4	66.5	74.8	75.4	-	7.8	3.8	32.9	30.7
9/14/2022	73.5	66.2	74.9	70.8	-	4.0	7.0	33.6	30.1
9/15/2022	69.8	64.5	74.4	62.4	-	6.9	3.3	35.1	31.5
9/16/2022	67.9	62.0	73.5	51.6	-	3.3	5.6	35.6	29.2
9/17/2022	69.2	62.7	73.2	59.7	-	6.5	3.4	36.0	35.0
9/18/2022	75.9	64.3	73.9	66.4	-	4.0	6.6	35.2	30.6
9/19/2022	77.0	66.0	74.6	75.8	-	8.0	3.7	34.5	32.8
9/20/2022	73.6	65.5	74.6	71.1	-	4.0	7.0	35.5	33.8
9/21/2022	72.6	65.3	74.6	70.2	-	7.4	3.7	35.1	30.7
9/22/2022	69.0	64.6	74.5	62.7	-	3.4	6.7	33.4	28.2
9/23/2022	57.5	61.6	73.0	49.4	-	6.1	2.7	36.8	32.6
9/24/2022	61.0	60.3	72.0	46.8	-	3.1	5.4	36.2	32.8
9/25/2022	66.1	60.5	71.9	51.1	-	5.8	3.3	38.6	39.2
9/26/2022	68.2	61.4	72.1	57.8	-	3.4	6.2	40.2	33.0
9/27/2022	66.3	60.4	71.7	48.9	-	5.9	2.9	39.6	35.5
9/28/2022	63.3	59.9	71.5	53.6	-	3.4	5.7	41.5	42.0
9/29/2022	61.0	58.7	70.6	54.2	-	6.3	3.1	40.2	38.6
9/30/2022	58.2	58.2	70.3	54.2	-	3.1	6.1	39.3	36.2

Table B-7. Daily Ground Loop Data and Loop Pump and WWHP Energy Use – Oct 2022

Date	TAO (F)	Avg TLS (F)	Avg TLR (F)	Avg Loop Flow (gpm)	Loop Heat (MBtu/day)	Pump 1 (kWh/day)	Pump 2 (kWh/day)	WWHP 1 (kWh/day)	WWHP 2 (kWh/day)
10/1/2022	58.6	58.3	70.3	50.8	-	6.2	2.8	39.3	37.9
10/2/2022	57.8	58.5	70.3	48.6	-	2.9	5.7	38.7	33.5
10/3/2022	51.9	57.6	63.5	45.1	-	5.7	2.8	43.3	42.6
10/4/2022	52.1	57.4	57.7	48.7	-	2.9	5.8	40.3	38.3
10/5/2022	57.2	57.6	57.9	45.6	-	5.8	2.8	39.1	34.1
10/6/2022	65.7	57.7	68.9	46.0	-	3.0	5.4	42.0	36.1
10/7/2022	68.1	58.4	69.5	48.5	-	6.1	2.7	41.2	33.7
10/8/2022	54.5	57.2	68.9	46.9	-	3.1	5.4	40.1	41.8
10/9/2022	55.5	56.6	62.4	47.6	-	6.0	2.7	40.2	37.6
10/10/2022	61.5	56.5	68.3	46.0	-	2.8	5.7	39.2	35.4
10/11/2022	62.6	56.7	65.5	46.5	-	5.9	2.8	41.1	37.9
10/12/2022	64.0	57.1	68.6	42.6	-	2.8	5.3	39.9	35.5
10/13/2022	65.6	57.3	68.8	42.9	-	5.6	2.7	39.4	36.1
10/14/2022	59.9	57.6	69.2	45.6	-	3.0	5.4	39.9	36.8
10/15/2022	61.7	56.9	68.8	46.4	-	6.0	2.6	40.5	37.7
10/16/2022	60.9	57.2	68.9	45.0	-	3.0	5.3	39.2	34.4
10/17/2022	61.0	56.4	68.1	44.0	-	5.7	2.7	40.3	37.9
10/18/2022	53.3	55.8	67.9	44.2	-	2.8	5.4	38.7	31.0
10/19/2022	50.1	55.3	67.3	46.4	-	5.8	2.8	39.4	35.5
10/20/2022	52.6	54.8	67.0	48.6	-	3.0	5.7	40.9	35.6
10/21/2022	56.6	54.4	66.7	53.0	-	6.4	2.8	41.8	35.6
10/22/2022	58.2	54.5	66.5	50.5	-	2.9	6.0	40.9	33.3
10/23/2022	58.4	54.8	66.7	49.3	-	6.2	2.7	39.8	35.9
10/24/2022	58.1	55.5	67.3	44.3	-	3.0	5.3	41.1	35.9
10/25/2022	63.1	56.3	68.0	42.9	-	5.6	2.7	40.1	34.2
10/26/2022	65.4	57.4	68.9	45.6	-	3.0	5.3	38.5	36.3
10/27/2022	60.5	57.7	69.2	46.1	-	6.0	2.6	37.9	34.1
10/28/2022	51.6	56.0	68.1	48.7	-	3.1	5.6	38.7	35.6
10/29/2022	51.6	55.0	67.4	54.1	-	6.5	2.8	40.6	36.3
10/30/2022	55.0	54.2	66.7	54.0	-	3.0	6.2	41.6	33.8
10/31/2022	59.0	54.4	66.8	49.1	-	6.2	2.7	40.7	39.7

Table B-8. Daily Ground Loop Data and Loop Pump and WWHP Energy Use – Nov 2022

Date	TAO (F)	Avg TLS (F)	Avg TLR (F)	Avg Loop Flow (gpm)	Loop Heat (MBtu/day)	Pump 1 (kWh/day)	Pump 2 (kWh/day)	WWHP 1 (kWh/day)	WWHP 2 (kWh/day)
11/1/2022	62.9	56.2	68.1	43.6	-	3.0	5.1	40.4	40.2
11/2/2022	63.4	56.4	67.9	43.2	-	5.7	2.7	38.7	34.2
11/3/2022	59.4	55.9	67.7	43.6	-	2.9	5.3	39.7	39.7
11/4/2022	61.0	55.5	67.8	48.5	-	6.0	2.8	40.3	39.0
11/5/2022	67.5	56.9	68.6	48.4	-	3.2	5.5	40.8	39.2
11/6/2022	68.2	58.5	69.6	55.4	-	6.0	3.5	37.7	36.3
11/7/2022	69.9	59.4	70.0	55.4	-	3.4	6.0	37.7	40.9
11/8/2022	52.8	57.1	69.0	46.7	-	5.6	3.0	43.4	43.5
11/9/2022	47.4	55.5	67.9	47.9	-	3.4	5.3	39.3	36.8
11/10/2022	56.9	55.2	66.0	47.0	-	5.8	2.9	43.5	45.7
11/11/2022	62.9	56.0	68.1	40.6	-	3.0	4.9	40.5	38.2
11/12/2022	66.8	57.3	68.7	47.9	-	5.8	3.0	38.2	37.1
11/13/2022	51.8	56.4	68.1	45.0	-	3.3	5.0	43.4	40.7
11/14/2022	42.1	54.7	67.0	51.0	-	5.8	3.3	43.4	40.9
11/15/2022	41.3	53.2	64.5	59.2	-	3.7	6.1	43.5	44.3
11/16/2022	45.4	52.5	58.5	61.4	-	6.6	3.5	46.3	41.1
11/17/2022	41.6	51.9	50.0	65.3	-	4.0	6.5	46.0	42.0
11/18/2022	39.9	51.0	52.5	68.2	-	7.1	3.8	45.8	37.9
11/19/2022	37.0	50.6	63.2	70.0	-	4.1	6.8	46.9	41.5
11/20/2022	35.7	49.4	62.6	77.7	-	7.9	4.1	40.0	46.7
11/21/2022	36.0	49.0	61.7	75.9	-	4.4	7.3	50.2	45.1
11/22/2022	45.2	49.3	62.1	72.8	-	7.6	3.8	49.1	47.4
11/23/2022	49.2	49.7	62.0	68.9	-	4.0	6.9	53.7	57.9
11/24/2022	46.6	49.8	61.9	70.1	-	7.4	3.6	47.6	46.6
11/25/2022	49.8	50.3	62.3	64.0	-	3.7	6.6	47.4	46.4
11/26/2022	49.8	50.9	62.3	60.7	-	6.7	3.3	43.5	43.2
11/27/2022	52.5	50.9	52.0	59.7	-	3.5	6.3	48.2	41.7
11/28/2022	51.3	51.7	50.0	54.5	-	6.0	3.4	44.7	47.8
11/29/2022	40.9	50.2	59.2	67.4	-	4.0	6.6	49.5	44.2
11/30/2022	49.4	49.5	62.1	70.6	-	7.6	3.5	52.2	42.2

Table B-9. Daily Ground Loop Data and Loop Pump and WWHP Energy Use – Dec 2022

Date	TAO (F)	Avg TLS (F)	Avg TLR (F)	Avg Loop Flow (gpm)	Loop Heat (MBtu/day)	Pump 1 (kWh/day)	Pump 2 (kWh/day)	WWHP 1 (kWh/day)	WWHP 2 (kWh/day)
12/1/2022	39.9	49.5	61.7	72.7	-	4.2	7.0	62.6	40.1
12/2/2022	39.3	49.0	53.7	75.6	-	7.8	3.9	60.8	38.4
12/3/2022	53.0	49.8	56.4	64.4	-	3.3	7.0	59.0	37.5
12/4/2022	42.7	49.8	55.6	70.6	-	7.3	3.8	65.5	33.2
12/5/2022	41.9	48.7	58.3	74.1	-	4.2	7.2	65.2	33.9
12/6/2022	51.2	48.4	61.1	75.8	-	8.1	3.6	66.6	31.0
12/7/2022	57.0	51.1	62.1	53.0	-	3.3	5.8	62.7	32.9
12/8/2022	50.6	51.0	53.2	58.3	-	6.3	3.6	63.5	46.9
12/9/2022	39.9	50.1	62.1	67.6	-	4.1	6.7	57.7	41.9
12/10/2022	36.3	48.7	52.7	77.7	-	8.1	4.0	58.4	48.9
12/11/2022	37.6	48.4	61.4	76.5	-	4.2	7.6	57.8	42.7
12/12/2022	34.4	47.6	59.3	82.4	-	8.3	4.3	63.2	44.8
12/13/2022	33.3	46.0	51.5	86.8	-	4.8	8.3	67.3	52.8
12/14/2022	35.4	46.3	46.2	85.0	-	8.6	4.4	66.6	47.5
12/15/2022	38.7	46.2	56.2	83.2	-	4.4	8.3	63.3	46.5
12/16/2022	42.4	47.2	60.2	80.5	-	8.3	4.0	63.1	47.0
12/17/2022	41.1	47.7	60.4	75.7	-	4.3	7.5	66.8	42.8
12/18/2022	36.8	47.4	59.9	78.8	-	8.1	4.1	61.9	50.9
12/19/2022	35.0	47.3	59.9	79.2	-	4.3	7.8	54.8	40.0
12/20/2022	35.4	46.9	60.1	81.7	-	8.3	4.2	57.6	46.5
12/21/2022	34.7	46.0	59.6	83.5	-	4.5	8.1	54.5	48.5
12/22/2022	40.8	45.9	58.6	84.2	-	8.7	4.1	55.4	48.4
12/23/2022	37.6	47.6	60.1	75.4	-	4.6	7.1	55.4	47.0
12/24/2022	11.6	44.2	58.1	91.0	-	9.2	4.5	60.0	34.0
12/25/2022	21.3	44.4	57.6	86.7	-	4.7	8.4	56.5	25.8
12/26/2022	24.5	44.4	57.9	89.5	-	9.1	4.3	54.6	46.9
12/27/2022	31.4	44.9	58.6	85.2	-	4.6	8.2	54.3	37.9
12/28/2022	39.9	46.1	59.0	79.5	-	8.3	3.9	54.5	49.4
12/29/2022	44.4	46.7	59.6	78.9	-	4.2	7.8	60.5	56.9
12/30/2022	48.9	48.0	59.9	68.3	-	7.3	3.6	57.1	50.4
12/31/2022	47.5	48.6	50.8	64.7	-	3.4	7.0	52.3	42.3

Table B-10. Daily Ground Loop Data and Loop Pump and WWHP Energy Use – Jan 2023

Date	TAO (F)	Avg TLS (F)	Avg TLR (F)	Avg Loop Flow (gpm)	Loop Heat (MBtu/day)	Pump 1 (kWh/day)	Pump 2 (kWh/day)	WWHP 1 (kWh/day)	WWHP 2 (kWh/day)
1/1/2023	51.8	49.6	61.3	63.0	-	6.7	3.6	55.4	36.7
1/2/2023	52.2	49.3	61.2	63.5	-	3.7	6.6	52.4	39.7
1/3/2023	49.3	49.1	61.2	67.5	-	7.3	3.5	52.3	42.3
1/4/2023	57.5	49.6	61.2	63.4	-	3.7	6.6	54.7	44.5
1/5/2023	45.6	47.3	51.7	59.4	876.0	7.2	2.6	53.9	46.5
1/6/2023	43.8	49.9	46.9	55.6	2,110.7	2.7	5.0	52.0	49.8
1/7/2023	41.2	48.9	45.2	65.2	2,966.1	5.6	2.9	49.1	60.2
1/8/2023	37.6	48.0	44.0	67.2	3,278.2	3.2	5.4	39.3	80.7
1/9/2023	40.2	47.2	43.2	66.8	3,367.2	5.8	2.9	47.9	67.6
1/10/2023	40.1	47.0	43.1	65.5	3,213.5	3.1	5.5	49.3	56.0
1/11/2023	37.2	46.2	42.1	72.5	3,732.3	6.1	3.1	49.4	59.6
1/12/2023	44.1	46.2	42.2	68.3	3,412.4	3.0	5.8	48.2	51.1
1/13/2023	48.4	47.8	44.7	61.8	2,440.8	5.4	2.8	46.4	49.1
1/14/2023	34.1	46.7	42.5	68.7	3,553.6	3.2	5.6	42.9	61.1
1/15/2023	34.0	45.9	41.8	71.9	3,700.1	6.2	2.9	51.2	60.8
1/16/2023	38.0	46.0	42.0	68.6	3,460.0	3.2	5.6	46.0	67.7
1/17/2023	42.4	45.3	41.1	73.4	3,880.3	6.3	3.0	49.5	74.1
1/18/2023	47.7	47.3	43.7	63.5	2,781.3	2.6	5.5	44.2	67.6
1/19/2023	42.0	46.4	42.7	71.0	3,334.6	6.5	2.5	46.7	67.8
1/20/2023	44.6	46.7	43.1	65.8	3,023.9	2.7	5.8	50.6	56.4
1/21/2023	39.0	46.4	42.6	69.5	3,284.0	6.4	2.6	48.7	61.9
1/22/2023	38.7	46.3	42.4	68.0	3,295.9	2.7	6.1	47.3	61.8
1/23/2023	37.8	46.4	42.6	67.9	3,235.1	6.3	2.5	53.1	62.6
1/24/2023	39.8	46.6	42.8	64.4	3,095.7	2.7	5.7	43.6	65.2
1/25/2023	40.8	46.3	42.5	69.9	3,331.8	6.4	2.5	50.2	55.2
1/26/2023	46.4	46.6	42.9	66.4	3,033.8	2.6	5.9	53.0	61.6
1/27/2023	39.8	46.2	42.4	69.3	3,263.6	6.4	2.5	44.8	79.0
1/28/2023	44.7	46.5	42.9	65.7	2,999.9	2.6	5.9	52.5	66.6
1/29/2023	47.1	46.4	42.7	67.2	3,170.9	6.4	2.3	52.5	67.4
1/30/2023	48.4	46.8	43.3	63.5	2,878.1	2.6	5.7	52.9	54.0
1/31/2023	38.3	46.4	42.6	68.3	3,242.5	6.2	2.6	53.9	49.0

Table B-11. Daily Ground Loop Data and Loop Pump and WWHP Energy Use – Feb 2023

Date	TAO (F)	Avg TLS (F)	Avg TLR (F)	Avg Loop Flow (gpm)	Loop Heat (MBtu/day)	Pump 1 (kWh/day)	Pump 2 (kWh/day)	WWHP 1 (kWh/day)	WWHP 2 (kWh/day)
2/1/2023	32.2	45.6	41.5	69.3	3,619.1	2.8	6.0	51.1	53.2
2/2/2023	34.9	45.0	40.8	73.5	3,887.3	6.6	2.6	45.6	71.9
2/3/2023	23.8	44.0	39.2	74.8	4,573.3	3.0	6.4	35.6	83.6
2/4/2023	15.0	41.9	36.4	81.6	5,567.4	7.3	2.8	56.0	51.6
2/5/2023	37.5	42.8	38.2	74.5	4,356.2	2.7	6.6	48.3	80.0
2/6/2023	42.3	44.9	41.3	70.0	3,228.2	6.4	2.6	51.5	52.4
2/7/2023	36.8	44.9	40.8	70.0	3,643.0	2.7	6.1	54.0	50.5
2/8/2023	45.7	45.7	42.2	67.3	2,959.9	6.2	2.5	53.4	56.7
2/9/2023	45.7	45.8	42.1	67.3	3,124.0	2.6	6.0	46.9	55.5
2/10/2023	53.8	47.1	44.2	59.0	2,238.7	5.7	2.2	52.3	55.2
2/11/2023	41.5	47.3	44.1	59.5	2,414.6	2.5	5.4	49.5	46.6
2/12/2023	42.4	46.5	42.9	67.1	3,009.7	6.2	2.4	35.4	91.1
2/13/2023	48.2	47.2	44.1	58.6	2,323.3	2.4	5.5	52.2	53.9
2/14/2023	47.4	47.9	45.1	55.8	2,058.7	5.5	2.2	49.9	49.5
2/15/2023	53.3	48.5	46.4	51.3	1,513.2	2.1	5.2	54.2	49.3
2/16/2023	60.2	49.3	47.0	52.7	1,570.1	5.4	2.1	52.6	59.7
2/17/2023	49.6	49.1	46.5	52.7	1,752.0	2.4	5.0	52.5	56.1
2/18/2023	36.2	47.5	44.0	62.2	2,752.3	6.0	2.3	52.6	56.3
2/19/2023	42.5	47.2	43.7	62.9	2,804.7	2.5	5.8	54.5	49.2
2/20/2023	52.1	47.6	44.6	61.3	2,337.8	6.2	2.4	54.3	57.6
2/21/2023	41.8	47.5	44.4	64.0	2,570.8	2.9	6.2	53.4	57.4
2/22/2023	40.3	46.6	43.1	68.8	3,007.3	7.0	2.7	54.4	54.5
2/23/2023	39.4	46.6	43.1	66.8	2,927.8	2.8	6.6	54.1	60.6
2/24/2023	40.0	47.0	43.6	66.8	2,826.5	6.7	2.7	51.3	51.3
2/25/2023	27.3	44.6	40.2	75.2	4,158.8	3.0	7.2	55.1	61.2
2/26/2023	37.6	44.0	39.8	78.0	4,162.5	7.7	2.8	53.9	56.8
2/27/2023	37.8	44.6	40.7	70.8	3,532.3	2.9	6.8	55.6	57.6
2/28/2023	35.5	45.3	41.7	71.8	3,253.7	7.1	2.7	53.4	51.7

Table B-12. Daily Ground Loop Data and Loop Pump and WWHP Energy Use – Mar 2023

Date	TAO (F)	Avg TLS (F)	Avg TLR (F)	Avg Loop Flow (gpm)	Loop Heat (MBtu/day)	Pump 1 (kWh/day)	Pump 2 (kWh/day)	WWHP 1 (kWh/day)	WWHP 2 (kWh/day)
3/1/2023	39.7	45.4	41.6	68.9	3,279.2	2.9	6.7	54.6	52.9
3/2/2023	44.5	46.5	43.6	65.6	2,511.6	6.8	2.5	51.6	41.7
3/3/2023	40.7	46.2	42.8	66.1	2,930.5	2.7	6.5	51.4	51.5
3/4/2023	41.8	46.6	43.5	66.7	2,633.1	6.9	2.5	50.9	51.2
3/5/2023	44.5	47.0	43.8	62.5	2,542.5	2.6	6.2	50.8	51.9
3/6/2023	46.4	47.0	43.9	63.3	2,500.0	6.5	2.6	52.3	50.3
3/7/2023	39.7	46.9	43.4	61.5	2,711.5	2.8	6.0	54.2	46.6
3/8/2023	39.9	46.4	43.1	64.6	2,749.6	6.7	2.5	51.8	54.4
3/9/2023	41.4	46.7	43.3	62.0	2,675.3	2.7	6.1	53.2	51.8
3/10/2023	39.8	46.4	43.0	67.1	2,890.2	6.8	2.6	50.9	51.4
3/11/2023	40.4	46.7	43.3	64.2	2,709.0	2.7	6.3	51.8	51.6
3/12/2023	40.2	40.4	37.2	57.9	2,604.8	6.7	2.1	51.4	51.1
3/13/2023	41.5	46.6	43.2	63.5	2,729.9	2.3	6.7	56.6	63.2
3/14/2023	36.6	46.4	43.0	65.8	2,850.0	6.9	2.2	54.9	46.8
3/15/2023	39.0	46.7	43.3	62.4	2,654.6	2.4	6.5	60.0	49.2
3/16/2023	46.1	46.9	44.0	62.7	2,398.3	7.0	2.0	54.8	45.9
3/17/2023	52.6	47.6	44.9	58.0	2,073.5	2.0	6.5	55.2	44.9
3/18/2023	48.3	48.5	46.1	56.1	1,704.4	6.4	2.0	50.7	42.4
3/19/2023	36.6	46.9	43.3	66.2	2,996.3	2.4	6.8	55.1	45.0
3/20/2023	41.6	46.7	43.3	66.3	2,806.7	7.1	2.2	60.1	54.5
3/21/2023	51.9	47.2	44.2	55.7	2,226.9	2.0	6.2	56.3	43.1
3/22/2023	51.7	48.1	45.5	57.3	1,957.7	6.6	1.9	57.5	49.4
3/23/2023	54.1	49.1	47.5	47.7	1,064.7	1.9	5.7	54.0	44.4
3/24/2023	49.2	49.1	46.7	54.6	1,700.5	6.3	2.0	53.4	47.4
3/25/2023	43.6	47.8	44.7	60.5	2,389.5	2.1	6.5	58.2	46.7
3/26/2023	53.3	48.6	46.3	56.1	1,677.6	6.5	1.9	53.7	44.5
3/27/2023	49.1	48.5	45.8	53.1	1,918.5	2.0	6.0	52.9	43.7
3/28/2023	46.5	48.6	45.8	52.6	1,910.1	6.2	2.0	52.1	37.5
3/29/2023	46.4	48.4	45.8	55.0	1,927.1	2.0	6.2	53.0	42.8
3/30/2023	40.1	48.0	45.0	60.4	2,341.6	6.6	2.2	53.4	42.2
3/31/2023	46.7	47.6	44.5	60.6	2,387.2	2.0	6.7	54.0	38.2

Table B-13. Daily Ground Loop Data and Loop Pump and WWHP Energy Use – April 2023

Date	TAO (F)	Avg TLS (F)	Avg TLR (F)	Avg Loop Flow (gpm)	Loop Heat (MBtu/day)	Pump 1 (kWh/day)	Pump 2 (kWh/day)	WWHP 1 (kWh/day)	WWHP 2 (kWh/day)
4/1/2023	59.1	49.3	47.9	51.2	1,033.3	6.2	1.8	52.5	43.3
4/2/2023	46.7	49.3	46.9	53.4	1,706.3	2.2	5.9	54.7	44.9
4/3/2023	48.0	48.3	45.7	57.9	2,000.7	6.8	1.8	56.3	47.7
4/4/2023	57.5	49.3	47.4	44.7	1,238.1	1.8	5.6	54.3	45.8
4/5/2023	48.7	50.3	48.9	44.3	876.8	5.6	1.8	53.4	46.6
4/6/2023	57.8	51.1	50.9	42.0	185.7	1.8	5.3	50.2	39.3
4/7/2023	52.8	50.7	49.3	48.8	926.3	6.0	1.9	52.8	44.5
4/8/2023	45.1	49.6	47.3	54.5	1,580.5	2.0	6.2	52.2	40.6
4/9/2023	46.4	49.1	46.8	55.8	1,719.2	6.5	1.9	50.4	39.4
4/10/2023	52.9	49.6	47.7	49.1	1,334.1	1.8	5.9	55.0	43.8
4/11/2023	64.1	50.4	49.2	43.6	775.7	5.6	1.8	49.0	35.4
4/12/2023	73.1	52.2	53.3	47.5	(623.4)	1.9	5.7	49.0	39.5
4/13/2023	78.5	54.8	57.6	57.5	(1,952.2)	6.4	2.2	48.4	37.4
4/14/2023	77.8	56.5	59.8	60.4	(2,509.2)	2.4	6.4	46.7	38.7
4/15/2023	63.4	57.7	61.5	64.4	(2,977.1)	7.1	2.2	44.7	32.8
4/16/2023	58.9	57.7	61.1	63.3	(2,636.4)	2.3	6.7	48.2	41.8
4/17/2023	57.2	56.3	58.3	54.8	(1,260.7)	6.5	1.9	46.0	35.9
4/18/2023	52.6	53.8	53.0	42.6	502.5	1.9	5.2	46.5	32.9
4/19/2023	52.5	52.5	51.4	50.4	781.7	6.0	1.9	49.0	38.2
4/20/2023	52.7	52.4	51.8	48.8	478.9	2.0	5.7	50.4	38.9
4/21/2023	57.4	53.1	53.6	48.4	(206.1)	6.0	1.8	49.8	38.4
4/22/2023	55.1	53.9	54.8	46.6	(463.6)	2.0	5.5	48.9	37.1
4/23/2023	58.1	54.1	55.1	50.8	(514.5)	6.0	2.0	47.8	34.2
4/24/2023	53.5	53.1	52.3	49.4	583.7	2.0	5.7	51.5	40.8
4/25/2023	53.5	51.8	50.2	47.8	1,091.3	5.9	1.8	48.1	32.1
4/26/2023	52.7	51.7	50.5	47.0	834.8	1.9	5.6	50.7	39.5
4/27/2023	53.1	52.1	51.6	48.3	368.9	5.9	1.9	50.2	42.0
4/28/2023	51.9	52.3	51.6	44.4	521.2	1.9	5.4	48.9	34.3
4/29/2023	50.8	51.9	50.6	47.7	890.3	5.9	1.8	52.6	45.0
4/30/2023	55.1	51.9	51.1	45.9	559.3	1.8	5.6	51.8	40.6

Table B-14 Daily Ground Loop Data and Loop Pump and WWHP Energy Use – May 2023

Date	TAO (F)	Avg TLS (F)	Avg TLR (F)	Avg Loop Flow (gpm)	Loop Heat (MBtu/day)	Pump 1 (kWh/day)	Pump 2 (kWh/day)	WWHP 1 (kWh/day)	WWHP 2 (kWh/day)
5/1/2023	57.5	51.8	51.1	47.7	558.5	5.8	1.9	50.3	42.5
5/2/2023	52.3	51.8	50.9	48.8	666.6	1.9	5.7	49.8	37.0
5/3/2023	50.5	51.7	50.4	47.9	857.7	5.9	1.8	50.8	42.0
5/4/2023	52.6	51.8	50.8	46.2	682.9	1.8	5.6	47.0	34.3
5/5/2023	55.2	52.1	51.7	47.6	323.2	5.9	1.8	47.0	36.0
5/6/2023	61.8	52.6	52.5	48.8	99.8	1.8	5.9	52.3	40.7
5/7/2023	66.6	53.3	54.2	50.0	(561.4)	6.0	1.9	46.4	33.5
5/8/2023	67.1	54.8	56.6	50.4	(1,084.4)	1.9	5.9	47.7	37.9
5/9/2023	60.4	53.5	53.5	46.2	72.0	5.8	1.8	45.3	32.8
5/10/2023	62.0	53.8	54.4	46.9	(315.1)	1.9	5.6	47.9	36.4
5/11/2023	71.7	54.2	55.4	48.3	(703.9)	5.9	1.9	49.2	38.0
5/12/2023	78.3	56.2	58.8	56.9	(1,947.5)	2.1	6.3	46.0	34.7
5/13/2023	75.6	57.6	60.6	62.1	(2,333.0)	7.1	2.0	46.5	37.3
5/14/2023	66.1	56.4	58.3	53.7	(1,255.8)	2.0	6.1	44.4	35.3
5/15/2023	66.1	55.9	57.5	50.9	(1,020.6)	6.1	1.9	45.3	31.3
5/16/2023	72.2	55.5	57.0	48.3	(827.8)	2.0	5.7	48.6	39.0
5/17/2023	60.6	55.5	56.8	49.4	(759.5)	6.1	1.8	47.7	36.0
5/18/2023	53.4	54.6	55.0	44.4	(194.6)	1.8	5.5	48.6	36.1
5/19/2023	61.2	54.6	55.3	43.8	(360.6)	5.8	1.7	45.1	32.8
5/20/2023	60.6	55.0	56.2	43.0	(652.4)	1.9	5.3	44.2	29.5
5/21/2023	64.3	55.8	57.9	48.4	(1,243.0)	6.0	1.8	44.3	31.9
5/22/2023	64.9	56.2	58.5	48.5	(1,339.4)	2.0	5.6	44.9	31.8
5/23/2023	60.6	56.3	58.4	48.8	(1,262.2)	5.9	2.0	43.0	27.4
5/24/2023	63.0	56.7	58.8	49.6	(1,278.7)	1.9	5.9	46.0	36.0
5/25/2023	59.5	56.0	57.5	47.1	(847.4)	5.9	1.8	45.3	30.2
5/26/2023	64.4	55.8	57.1	45.5	(747.6)	1.8	5.6	46.5	35.1
5/27/2023	67.1	56.1	58.1	49.0	(1,159.5)	6.1	1.7	45.1	31.6
5/28/2023	68.4	58.1	61.4	55.3	(2,342.2)	2.1	6.2	44.9	30.5
5/29/2023	68.9	59.0	62.5	61.0	(2,665.4)	6.9	2.0	45.3	31.6
5/30/2023	61.4	57.8	60.3	53.2	(1,566.1)	2.1	6.0	44.5	32.2
5/31/2023	63.0	58.5	61.7	60.2	(2,368.8)	6.7	2.1	44.5	33.4

Table B-15 Daily Ground Loop Data and Loop Pump and WWHP Energy Use – June 2023

Date	TAO (F)	Avg TLS (F)	Avg TLR (F)	Avg Loop Flow (gpm)	Loop Heat (MBtu/day)	Pump 1 (kWh/day)	Pump 2 (kWh/day)	WWHP 1 (kWh/day)	WWHP 2 (kWh/day)
6/1/2023	71.8	60.4	64.5	64.2	(3,398.9)	2.3	6.8	44.0	29.1
6/2/2023	76.5	62.9	68.1	71.2	(4,537.0)	7.7	2.2	41.7	29.0
6/3/2023	64.3	61.5	65.4	59.7	(2,861.9)	2.0	6.6	38.7	22.5
6/4/2023	59.5	58.5	60.4	50.7	(1,119.1)	6.1	1.8	43.1	28.9
6/5/2023	66.9	58.1	60.7	49.0	(1,539.4)	2.0	5.7	42.6	28.4
6/6/2023	68.5	57.8	59.7	50.8	(1,165.1)	6.1	1.9	42.7	28.1
6/7/2023	64.6	57.8	60.0	48.1	(1,278.9)	1.9	5.7	42.0	27.5
6/8/2023	64.3	57.5	59.3	49.4	(1,098.6)	6.0	1.9	46.0	33.1
6/9/2023	66.4	58.2	60.8	52.4	(1,665.9)	1.9	6.1	43.3	29.2
6/10/2023	68.7	58.0	60.2	53.5	(1,412.3)	6.3	1.9	46.3	33.3
6/11/2023	72.6	59.0	62.4	55.5	(2,378.6)	2.2	6.1	42.4	30.9
6/12/2023	71.7	60.8	64.9	62.8	(3,236.0)	7.0	2.1	41.7	25.8
6/13/2023	72.3	60.6	64.3	57.2	(2,572.3)	2.1	6.3	41.2	25.5
6/14/2023	69.9	59.5	62.4	56.3	(1,982.2)	6.5	1.9	43.4	31.2
6/15/2023	70.9	59.8	63.1	55.4	(2,294.2)	2.1	6.2	43.8	30.5
6/16/2023	70.1	60.2	63.6	56.3	(2,417.9)	6.5	1.9	39.2	24.6
6/17/2023	68.9	60.2	63.7	54.5	(2,363.3)	2.0	6.2	40.9	24.4
6/18/2023	72.8	60.4	64.0	60.1	(2,748.2)	6.8	2.1	42.3	28.4
6/19/2023	71.1	61.6	65.7	63.4	(3,301.3)	2.3	6.7	43.9	34.6
6/20/2023	68.2	62.1	66.2	64.7	(3,239.4)	7.1	2.2	41.0	24.1
6/21/2023	66.1	62.4	66.5	62.7	(3,188.7)	2.2	6.7	41.0	28.9
6/22/2023	65.2	62.3	66.4	64.8	(3,244.3)	7.1	2.1	40.0	26.3
6/23/2023	68.3	63.5	68.4	65.3	(3,917.8)	2.2	7.0	41.8	26.8
6/24/2023	72.9	64.7	70.0	71.5	(4,738.9)	7.6	2.4	42.0	30.7
6/25/2023	74.4	66.5	72.7	72.3	(5,506.9)	2.5	7.5	40.6	28.4
6/26/2023	73.3	65.6	70.8	72.2	(4,534.8)	7.8	2.3	43.4	31.1
6/27/2023	72.8	64.1	68.5	65.6	(3,546.9)	2.4	6.9	39.1	24.2
6/28/2023	75.2	65.0	70.1	70.8	(4,406.2)	7.6	2.3	40.8	25.9
6/29/2023	74.2	64.7	69.6	66.7	(4,015.4)	2.5	6.9	40.1	28.2
6/30/2023	76.0	66.1	71.4	73.2	(4,788.4)	7.9	2.3	40.2	23.9

Table B-16 Daily Ground Loop Data and Loop Pump and WWHP Energy Use – July 2023

Date	TAO (F)	Avg TLS (F)	Avg TLR (F)	Avg Loop Flow (gpm)	Loop Heat (MBtu/day)	Pump 1 (kWh/day)	Pump 2 (kWh/day)	WWHP 1 (kWh/day)	WWHP 2 (kWh/day)
7/1/2023	76.5	66.1	71.4	71.7	(4,636.4)	2.4	8.0	40.2	27.1
7/2/2023	77.8	67.0	72.9	75.2	(5,444.3)	8.0	2.4	37.4	25.0
7/3/2023	81.2	69.2	76.2	76.0	(6,499.9)	2.5	8.0	37.1	23.1
7/4/2023	78.2	69.3	75.6	78.3	(6,063.9)	8.3	2.4	37.8	21.9
7/5/2023	81.9	69.9	74.6	110.3	(6,178.2)	8.4	19.2	36.4	22.8
7/6/2023	82.5	72.5	79.1	99.1	(7,659.9)	15.9	2.6	38.2	25.7
7/7/2023	80.3	72.1	79.5	80.7	(7,374.7)	2.7	8.5	37.0	22.3
7/8/2023	79.6	72.1	78.9	84.9	(7,060.9)	9.3	2.6	38.1	27.8
7/9/2023	78.0	71.2	77.8	76.5	(6,181.5)	2.4	8.0	36.6	24.4
7/10/2023	78.4	69.6	75.3	76.2	(5,357.6)	8.2	2.3	37.9	21.0
7/11/2023	81.4	68.1	73.5	70.5	(4,831.0)	2.5	7.3	37.0	20.2
7/12/2023	85.2	70.2	76.5	80.2	(6,281.6)	8.5	2.5	36.9	24.3
7/13/2023	83.9	71.8	78.9	78.9	(6,959.5)	2.6	8.1	35.6	21.1
7/14/2023	77.7	70.9	77.1	79.4	(6,038.9)	8.3	2.5	38.9	26.3
7/15/2023	79.6	72.2	79.4	80.1	(7,105.3)	3.5	8.0	34.9	18.4
7/16/2023	78.5	73.8	81.1	86.2	(7,741.4)	9.2	2.6	39.3	27.7
7/17/2023	81.5	72.4	79.2	78.6	(6,529.8)	2.6	8.1	37.9	26.9
7/18/2023	79.3	71.3	77.3	80.0	(5,858.1)	8.4	2.5	37.7	22.4
7/19/2023	76.7	70.3	76.3	73.6	(5,451.7)	2.5	7.7	38.9	25.2
7/20/2023	78.3	71.1	77.2	78.5	(5,879.2)	8.3	2.5	37.8	22.0
7/21/2023	79.8	71.3	77.6	76.3	(5,889.8)	2.5	7.9	39.2	26.1
7/22/2023	77.7	70.7	76.4	77.0	(5,451.0)	8.3	2.2	38.0	24.7
7/23/2023	79.2	70.1	75.9	73.2	(5,331.6)	2.5	7.6	41.1	28.7
7/24/2023	79.8	70.5	76.4	77.4	(5,689.1)	8.2	2.4	37.0	22.0
7/25/2023	75.0	70.5	76.3	75.1	(5,329.2)	2.4	7.8	38.7	23.2
7/26/2023	79.5	70.4	76.4	77.0	(5,697.2)	8.1	2.4	36.2	21.0
7/27/2023	84.6	72.3	79.2	78.1	(6,668.1)	2.6	8.1	38.1	23.5
7/28/2023	85.4	73.9	81.2	83.4	(7,568.0)	8.7	2.6	37.3	24.2
7/29/2023	83.1	74.3	81.6	79.9	(7,148.6)	2.5	8.3	36.1	20.5
7/30/2023	73.5	70.3	75.3	73.2	(4,520.3)	7.8	2.3	38.1	21.6
7/31/2023	76.9	68.8	73.6	68.3	(4,102.9)	2.4	7.1	38.4	22.5

Table B-17 Daily Ground Loop Data and Loop Pump and WWHP Energy Use – Aug 2023

Date	TAO (F)	Avg TLS (F)	Avg TLR (F)	Avg Loop Flow (gpm)	Loop Heat (MBtu/day)	Pump 1 (kWh/day)	Pump 2 (kWh/day)	WWHP 1 (kWh/day)	WWHP 2 (kWh/day)
8/1/2023	73.8	67.6	71.7	67.5	(3,431.0)	7.3	2.2	37.7	22.8
8/2/2023	72.2	66.9	71.2	63.5	(3,398.1)	2.2	6.8	39.7	24.2
8/3/2023	74.3	66.9	71.4	67.0	(3,768.8)	7.2	2.2	39.4	23.6
8/4/2023	74.1	68.0	73.3	68.6	(4,436.9)	2.3	7.3	38.3	23.7
8/5/2023	77.9	68.6	73.9	73.0	(4,798.8)	7.7	2.3	40.0	26.7
8/6/2023	77.9	69.7	75.5	73.2	(5,288.4)	2.5	7.6	36.6	21.7
8/7/2023	75.7	69.7	75.2	75.2	(5,065.9)	7.9	2.3	38.3	23.3
8/8/2023	75.7	68.5	73.6	68.8	(4,300.0)	2.3	7.3	37.1	21.7
8/9/2023	78.5	69.0	74.5	72.8	(4,966.3)	7.7	2.3	36.2	18.9
8/10/2023	75.2	69.3	74.9	70.7	(4,783.2)	2.3	7.4	38.4	24.6
8/11/2023	77.7	68.6	73.6	72.1	(4,430.7)	7.8	2.2	41.7	29.9
8/12/2023	76.8	68.5	73.9	69.4	(4,686.0)	2.3	7.3	37.0	22.6
8/13/2023	79.2	70.7	76.8	77.2	(5,784.2)	8.1	2.3	37.9	23.1
8/14/2023	80.3	69.9	75.7	72.0	(5,081.2)	2.4	7.5	37.8	23.0
8/15/2023	73.8	69.3	74.2	71.8	(4,361.0)	7.6	2.2	37.0	20.1
8/16/2023	74.3	69.7	75.6	71.5	(5,167.4)	2.4	7.4	39.1	25.0
8/17/2023	75.0	70.2	76.0	75.7	(5,417.9)	8.0	2.4	39.2	23.5
8/18/2023	76.7	70.0	75.6	70.9	(4,885.4)	2.2	7.6	36.1	21.8
8/19/2023	72.9	67.9	72.3	67.4	(3,677.2)	7.3	2.1	38.5	23.6
8/20/2023	78.8	67.7	72.6	66.2	(4,080.9)	2.4	6.9	38.0	25.1
8/21/2023	81.3	69.8	75.5	75.6	(5,418.4)	7.8	2.5	38.9	25.8
8/22/2023	73.7	68.5	73.1	67.8	(3,763.8)	2.2	7.2	40.6	22.1
8/23/2023	71.2	67.0	71.3	66.1	(3,474.1)	7.1	2.2	40.2	23.5
8/24/2023	71.8	67.0	71.4	63.2	(3,392.0)	2.1	6.8	38.5	24.2
8/25/2023	74.5	68.5	73.9	71.1	(4,815.2)	7.5	2.3	38.0	22.3
8/26/2023	77.5	70.3	76.4	74.2	(5,538.6)	2.4	7.7	35.2	21.5
8/27/2023	76.5	70.0	75.3	75.8	(4,951.9)	8.0	2.3	38.7	26.0
8/28/2023	73.0	68.3	73.0	67.1	(3,912.6)	2.3	7.0	38.3	22.6
8/29/2023	73.0	69.4	74.7	75.2	(4,900.9)	7.9	2.3	38.0	21.3
8/30/2023	76.8	70.2	75.9	73.3	(5,207.8)	2.3	7.7	40.2	26.9
8/31/2023	70.5	68.1	72.4	67.5	(3,565.5)	7.4	2.0	37.1	24.8

Table B-18 Daily Ground Loop Data and Loop Pump and WWHP Energy Use – Sep 2023

Date	TAO (F)	Avg TLS (F)	Avg TLR (F)	Avg Loop Flow (gpm)	Loop Heat (MBtu/day)	Pump 1 (kWh/day)	Pump 2 (kWh/day)	WWHP 1 (kWh/day)	WWHP 2 (kWh/day)
9/1/2023	68.3	66.3	69.9	60.0	(2,716.0)	2.1	6.5	40.4	26.5
9/2/2023	71.4	66.6	70.6	65.9	(3,333.5)	7.1	2.2	39.5	25.4
9/3/2023	79.8	70.0	76.2	73.5	(5,691.8)	2.4	7.6	36.2	20.1
9/4/2023	82.0	72.0	78.5	80.7	(6,543.7)	8.4	2.5	37.9	24.8
9/5/2023	83.5	72.9	79.6	79.1	(6,519.9)	2.6	8.0	37.1	22.5
9/6/2023	85.5	74.3	81.5	84.7	(7,631.5)	8.7	2.8	39.0	27.9
9/7/2023	86.2	75.9	83.6	82.5	(7,864.7)	2.6	8.5	29.7	24.7
9/8/2023	78.4	75.6	82.5	86.3	(7,285.3)	9.9	2.3	27.9	33.8
9/9/2023	79.1	74.8	82.0	78.2	(6,961.1)	2.5	8.0	32.8	22.7
9/10/2023	74.7	74.0	80.4	79.9	(6,217.2)	8.4	2.4	32.2	23.4
9/11/2023	74.4	72.9	79.2	74.4	(5,772.7)	2.4	7.7	33.5	21.8
9/12/2023	75.0	70.6	75.4	70.9	(4,201.6)	7.6	2.2	34.0	22.9
9/13/2023	76.5	70.0	75.2	65.9	(4,244.2)	2.2	7.0	33.7	23.9
9/14/2023	71.4	68.9	73.2	65.1	(3,545.2)	7.2	2.0	36.1	26.1
9/15/2023	63.9	66.2	68.9	52.4	(1,819.9)	1.8	6.1	36.7	25.3
9/16/2023	69.2	65.3	68.0	55.8	(1,839.2)	6.5	1.8	35.0	24.9
9/17/2023	69.6	64.9	67.8	54.2	(2,014.7)	2.1	6.0	36.0	24.4
9/18/2023	67.0	64.7	67.4	56.5	(1,854.9)	6.5	1.9	37.2	28.4
9/19/2023	67.9	63.8	65.9	50.2	(1,285.3)	1.9	5.8	37.1	25.0
9/20/2023	68.6	63.0	64.8	52.4	(1,189.6)	6.2	1.9	37.4	26.0
9/21/2023	66.3	62.8	64.5	49.8	(1,059.6)	1.9	5.8	38.0	28.3
9/22/2023	65.2	62.9	64.8	52.4	(1,317.6)	6.3	1.8	37.7	26.2
9/23/2023	61.5	61.9	63.3	46.0	(739.4)	1.8	5.6	36.6	24.7
9/24/2023	64.2	62.0	63.4	51.7	(830.2)	6.2	1.8	39.0	29.6
9/25/2023	61.6	61.8	63.2	50.5	(780.1)	1.9	5.8	38.1	27.9
9/26/2023	60.8	61.1	61.9	48.1	(431.5)	5.9	1.8	40.3	25.9
9/27/2023	60.3	60.3	60.4	48.5	(24.8)	1.8	5.7	41.6	35.4
9/28/2023	60.4	59.9	60.2	46.8	(111.9)	5.9	1.7	40.0	30.6
9/29/2023	61.1	60.5	61.7	45.4	(542.7)	1.7	5.6	39.1	31.1
9/30/2023	61.6	60.8	62.2	51.3	(862.2)	6.2	1.8	40.2	34.7

Table B-19 Daily DHW Heat, Efficiency and Energy Use – April 2022

Date	HW Use (gal/day)	QHW (MBtu/day)	QR (MBtu/day)	Gross COP (-)	Net COP (-)	Predicted COP WWHP1 (-)	Predicted COP WWHP2 (-)	Recirc Losses (%)	Q Predicted (MBtu/day)	Heat Balance (%)
3/15/2022	462.7	268.7	274.2	2.83	1.40	2.81	3.53	51%	580.3	94%
3/16/2022	324.8	186.3	275.5	2.63	1.06	2.84	3.56	60%	533.6	87%
3/17/2022	602.2	346.6	271.3	2.94	1.65	2.84	3.58	44%	652.0	95%
3/18/2022	502.2	287.0	271.2	2.77	1.42	2.85	3.60	49%	627.4	89%
3/19/2022	476.5	272.0	265.5	2.93	1.48	2.87	3.67	49%	572.3	94%
3/20/2022	678.4	389.8	266.1	2.96	1.76	2.87	3.64	41%	704.1	93%
3/21/2022	603.3	343.0	269.6	2.78	1.56	2.85	3.59	44%	692.0	89%
3/22/2022	626.8	355.9	270.0	3.00	1.71	2.85	3.58	43%	650.5	96%
3/23/2022	664.7	374.1	272.7	2.89	1.67	2.84	3.61	42%	698.9	93%
3/24/2022	567.7	318.1	272.7	2.75	1.48	2.83	3.56	46%	668.1	88%
3/25/2022	852.7	488.8	272.6	3.09	1.99	2.84	3.61	36%	777.5	98%
3/26/2022	759.7	429.0	273.3	2.85	1.74	2.83	3.56	39%	773.9	91%
3/27/2022	793.9	451.8	268.9	2.95	1.85	2.82	3.59	37%	764.4	94%
3/28/2022	929.4	530.6	277.4	2.96	1.95	2.78	3.53	34%	846.1	95%
3/29/2022	886.2	506.9	274.3	2.91	1.89	2.77	3.56	35%	835.4	94%
3/30/2022	783.2	448.0	277.0	2.89	1.79	2.78	3.54	38%	774.9	94%
3/31/2022	913.8	529.8	271.7	3.00	1.98	2.79	3.59	34%	836.1	96%
4/1/2022	877.8	506.8	271.8	2.96	1.93	2.83	3.61	35%	832.7	94%
4/2/2022	856.6	493.0	266.8	3.03	1.96	2.82	3.55	35%	787.5	96%
4/3/2022	916.7	531.1	274.1	3.02	1.99	2.82	3.64	34%	844.9	95%
4/4/2022	951.0	546.5	268.7	3.03	2.03	2.82	3.59	33%	851.5	96%
4/5/2022	996.7	571.4	266.7	3.00	2.04	2.83	3.62	32%	894.9	94%
4/6/2022	1,019.0	585.2	267.9	3.12	2.14	2.84	3.64	31%	872.4	98%
4/7/2022	1,052.4	601.1	259.6	3.01	2.10	2.84	3.64	30%	922.2	93%
4/8/2022	1,001.7	567.2	265.3	3.17	2.16	2.85	3.69	32%	845.7	98%
4/9/2022	1,102.1	624.0	263.8	3.03	2.13	2.84	3.64	30%	943.9	94%
4/10/2022	814.0	460.3	266.1	2.97	1.88	2.84	3.60	37%	770.8	94%
4/11/2022	984.0	553.9	264.1	3.17	2.14	2.83	3.58	32%	817.8	100%
4/12/2022	985.3	556.6	258.2	3.06	2.09	2.85	3.62	32%	853.9	95%
4/13/2022	905.9	504.7	258.0	3.14	2.07	2.86	3.62	34%	775.7	98%
4/14/2022	1,238.0	699.3	246.6	3.14	2.32	2.88	3.68	26%	992.3	95%
4/15/2022	989.6	549.6	252.5	3.16	2.16	2.87	3.64	31%	817.1	98%
4/16/2022	980.9	545.7	249.8	3.16	2.17	2.87	3.76	31%	818.7	97%
4/17/2022	1,021.6	557.3	256.8	3.04	2.08	2.86	3.63	32%	861.6	94%
4/18/2022	1,144.1	630.4	261.3	3.13	2.21	2.84	3.65	29%	912.9	98%
4/19/2022	1,084.1	592.4	261.1	3.05	2.12	2.83	3.62	31%	894.3	95%
4/20/2022	1,140.1	624.6	258.4	3.13	2.21	2.83	3.62	29%	903.7	98%
4/21/2022	1,053.3	577.3	260.2	3.06	2.11	2.83	3.61	31%	874.3	96%
4/22/2022	1,141.3	629.3	259.2	3.23	2.29	2.85	3.71	29%	886.5	100%
4/23/2022	1,080.7	592.3	252.1	3.15	2.21	2.86	3.63	30%	863.1	98%
4/24/2022	1,276.1	700.6	253.1	3.09	2.27	2.85	3.65	27%	1,003.8	95%
4/25/2022	1,153.2	623.3	254.7	3.22	2.29	2.87	3.69	29%	883.7	99%
4/26/2022	1,136.0	611.3	250.1	3.13	2.22	2.86	3.62	29%	885.9	97%
4/27/2022	1,289.6	694.8	245.7	3.13	2.31	2.86	3.62	26%	975.9	96%
4/28/2022	1,133.5	604.9	260.2	3.10	2.17	2.86	3.62	30%	897.8	96%
4/29/2022	1,159.8	618.8	264.9	3.16	2.22	2.85	3.63	30%	894.6	99%
4/30/2022	1,348.9	719.0	258.3	3.19	2.35	2.86	3.63	26%	991.2	99%

Table B-20 Daily DHW Heat, Efficiency and Energy Use – May 2022

Date	HW Use (gal/day)	QHW (MBtu/day)	QR (MBtu/day)	Gross COP (-)	Net COP (-)	Predicted COP WWHP1 (-)	Predicted COP WWHP2 (-)	Recirc Losses (%)	Q Predicted (MBtu/day)	Heat Balance (%)
5/1/2022	1,188.8	631.5	258.7	3.11	2.21	2.86	3.63	29%	924.0	96%
5/2/2022	1,133.6	595.6	253.1	3.16	2.21	2.87	3.63	30%	869.2	98%
5/3/2022	1,132.9	591.8	255.8	3.19	2.23	2.88	3.67	30%	857.2	99%
5/4/2022	1,245.7	650.5	247.8	3.20	2.31	2.87	3.66	28%	912.0	98%
5/5/2022	1,170.5	605.0	254.2	3.09	2.18	2.90	3.66	30%	908.7	95%
5/6/2022	1,043.6	538.5	253.6	3.18	2.16	2.89	3.63	32%	803.0	99%
5/7/2022	1,364.4	702.7	254.5	3.17	2.33	2.87	3.64	27%	981.0	98%
5/8/2022	1,199.4	623.2	257.9	3.21	2.27	2.87	3.66	29%	886.4	99%
5/9/2022	1,301.0	682.9	255.2	3.09	2.25	2.87	3.63	27%	985.3	95%
5/10/2022	1,164.2	604.8	257.1	3.17	2.22	2.88	3.70	30%	884.1	97%
5/11/2022	1,348.7	697.3	251.6	3.29	2.42	2.88	3.75	27%	942.3	101%
5/12/2022	1,047.6	530.9	243.1	3.16	2.17	2.92	3.68	31%	800.0	97%
5/13/2022	1,039.8	519.8	241.8	3.12	2.13	2.95	3.72	32%	806.4	94%
5/14/2022	1,458.7	725.3	237.5	3.34	2.52	2.99	3.80	25%	979.8	98%
5/15/2022	1,223.2	600.2	238.3	3.36	2.40	3.00	3.76	28%	841.1	100%
5/16/2022	1,111.4	534.9	233.1	3.26	2.27	2.99	3.75	30%	789.0	97%
5/17/2022	1,160.8	553.2	240.4	3.18	2.22	2.97	3.72	30%	830.3	96%
5/18/2022	1,081.3	511.3	243.3	3.22	2.18	2.95	3.69	32%	768.9	98%
5/19/2022	1,015.8	479.1	241.6	3.19	2.12	2.94	3.66	34%	736.7	98%
5/20/2022	1,084.4	512.2	242.4	3.18	2.16	2.95	3.67	32%	779.1	97%
5/21/2022	1,358.1	648.1	237.2	3.27	2.40	2.99	3.76	27%	913.0	97%
5/22/2022	1,238.4	589.2	234.2	3.29	2.36	3.04	3.80	28%	854.3	96%
5/23/2022	1,104.0	518.9	235.0	3.33	2.29	3.00	3.75	31%	757.6	100%
5/24/2022	1,158.0	540.4	240.7	3.23	2.23	2.98	3.72	31%	804.9	97%
5/25/2022	1,328.9	618.9	239.7	3.26	2.35	2.97	3.73	28%	879.7	98%
5/26/2022	1,521.7	707.5	236.2	3.27	2.45	2.96	3.72	25%	966.0	98%
5/27/2022	1,169.4	535.5	236.7	3.20	2.22	2.99	3.73	31%	802.3	96%
5/28/2022	1,198.8	545.9	236.1	3.36	2.34	3.02	3.77	30%	784.5	100%
5/29/2022	1,159.7	526.9	241.5	3.30	2.26	3.01	3.73	31%	776.6	99%
5/30/2022	1,427.5	653.3	236.1	3.39	2.49	3.04	3.81	27%	896.4	99%
5/31/2022	1,099.0	498.3	236.2	3.24	2.20	3.08	3.84	32%	779.7	94%

Table B-21 Daily DHW Heat, Efficiency and Energy Use – June 2022

Date	HW Use (gal/day)	QHW (MBtu/day)	QR (MBtu/day)	Gross COP (-)	Net COP (-)	Predicted COP WWHP1 (-)	Predicted COP WWHP2 (-)	Recirc Losses (%)	Q Predicted (MBtu/day)	Heat Balance (%)
6/1/2022	1,299.2	583.8	231.5	3.34	2.39	3.05	3.80	28%	833.0	98%
6/2/2022	1,376.0	616.4	231.8	3.46	2.51	3.04	3.82	27%	834.4	102%
6/3/2022	1,427.0	631.9	231.9	3.35	2.45	3.05	3.80	27%	881.8	98%
6/4/2022	1,387.9	611.8	231.4	3.32	2.41	3.03	3.77	27%	859.9	98%
6/5/2022	1,293.8	569.5	233.6	3.32	2.35	3.01	3.76	29%	815.0	99%
6/6/2022	1,662.6	726.1	230.2	3.33	2.53	3.02	3.77	24%	979.7	98%
6/7/2022	1,316.5	573.8	232.5	3.34	2.38	3.02	3.77	29%	809.6	100%
6/8/2022	1,225.8	528.5	234.9	3.25	2.25	3.04	3.77	31%	795.1	96%
6/9/2022	1,322.6	570.8	226.2	3.36	2.40	3.05	3.79	28%	808.2	99%
6/10/2022	1,307.8	561.5	230.8	3.35	2.37	3.04	3.78	29%	801.5	99%
6/11/2022	1,376.0	587.0	228.1	3.29	2.37	3.04	3.75	28%	842.1	97%
6/12/2022	1,646.3	705.5	232.1	3.41	2.57	3.02	3.80	25%	932.8	101%
6/13/2022	1,172.6	496.2	230.2	3.21	2.19	3.06	3.78	32%	770.6	94%
6/14/2022	1,259.5	534.4	231.9	3.40	2.37	3.04	3.78	30%	759.4	101%
6/15/2022	1,543.2	657.2	225.8	3.33	2.48	3.07	3.82	26%	916.2	96%
6/16/2022	1,183.2	491.6	230.2	3.31	2.25	3.06	3.77	32%	739.5	98%
6/17/2022	1,119.6	462.0	227.9	3.33	2.23	3.08	3.78	33%	702.8	98%
6/18/2022	1,251.4	516.7	231.7	3.32	2.30	3.05	3.75	31%	760.6	98%
6/19/2022	1,141.3	471.6	234.2	3.16	2.11	3.02	3.69	33%	742.6	95%
6/20/2022	1,088.2	450.3	234.8	3.14	2.07	3.01	3.70	34%	722.9	95%
6/21/2022	1,192.3	497.6	233.4	3.29	2.24	3.00	3.69	32%	734.9	99%
6/22/2022	1,346.8	562.7	233.2	3.22	2.28	3.01	3.71	29%	826.4	96%
6/23/2022	1,339.3	561.4	231.7	3.32	2.35	3.01	3.74	29%	798.2	99%
6/24/2022	1,352.6	570.6	231.7	3.23	2.29	3.03	3.74	29%	841.4	95%
6/25/2022	1,528.8	649.0	231.3	3.39	2.50	3.08	3.84	26%	894.7	98%
6/26/2022	1,225.1	515.5	230.2	3.41	2.36	3.10	3.86	31%	755.4	99%
6/27/2022	1,400.0	584.9	225.7	3.39	2.45	3.09	3.86	28%	826.9	98%
6/28/2022	1,274.7	526.8	226.5	3.35	2.34	3.08	3.80	30%	767.1	98%
6/29/2022	1,351.6	552.9	231.5	3.34	2.35	3.07	3.79	30%	801.2	98%
6/30/2022	1,115.5	450.2	228.8	3.30	2.19	3.10	3.81	34%	703.7	96%

Table B-22 Daily DHW Heat, Efficiency and Energy Use – July 2022

Date	HW Use (gal/day)	QHW (MBtu/day)	QR (MBtu/day)	Gross COP (-)	Net COP (-)	Predicted COP WWHP1 (-)	Predicted COP WWHP2 (-)	Recirc Losses (%)	Q Predicted (MBtu/day)	Heat Balance (%)
7/1/2022	1,132.4	451.5	226.4	3.32	2.21	3.12	3.85	33%	702.6	96%
7/2/2022	1,285.9	508.9	224.0	3.47	2.41	3.14	3.89	31%	736.6	99%
7/3/2022	1,096.3	429.0	230.4	3.28	2.13	3.12	3.81	35%	688.5	96%
7/4/2022	1,132.5	442.3	231.9	3.27	2.14	3.10	3.78	34%	703.1	96%
7/5/2022	1,193.8	464.3	229.3	3.32	2.22	3.10	3.80	33%	713.2	97%
7/6/2022	1,309.8	505.4	226.6	3.39	2.34	3.13	3.83	31%	747.9	98%
7/7/2022	1,275.2	492.2	229.2	3.41	2.33	3.12	3.84	32%	726.7	99%
7/8/2022	1,329.1	511.9	227.1	3.44	2.38	3.14	3.88	31%	748.9	99%
7/9/2022	1,205.6	461.2	229.0	3.38	2.26	3.15	3.84	33%	707.9	98%
7/10/2022	1,321.0	505.0	230.8	3.38	2.32	3.12	3.83	31%	749.7	98%
7/11/2022	1,330.5	503.1	233.1	3.33	2.27	3.12	3.81	32%	762.1	97%
7/12/2022	1,228.9	462.1	227.8	3.41	2.28	3.14	3.84	33%	698.3	99%
7/13/2022	1,154.3	434.3	223.8	3.36	2.22	3.15	3.84	34%	678.5	97%
7/14/2022	1,573.4	591.7	228.2	3.47	2.51	3.15	3.88	28%	827.1	99%
7/15/2022	1,197.7	449.0	229.5	3.38	2.23	3.12	3.81	34%	687.0	99%
7/16/2022	1,223.9	460.5	228.2	3.43	2.29	3.13	3.83	33%	692.3	99%
7/17/2022	1,116.0	419.7	224.8	3.38	2.20	3.17	3.87	35%	663.3	97%
7/18/2022	1,487.2	561.7	223.4	3.44	2.46	3.16	3.89	28%	800.1	98%
7/19/2022	1,235.6	458.8	227.5	3.43	2.30	3.18	3.91	33%	700.8	98%
7/20/2022	1,254.2	464.4	226.7	3.55	2.39	3.21	3.94	33%	688.4	100%
7/21/2022	1,341.4	500.4	223.6	3.55	2.45	3.22	3.96	31%	728.0	99%
7/22/2022	1,072.7	396.8	224.2	3.55	2.27	3.21	3.95	36%	614.4	101%
7/23/2022	1,226.0	453.2	224.3	3.46	2.32	3.21	3.92	33%	693.3	98%
7/24/2022	1,104.3	406.6	227.1	3.52	2.26	3.22	3.94	36%	635.1	100%
7/25/2022	1,112.3	407.1	222.1	3.49	2.26	3.22	3.95	35%	637.3	99%
7/26/2022	1,288.3	472.2	226.2	3.41	2.30	3.19	3.91	32%	722.8	97%
7/27/2022	1,168.0	427.2	228.1	3.45	2.25	3.18	3.91	35%	662.3	99%
7/28/2022	1,306.4	478.0	226.8	3.56	2.41	3.20	3.91	32%	698.2	101%
7/29/2022	1,187.0	434.7	225.2	3.48	2.30	3.22	3.93	34%	670.9	98%
7/30/2022	1,029.6	369.7	226.2	3.40	2.11	3.21	3.92	38%	616.0	97%
7/31/2022	1,301.4	461.0	225.7	3.46	2.32	3.18	3.91	33%	696.5	99%

Table B-23 Daily DHW Heat, Efficiency and Energy Use – Aug 2022

Date	HW Use (gal/day)	QHW (MBtu/day)	QR (MBtu/day)	Gross COP (-)	Net COP (-)	Predicted COP WWHP1 (-)	Predicted COP WWHP2 (-)	Recirc Losses (%)	Q Predicted (MBtu/day)	Heat Balance (%)
8/1/2022	955.3	334.8	219.0	3.08	1.86	3.19	3.77	40%	618.3	90%
8/2/2022	1,314.0	469.8	221.4	3.56	2.42	3.21	3.93	32%	682.8	101%
8/3/2022	1,417.6	515.7	223.3	3.56	2.48	3.20	3.93	30%	737.2	100%
8/4/2022	1,443.1	564.2	221.4	3.65	2.62	3.22	3.98	28%	772.5	102%
8/5/2022	1,288.5	515.9	224.0	3.64	2.54	3.23	4.01	30%	732.7	101%
8/6/2022	1,365.9	554.2	223.7	3.68	2.62	3.23	4.01	29%	765.5	102%
8/7/2022	1,457.7	597.9	224.5	3.67	2.67	3.23	4.02	27%	813.6	101%
8/8/2022	1,213.1	494.9	219.5	3.65	2.53	3.24	4.03	31%	708.6	101%
8/9/2022	1,336.5	541.9	222.9	3.71	2.63	3.24	4.02	29%	747.0	102%
8/10/2022	1,228.1	503.1	227.9	3.58	2.47	3.21	4.00	31%	728.1	100%
8/11/2022	1,436.2	599.8	224.2	3.69	2.68	3.20	3.98	27%	800.7	103%
8/12/2022	1,377.7	560.8	224.3	3.52	2.52	3.18	3.91	29%	790.0	99%
8/13/2022	1,254.1	504.5	225.8	3.53	2.44	3.15	3.90	31%	722.9	101%
8/14/2022	1,036.3	417.6	229.6	3.33	2.15	3.15	3.88	35%	674.9	96%
8/15/2022	1,328.1	539.4	225.2	3.57	2.52	3.16	3.92	29%	756.4	101%
8/16/2022	1,368.5	514.2	224.5	3.51	2.44	3.17	3.88	30%	737.6	100%
8/17/2022	1,275.9	502.9	229.5	3.51	2.41	3.15	3.88	31%	724.7	101%
8/18/2022	1,282.6	521.6	225.2	3.47	2.42	3.14	3.89	30%	753.4	99%
8/19/2022	1,481.1	615.6	227.3	3.60	2.63	3.16	3.92	27%	830.4	102%
8/20/2022	1,408.6	588.7	220.9	3.58	2.60	3.18	3.94	27%	806.5	100%
8/21/2022	1,574.8	666.5	224.2	3.69	2.76	3.20	4.03	25%	871.0	102%
8/22/2022	1,541.3	646.9	224.3	3.60	2.67	3.19	3.98	26%	867.1	100%
8/23/2022	1,324.1	551.5	221.5	3.54	2.53	3.19	3.97	29%	781.0	99%
8/24/2022	1,226.2	507.8	224.7	3.60	2.49	3.19	3.94	31%	722.0	101%
8/25/2022	1,156.9	479.2	225.9	3.43	2.33	3.19	3.95	32%	729.0	97%
8/26/2022	1,228.3	505.3	224.8	3.59	2.49	3.19	3.98	31%	722.3	101%
8/27/2022	1,422.8	588.1	221.4	3.63	2.64	3.20	3.95	27%	798.6	101%
8/28/2022	1,237.0	512.7	222.4	3.43	2.39	3.18	3.96	30%	761.5	97%
8/29/2022	1,431.0	606.0	222.5	3.74	2.73	3.21	4.02	27%	800.1	104%
8/30/2022	1,227.6	512.4	222.3	3.58	2.50	3.22	4.02	30%	741.2	99%
8/31/2022	1,241.5	520.0	224.8	3.44	2.40	3.19	3.98	30%	769.3	97%

Table B-24 Daily DHW Heat, Efficiency and Energy Use – Sep 2022

Date	HW Use (gal/day)	QHW (MBtu/day)	QR (MBtu/day)	Gross COP (-)	Net COP (-)	Predicted COP WWHP1 (-)	Predicted COP WWHP2 (-)	Recirc Losses (%)	Q Predicted (MBtu/day)	Heat Balance (%)
9/1/2022	1,189.8	485.6	223.1	3.49	2.39	3.15	3.89	31%	711.8	100%
9/2/2022	1,246.0	510.7	227.7	3.46	2.39	3.14	3.86	31%	740.2	100%
9/3/2022	1,277.9	521.4	223.5	3.44	2.41	3.14	3.89	30%	758.0	98%
9/4/2022	1,274.1	517.9	224.8	3.43	2.39	3.17	3.92	30%	766.0	97%
9/5/2022	1,377.8	560.2	222.9	3.54	2.53	3.15	3.90	28%	776.8	101%
9/6/2022	1,317.7	531.1	224.7	3.42	2.41	3.14	3.87	30%	768.8	98%
9/7/2022	1,284.9	514.8	227.8	3.40	2.36	3.13	3.85	31%	758.3	98%
9/8/2022	1,265.9	510.6	225.9	3.36	2.33	3.12	3.83	31%	759.2	97%
9/9/2022	1,410.2	584.0	228.0	3.52	2.53	3.12	3.86	28%	800.9	101%
9/10/2022	1,164.9	489.1	229.4	3.36	2.28	3.12	3.87	32%	741.6	97%
9/11/2022	1,314.0	556.9	224.2	3.45	2.46	3.13	3.88	29%	793.7	98%
9/12/2022	1,279.8	536.7	232.1	3.46	2.42	3.13	3.90	30%	771.7	100%
9/13/2022	1,260.7	516.3	225.9	3.42	2.38	3.14	3.88	30%	759.3	98%
9/14/2022	1,229.0	496.1	227.4	3.33	2.28	3.13	3.86	31%	754.5	96%
9/15/2022	1,356.4	546.3	228.7	3.41	2.41	3.11	3.81	30%	781.0	99%
9/16/2022	1,282.9	512.7	230.0	3.36	2.32	3.07	3.78	31%	748.4	99%
9/17/2022	1,443.9	582.8	228.1	3.35	2.41	3.08	3.79	28%	830.9	98%
9/18/2022	1,310.9	529.5	226.1	3.37	2.36	3.10	3.85	30%	774.1	98%
9/19/2022	1,420.3	577.1	223.5	3.49	2.52	3.13	3.85	28%	798.6	100%
9/20/2022	1,511.7	614.1	221.7	3.54	2.60	3.12	3.88	27%	825.2	101%
9/21/2022	1,312.0	532.5	225.1	3.37	2.37	3.12	3.85	30%	777.0	98%
9/22/2022	1,183.7	475.5	223.3	3.33	2.26	3.11	3.83	32%	722.4	97%
9/23/2022	1,404.4	563.2	230.9	3.35	2.38	3.06	3.76	29%	802.6	99%
9/24/2022	1,278.9	525.2	232.0	3.21	2.23	3.04	3.75	31%	796.1	95%
9/25/2022	1,590.1	675.1	229.7	3.41	2.55	3.04	3.78	25%	905.2	100%
9/26/2022	1,429.9	621.7	227.6	3.40	2.49	3.05	3.86	27%	852.2	100%
9/27/2022	1,445.3	629.0	234.9	3.37	2.46	3.04	3.81	27%	871.8	99%
9/28/2022	1,672.7	730.3	233.8	3.38	2.56	3.02	3.80	24%	972.1	99%
9/29/2022	1,528.0	674.2	233.9	3.38	2.51	3.01	3.74	26%	905.4	100%
9/30/2022	1,357.9	598.7	236.0	3.24	2.32	3.00	3.73	28%	863.2	97%

Table B-25 Daily DHW Heat, Efficiency and Energy Use – Oct 2022

Date	HW Use (gal/day)	QHW (MBtu/day)	QR (MBtu/day)	Gross COP (-)	Net COP (-)	Predicted COP WWHP1 (-)	Predicted COP WWHP2 (-)	Recirc Losses (%)	Q Predicted (MBtu/day)	Heat Balance (%)
10/1/2022	1,427.7	632.6	235.5	3.29	2.40	3.00	3.74	27%	886.1	98%
10/2/2022	1,320.0	583.1	237.2	3.33	2.37	3.01	3.74	29%	824.2	100%
10/3/2022	1,656.8	733.9	238.5	3.32	2.50	2.99	3.74	25%	985.1	99%
10/4/2022	1,391.2	620.5	239.3	3.21	2.31	2.99	3.73	28%	898.4	96%
10/5/2022	1,275.7	574.9	238.5	3.26	2.30	2.99	3.73	29%	833.0	98%
10/6/2022	1,355.7	620.1	243.7	3.24	2.33	3.00	3.79	28%	896.5	96%
10/7/2022	1,361.1	624.4	238.9	3.38	2.44	3.01	3.81	28%	861.6	100%
10/8/2022	1,428.2	654.0	240.5	3.20	2.34	2.99	3.72	27%	939.6	95%
10/9/2022	1,405.0	648.2	239.1	3.34	2.44	2.97	3.73	27%	886.3	100%
10/10/2022	1,207.3	552.1	246.8	3.14	2.17	2.98	3.69	31%	844.6	95%
10/11/2022	1,367.6	641.6	244.1	3.29	2.38	2.97	3.71	28%	895.8	99%
10/12/2022	1,290.8	598.5	243.0	3.27	2.32	2.98	3.73	29%	858.2	98%
10/13/2022	1,306.5	608.0	238.6	3.29	2.36	2.98	3.74	28%	861.4	98%
10/14/2022	1,293.1	600.3	239.8	3.21	2.29	2.99	3.75	29%	877.7	96%
10/15/2022	1,392.6	648.0	241.7	3.34	2.43	2.99	3.75	27%	895.4	99%
10/16/2022	1,185.7	545.5	245.8	3.15	2.17	2.99	3.74	31%	839.2	94%
10/17/2022	1,345.6	622.6	242.6	3.24	2.33	2.98	3.70	28%	888.5	97%
10/18/2022	1,122.7	520.0	248.0	3.23	2.19	2.97	3.70	32%	783.9	98%
10/19/2022	1,201.4	562.9	246.0	3.17	2.20	2.95	3.68	30%	842.2	96%
10/20/2022	1,193.2	562.4	249.9	3.11	2.15	2.95	3.68	31%	858.7	95%
10/21/2022	1,235.0	591.3	253.5	3.20	2.24	2.94	3.69	30%	867.4	97%
10/22/2022	1,189.4	571.9	253.5	3.26	2.26	2.94	3.68	31%	828.2	100%
10/23/2022	1,178.8	565.4	249.8	3.16	2.19	2.95	3.68	31%	850.4	96%
10/24/2022	1,244.1	605.9	247.9	3.25	2.31	2.96	3.75	29%	873.4	98%
10/25/2022	1,167.1	570.8	246.1	3.22	2.25	2.97	3.75	30%	843.4	97%
10/26/2022	1,226.6	597.1	239.3	3.28	2.34	2.99	3.77	29%	858.6	97%
10/27/2022	1,170.7	564.3	239.2	3.27	2.30	2.99	3.77	30%	824.5	97%
10/28/2022	1,169.0	563.2	244.5	3.19	2.22	2.97	3.70	30%	841.8	96%
10/29/2022	1,225.8	591.2	251.2	3.21	2.25	2.95	3.70	30%	866.4	97%
10/30/2022	1,200.4	582.2	250.1	3.23	2.26	2.94	3.71	30%	845.6	98%
10/31/2022	1,274.6	617.5	248.4	3.16	2.25	2.94	3.68	29%	905.7	96%

Table B-26 Daily DHW Heat, Efficiency and Energy Use – Nov 2022

Date	HW Use (gal/day)	QHW (MBtu/day)	QR (MBtu/day)	Gross COP (-)	Net COP (-)	Predicted COP WWHP1 (-)	Predicted COP WWHP2 (-)	Recirc Losses (%)	Q Predicted (MBtu/day)	Heat Balance (%)
11/1/2022	1,337.7	657.0	241.8	3.27	2.39	2.97	3.75	27%	924.6	97%
11/2/2022	1,207.1	594.6	240.3	3.36	2.39	2.97	3.74	29%	829.0	101%
11/3/2022	1,246.2	605.3	246.4	3.14	2.23	2.96	3.72	29%	904.9	94%
11/4/2022	1,304.8	634.4	243.2	3.24	2.35	2.96	3.71	28%	900.5	97%
11/5/2022	1,347.9	661.5	241.4	3.31	2.42	2.98	3.75	27%	916.7	98%
11/6/2022	1,284.6	625.3	236.5	3.41	2.48	3.01	3.79	27%	857.0	101%
11/7/2022	1,368.5	667.3	234.8	3.36	2.49	3.02	3.81	26%	919.9	98%
11/8/2022	1,511.6	736.9	245.1	3.31	2.49	2.98	3.77	25%	1,000.4	98%
11/9/2022	1,269.7	611.8	247.4	3.31	2.36	2.96	3.71	29%	863.2	100%
11/10/2022	1,528.8	751.7	244.9	3.28	2.47	2.95	3.73	25%	1,019.0	98%
11/11/2022	1,315.7	647.2	247.8	3.33	2.41	2.97	3.72	28%	895.6	100%
11/12/2022	1,242.7	614.6	238.5	3.32	2.39	2.99	3.78	28%	867.7	98%
11/13/2022	1,424.4	711.9	246.4	3.34	2.48	2.97	3.79	26%	966.2	99%
11/14/2022	1,337.6	663.0	249.9	3.18	2.31	2.94	3.71	27%	952.6	96%
11/15/2022	1,427.0	713.3	253.5	3.23	2.38	2.92	3.67	26%	988.5	98%
11/16/2022	1,348.9	682.9	261.1	3.17	2.29	2.90	3.68	28%	973.7	97%
11/17/2022	1,344.7	690.7	260.2	3.17	2.30	2.89	3.67	27%	979.4	97%
11/18/2022	1,212.9	628.9	267.4	3.14	2.20	2.88	3.67	30%	924.0	97%
11/19/2022	1,228.1	650.7	271.1	3.06	2.16	2.88	3.63	29%	974.3	95%
11/20/2022	1,221.5	648.9	270.0	3.11	2.19	2.85	3.65	29%	970.9	95%
11/21/2022	1,360.5	750.3	271.7	3.14	2.31	2.84	3.64	27%	1,046.8	98%
11/22/2022	1,377.5	770.2	270.8	3.16	2.34	2.85	3.65	26%	1,068.4	97%
11/23/2022	1,663.6	944.1	268.0	3.18	2.48	2.85	3.72	22%	1,256.8	96%
11/24/2022	1,377.6	777.4	269.6	3.26	2.42	2.86	3.67	26%	1,047.8	100%
11/25/2022	1,248.7	702.2	273.6	3.05	2.19	2.87	3.67	28%	1,044.8	93%
11/26/2022	1,204.6	674.3	265.0	3.18	2.28	2.88	3.66	28%	966.4	97%
11/27/2022	1,282.0	725.1	270.4	3.24	2.36	2.88	3.73	27%	1,004.6	99%
11/28/2022	1,328.7	749.2	259.2	3.20	2.37	2.89	3.71	26%	1,045.6	96%
11/29/2022	1,321.1	743.5	285.6	3.22	2.32	2.86	3.70	28%	1,041.4	99%
11/30/2022	1,252.2	709.4	306.3	3.15	2.20	2.85	3.70	30%	1,040.6	98%

Table B-27 Daily DHW Heat, Efficiency and Energy Use – Dec 2022

Date	HW Use (gal/day)	QHW (MBtu/day)	QR (MBtu/day)	Gross COP (-)	Net COP (-)	Predicted COP WWHP1 (-)	Predicted COP WWHP2 (-)	Recirc Losses (%)	Q Predicted (MBtu/day)	Heat Balance (%)
12/1/2022	1,186.8	675.2	420.0	3.13	1.93	2.85	3.65	38%	1,107.5	99%
12/2/2022	1,177.8	673.8	396.0	3.16	1.99	2.84	3.67	37%	1,069.6	100%
12/3/2022	1,199.0	694.5	378.9	3.26	2.11	2.85	3.71	35%	1,047.6	102%
12/4/2022	1,020.5	591.7	470.0	3.15	1.76	2.85	3.66	44%	1,051.1	101%
12/5/2022	1,089.7	635.0	468.8	3.27	1.88	2.83	3.65	42%	1,050.6	105%
12/6/2022	962.3	560.7	471.3	3.10	1.68	2.83	3.66	46%	1,030.4	100%
12/7/2022	1,066.9	622.2	450.0	3.29	1.91	2.88	3.72	42%	1,034.3	104%
12/8/2022	1,413.2	828.2	395.0	3.25	2.20	2.87	3.78	32%	1,226.8	100%
12/9/2022	1,349.3	782.6	344.6	3.32	2.30	2.86	3.76	31%	1,100.7	102%
12/10/2022	1,431.3	831.8	356.5	3.25	2.27	2.83	3.70	30%	1,180.9	101%
12/11/2022	1,227.1	715.6	369.0	3.16	2.09	2.83	3.61	34%	1,084.4	100%
12/12/2022	1,346.9	796.0	377.2	3.18	2.16	2.81	3.66	32%	1,165.7	101%
12/13/2022	1,508.3	896.8	398.0	3.16	2.19	2.78	3.64	31%	1,294.6	100%
12/14/2022	1,383.4	832.1	388.2	3.14	2.14	2.78	3.69	32%	1,229.6	99%
12/15/2022	1,294.8	781.6	390.6	3.13	2.09	2.79	3.65	33%	1,181.7	99%
12/16/2022	1,324.2	800.5	398.0	3.19	2.13	2.81	3.65	33%	1,190.2	101%
12/17/2022	1,299.4	793.5	423.3	3.25	2.12	2.81	3.68	35%	1,178.0	103%
12/18/2022	1,414.2	860.9	367.6	3.19	2.24	2.81	3.69	30%	1,235.0	99%
12/19/2022	1,155.6	698.2	337.9	3.20	2.16	2.81	3.61	33%	1,018.6	102%
12/20/2022	1,207.3	728.0	356.1	3.05	2.05	2.80	3.62	33%	1,124.1	96%
12/21/2022	1,284.5	774.8	311.6	3.09	2.21	2.79	3.59	29%	1,112.1	98%
12/22/2022	1,393.4	843.9	290.6	3.21	2.38	2.78	3.63	26%	1,124.1	101%
12/23/2022	1,202.3	727.4	342.4	3.06	2.08	2.81	3.65	32%	1,117.1	96%
12/24/2022	1,054.5	636.7	371.9	3.15	1.99	2.75	3.59	37%	979.3	103%
12/25/2022	697.5	418.1	391.6	2.89	1.49	2.76	3.51	48%	840.5	96%
12/26/2022	1,179.7	716.5	319.7	2.99	2.07	2.76	3.56	31%	1,083.8	96%
12/27/2022	1,003.9	610.9	333.2	3.00	1.94	2.76	3.54	35%	969.0	97%
12/28/2022	1,323.8	811.0	308.4	3.16	2.29	2.79	3.60	28%	1,125.6	99%
12/29/2022	1,576.2	974.8	309.9	3.21	2.43	2.80	3.73	24%	1,302.8	99%
12/30/2022	1,470.2	904.7	297.3	3.28	2.47	2.82	3.78	25%	1,198.7	100%
12/31/2022	1,148.1	700.1	327.3	3.18	2.17	2.83	3.65	32%	1,032.5	100%

Table B-28 Daily DHW Heat, Efficiency and Energy Use – Jan 2023

Date	HW Use (gal/day)	QHW (MBtu/day)	QR (MBtu/day)	Gross COP (-)	Net COP (-)	Predicted COP WWHP1 (-)	Predicted COP WWHP2 (-)	Recirc Losses (%)	Q Predicted (MBtu/day)	Heat Balance (%)
1/1/2023	977.3	594.4	373.9	3.08	1.89	2.85	3.68	39%	999.9	97%
1/2/2023	1,163.8	708.5	313.2	3.25	2.26	2.85	3.71	31%	1,011.7	101%
1/3/2023	1,168.0	707.6	324.3	3.20	2.19	2.85	3.66	31%	1,037.1	100%
1/4/2023	1,279.4	775.8	331.9	3.27	2.29	2.85	3.70	30%	1,093.2	101%
1/5/2023	1,323.0	809.5	293.1	3.22	2.36	2.83	3.75	27%	1,115.6	99%
1/6/2023	1,397.1	858.6	256.0	3.21	2.47	2.87	3.82	23%	1,157.8	96%
1/7/2023	1,491.8	925.6	259.5	3.18	2.48	2.85	3.97	22%	1,293.0	92%
1/8/2023	1,523.0	983.9	275.7	3.08	2.40	2.85	4.91	22%	1,733.1	73%
1/9/2023	1,437.9	886.1	258.7	2.91	2.25	2.82	4.03	23%	1,389.8	82%
1/10/2023	1,380.9	845.3	260.7	3.08	2.35	2.81	3.56	24%	1,152.9	96%
1/11/2023	1,456.4	897.0	255.4	3.10	2.41	2.79	3.53	22%	1,187.7	97%
1/12/2023	1,202.2	740.0	253.2	2.93	2.19	2.80	3.53	25%	1,075.2	92%
1/13/2023	1,227.6	756.5	271.0	3.15	2.32	2.83	3.56	26%	1,043.9	98%
1/14/2023	1,289.7	812.0	275.7	3.06	2.29	2.81	3.81	25%	1,205.8	90%
1/15/2023	1,506.9	931.5	256.2	3.11	2.44	2.80	3.56	22%	1,226.9	97%
1/16/2023	1,497.0	943.0	259.1	3.10	2.43	2.79	3.71	22%	1,295.5	93%
1/17/2023	1,659.6	1,044.3	260.8	3.10	2.48	2.78	3.62	20%	1,384.0	94%
1/18/2023	1,471.7	940.4	264.4	3.16	2.47	2.82	3.98	22%	1,343.0	90%
1/19/2023	1,436.5	899.4	272.0	3.00	2.30	2.80	3.66	23%	1,292.5	91%
1/20/2023	1,374.8	859.1	268.9	3.09	2.35	2.81	3.54	24%	1,166.6	97%
1/21/2023	1,482.2	931.8	263.1	3.17	2.47	2.80	3.65	22%	1,235.8	97%
1/22/2023	1,427.7	891.5	253.2	3.07	2.39	2.80	3.59	22%	1,209.0	95%
1/23/2023	1,604.0	1,003.8	251.7	3.18	2.54	2.80	3.62	20%	1,280.6	98%
1/24/2023	1,485.4	942.9	231.5	3.16	2.54	2.81	3.83	20%	1,270.1	92%
1/25/2023	1,370.9	859.7	267.9	3.13	2.39	2.80	3.55	24%	1,149.0	98%
1/26/2023	1,426.0	894.2	288.2	3.02	2.29	2.80	3.54	24%	1,250.9	95%
1/27/2023	1,515.2	977.9	308.2	3.04	2.31	2.80	4.03	24%	1,514.8	85%
1/28/2023	1,562.8	989.2	299.6	3.17	2.43	2.80	3.70	23%	1,342.7	96%
1/29/2023	1,500.6	953.4	295.0	3.05	2.33	2.80	3.73	24%	1,358.8	92%
1/30/2023	1,314.1	819.1	300.9	3.07	2.24	2.81	3.57	27%	1,165.4	96%
1/31/2023	1,287.4	804.0	309.9	3.17	2.29	2.80	3.59	28%	1,114.3	100%

Table B-29 Daily DHW Heat, Efficiency and Energy Use – Feb 2023

Date	HW Use (gal/day)	QHW (MBtu/day)	QR (MBtu/day)	Gross COP (-)	Net COP (-)	Predicted COP WWHP1 (-)	Predicted COP WWHP2 (-)	Recirc Losses (%)	Q Predicted (MBtu/day)	Heat Balance (%)
2/1/2023	1,188.5	741.3	304.0	2.93	2.08	2.78	3.49	29%	1,119.1	93%
2/2/2023	1,422.3	921.3	315.1	3.09	2.30	2.77	4.06	25%	1,426.4	87%
2/3/2023	1,260.3	816.2	319.2	2.79	2.01	2.76	3.96	28%	1,464.2	78%
2/4/2023	1,288.9	810.4	304.5	3.04	2.21	2.72	3.48	27%	1,132.3	98%
2/5/2023	1,456.7	951.7	314.2	2.89	2.18	2.73	3.87	25%	1,505.6	84%
2/6/2023	1,228.4	783.0	297.8	3.05	2.21	2.77	3.51	28%	1,114.1	97%
2/7/2023	1,249.0	795.7	304.6	3.09	2.23	2.77	3.57	28%	1,125.4	98%
2/8/2023	1,297.8	827.3	299.2	3.00	2.20	2.79	3.53	27%	1,191.5	95%
2/9/2023	1,185.6	756.6	303.2	3.04	2.17	2.79	3.62	29%	1,131.2	94%
2/10/2023	1,276.0	806.9	292.0	3.00	2.20	2.81	3.63	27%	1,184.6	93%
2/11/2023	1,129.5	714.8	296.9	3.09	2.18	2.82	3.59	29%	1,046.6	97%
2/12/2023	1,449.2	972.7	316.5	2.99	2.25	2.80	4.50	25%	1,736.8	74%
2/13/2023	1,361.2	858.6	293.8	3.18	2.37	2.82	3.62	25%	1,167.7	99%
2/14/2023	1,177.8	734.9	294.6	3.03	2.17	2.82	3.57	29%	1,083.8	95%
2/15/2023	1,385.5	868.9	286.0	3.27	2.46	2.84	3.73	25%	1,153.1	100%
2/16/2023	1,480.9	925.4	287.7	3.17	2.42	2.85	3.65	24%	1,255.0	97%
2/17/2023	1,504.0	934.1	285.2	3.29	2.52	2.85	3.65	23%	1,209.2	101%
2/18/2023	1,423.3	878.7	295.8	3.16	2.36	2.82	3.61	25%	1,199.7	98%
2/19/2023	1,259.9	780.2	316.9	3.10	2.20	2.82	3.61	29%	1,130.5	97%
2/20/2023	1,463.3	911.9	301.5	3.18	2.39	2.82	3.62	25%	1,233.5	98%
2/21/2023	1,409.0	871.2	291.1	3.07	2.30	2.82	3.60	25%	1,219.0	95%
2/22/2023	1,411.7	874.3	296.3	3.15	2.35	2.80	3.60	25%	1,189.8	98%
2/23/2023	1,493.2	932.6	292.1	3.13	2.38	2.80	3.55	24%	1,250.8	98%
2/24/2023	1,267.4	789.1	294.6	3.09	2.25	2.81	3.56	27%	1,115.4	97%
2/25/2023	1,487.0	929.3	301.2	3.10	2.34	2.76	3.52	24%	1,254.4	98%
2/26/2023	1,332.0	836.5	301.6	3.01	2.21	2.76	3.45	27%	1,176.5	97%
2/27/2023	1,385.0	870.3	303.4	3.04	2.25	2.77	3.50	26%	1,213.6	97%
2/28/2023	1,209.0	762.5	307.0	2.98	2.13	2.78	3.51	29%	1,124.8	95%

Table B-30 Daily DHW Heat, Efficiency and Energy Use – Mar 2023

Date	HW Use (gal/day)	QHW (MBtu/day)	QR (MBtu/day)	Gross COP (-)	Net COP (-)	Predicted COP WWHP1 (-)	Predicted COP WWHP2 (-)	Recirc Losses (%)	Q Predicted (MBtu/day)	Heat Balance (%)
3/1/2023	1,334.8	840.7	302.8	3.12	2.29	2.78	3.61	26%	1,168.6	98%
3/2/2023	1,079.8	677.4	302.7	3.08	2.13	2.80	3.63	31%	1,009.2	97%
3/3/2023	1,198.5	756.2	299.1	3.01	2.15	2.80	3.50	28%	1,105.7	95%
3/4/2023	1,255.8	791.9	291.6	3.11	2.27	2.81	3.54	27%	1,106.9	98%
3/5/2023	1,226.6	775.3	293.0	3.05	2.21	2.81	3.57	27%	1,119.1	95%
3/6/2023	1,300.3	818.9	299.2	3.19	2.34	2.81	3.57	27%	1,113.9	100%
3/7/2023	1,213.1	756.4	306.6	3.09	2.20	2.81	3.67	29%	1,103.4	96%
3/8/2023	1,312.9	818.0	297.2	3.08	2.26	2.80	3.53	27%	1,150.7	97%
3/9/2023	1,305.6	817.2	294.5	3.10	2.28	2.81	3.63	26%	1,151.5	97%
3/10/2023	1,283.9	796.7	294.0	3.12	2.28	2.80	3.53	27%	1,106.1	99%
3/11/2023	1,292.6	800.8	299.3	3.12	2.27	2.81	3.60	27%	1,130.5	97%
3/12/2023	1,278.5	795.3	286.5	3.09	2.27	2.80	3.61	26%	1,120.9	97%
3/13/2023	1,617.4	1,006.3	295.1	3.18	2.46	2.80	3.57	23%	1,310.5	99%
3/14/2023	1,260.1	775.8	297.5	3.09	2.24	2.81	3.67	28%	1,112.1	97%
3/15/2023	1,416.1	876.1	299.1	3.15	2.35	2.81	3.77	25%	1,208.4	97%
3/16/2023	1,231.5	764.3	290.1	3.07	2.22	2.81	3.76	28%	1,114.5	95%
3/17/2023	1,311.5	810.6	289.0	3.22	2.37	2.82	3.74	26%	1,103.5	100%
3/18/2023	1,099.7	678.1	290.6	3.05	2.13	2.84	3.72	30%	1,029.7	94%
3/19/2023	1,257.2	771.6	288.8	3.11	2.26	2.81	3.70	27%	1,096.3	97%
3/20/2023	1,527.6	941.5	298.0	3.17	2.41	2.81	3.86	24%	1,293.6	96%
3/21/2023	1,271.4	776.5	299.9	3.17	2.29	2.81	3.71	28%	1,085.0	99%
3/22/2023	1,390.3	849.0	289.5	3.12	2.33	2.83	3.80	25%	1,195.1	95%
3/23/2023	1,308.7	796.7	287.0	3.23	2.37	2.85	3.77	26%	1,096.0	99%
3/24/2023	1,312.3	794.3	287.2	3.14	2.31	2.85	3.75	27%	1,126.3	96%
3/25/2023	1,436.6	868.9	285.6	3.23	2.43	2.83	3.76	25%	1,161.0	99%
3/26/2023	1,274.6	763.8	290.7	3.15	2.28	2.84	3.75	28%	1,090.0	97%
3/27/2023	1,197.4	716.9	289.4	3.06	2.18	2.84	3.73	29%	1,067.9	94%
3/28/2023	1,137.6	674.4	297.4	3.18	2.21	2.84	3.74	31%	983.1	99%
3/29/2023	1,175.9	696.0	289.8	3.02	2.13	2.83	3.72	29%	1,054.6	93%
3/30/2023	1,226.5	723.4	301.3	3.14	2.22	2.83	3.72	29%	1,050.4	98%
3/31/2023	1,169.0	693.0	298.9	3.15	2.20	2.82	3.71	30%	1,003.3	99%

Table B-31 Daily DHW Heat, Efficiency and Energy Use – April 2023

Date	HW Use (gal/day)	QHW (MBtu/day)	QR (MBtu/day)	Gross COP (-)	Net COP (-)	Predicted COP WWHP1 (-)	Predicted COP WWHP2 (-)	Recirc Losses (%)	Q Predicted (MBtu/day)	Heat Balance (%)
4/1/2023	1,252.5	737.1	286.1	3.13	2.25	2.85	3.72	28%	1,060.4	97%
4/2/2023	1,365.8	807.8	289.5	3.23	2.38	2.85	3.78	26%	1,110.7	99%
4/3/2023	1,455.4	858.0	291.4	3.24	2.42	2.84	3.75	25%	1,155.9	99%
4/4/2023	1,328.7	771.6	288.5	3.10	2.26	2.85	3.73	27%	1,111.3	95%
4/5/2023	1,342.4	778.7	288.4	3.13	2.28	2.87	3.77	27%	1,123.0	95%
4/6/2023	1,214.5	699.5	280.7	3.21	2.29	2.88	3.77	29%	998.3	98%
4/7/2023	1,388.9	799.9	279.7	3.25	2.41	2.88	3.78	26%	1,092.4	99%
4/8/2023	1,204.9	688.3	282.4	3.07	2.17	2.86	3.75	29%	1,028.5	94%
4/9/2023	1,236.6	703.0	286.0	3.23	2.29	2.85	3.73	29%	991.7	100%
4/10/2023	1,354.2	768.1	282.0	3.12	2.28	2.86	3.75	27%	1,096.8	96%
4/11/2023	1,118.3	627.2	288.6	3.18	2.18	2.87	3.74	32%	931.2	98%
4/12/2023	1,216.3	682.5	272.2	3.16	2.26	2.90	3.82	29%	999.7	96%
4/13/2023	1,223.4	680.6	271.7	3.25	2.32	2.95	3.86	29%	980.2	97%
4/14/2023	1,277.4	708.0	261.1	3.33	2.43	2.98	3.88	27%	987.3	98%
4/15/2023	1,140.5	621.9	265.2	3.36	2.35	2.99	3.92	30%	894.8	99%
4/16/2023	1,419.6	768.3	265.6	3.37	2.50	3.00	3.91	26%	1,050.4	98%
4/17/2023	1,240.9	660.9	266.3	3.32	2.37	2.97	3.85	29%	937.8	99%
4/18/2023	1,100.3	577.7	272.9	3.14	2.13	2.93	3.77	32%	888.0	96%
4/19/2023	1,259.4	667.1	278.4	3.18	2.24	2.91	3.76	29%	976.9	97%
4/20/2023	1,316.1	700.9	277.9	3.21	2.30	2.90	3.77	28%	998.6	98%
4/21/2023	1,352.6	722.7	271.2	3.30	2.40	2.92	3.80	27%	994.0	100%
4/22/2023	1,265.0	676.2	274.9	3.24	2.31	2.93	3.82	29%	971.5	98%
4/23/2023	1,150.6	611.6	269.9	3.15	2.19	2.94	3.83	31%	926.6	95%
4/24/2023	1,415.7	754.3	274.1	3.26	2.39	2.92	3.83	27%	1,046.9	98%
4/25/2023	1,057.1	557.6	283.1	3.07	2.04	2.90	3.72	34%	883.3	95%
4/26/2023	1,340.8	715.7	275.0	3.22	2.32	2.89	3.74	28%	1,004.4	99%
4/27/2023	1,338.8	719.6	274.0	3.16	2.29	2.90	3.78	28%	1,038.2	96%
4/28/2023	1,175.0	626.5	275.4	3.18	2.21	2.90	3.74	31%	921.5	98%
4/29/2023	1,498.9	806.5	272.2	3.24	2.42	2.90	3.78	25%	1,100.9	98%
4/30/2023	1,387.5	746.9	273.1	3.24	2.37	2.90	3.76	27%	1,032.9	99%

Table B-32 Daily DHW Heat, Efficiency and Energy Use – May 2023

Date	HW Use (gal/day)	QHW (MBtu/day)	QR (MBtu/day)	Gross COP (-)	Net COP (-)	Predicted COP WWHP1 (-)	Predicted COP WWHP2 (-)	Recirc Losses (%)	Q Predicted (MBtu/day)	Heat Balance (%)
5/1/2023	1,378.4	746.2	270.0	3.21	2.36	2.89	3.74	27%	1,037.9	98%
5/2/2023	1,205.8	651.1	283.3	3.16	2.20	2.90	3.71	30%	960.7	97%
5/3/2023	1,353.5	738.2	278.5	3.21	2.33	2.89	3.73	27%	1,034.5	98%
5/4/2023	1,056.0	573.5	277.5	3.07	2.07	2.89	3.73	33%	899.6	95%
5/5/2023	1,140.6	621.6	278.1	3.18	2.19	2.90	3.72	31%	922.6	98%
5/6/2023	1,354.1	739.3	274.4	3.19	2.33	2.91	3.83	27%	1,051.3	96%
5/7/2023	1,103.8	600.4	275.0	3.21	2.20	2.92	3.80	31%	896.4	98%
5/8/2023	1,275.4	686.7	273.8	3.29	2.35	2.95	3.82	29%	974.1	99%
5/9/2023	1,066.8	568.3	275.9	3.17	2.13	2.93	3.75	33%	872.5	97%
5/10/2023	1,208.9	642.6	272.7	3.18	2.23	2.93	3.78	30%	948.1	97%
5/11/2023	1,328.0	697.7	266.7	3.24	2.35	2.94	3.82	28%	988.1	98%
5/12/2023	1,239.4	639.3	267.2	3.29	2.32	2.97	3.81	29%	917.0	99%
5/13/2023	1,289.2	661.3	258.9	3.22	2.31	2.99	3.86	28%	965.7	95%
5/14/2023	1,229.5	623.0	263.5	3.26	2.29	2.97	3.80	30%	907.1	98%
5/15/2023	1,168.0	587.4	263.1	3.26	2.25	2.96	3.79	31%	861.7	99%
5/16/2023	1,418.2	714.5	266.2	3.28	2.39	2.96	3.83	27%	1,000.6	98%
5/17/2023	1,330.6	665.2	260.9	3.25	2.33	2.96	3.82	28%	950.1	97%
5/18/2023	1,293.9	644.2	266.5	3.15	2.23	2.94	3.78	29%	952.2	96%
5/19/2023	1,156.6	570.4	266.3	3.15	2.15	2.94	3.76	32%	873.1	96%
5/20/2023	1,076.1	532.2	259.9	3.15	2.12	2.94	3.77	33%	822.6	96%
5/21/2023	1,176.0	581.1	259.2	3.23	2.23	2.96	3.78	31%	859.2	98%
5/22/2023	1,157.0	569.8	263.5	3.19	2.18	2.97	3.78	32%	864.1	96%
5/23/2023	1,027.2	502.5	266.7	3.20	2.09	2.97	3.79	35%	789.6	97%
5/24/2023	1,247.3	611.4	263.7	3.13	2.19	2.97	3.79	30%	931.8	94%
5/25/2023	1,171.7	572.2	265.0	3.25	2.22	2.96	3.79	32%	847.8	99%
5/26/2023	1,285.9	624.3	263.3	3.18	2.24	2.96	3.80	30%	925.6	96%
5/27/2023	1,189.5	578.0	263.1	3.21	2.21	2.97	3.78	31%	864.5	97%
5/28/2023	1,168.4	566.4	258.4	3.21	2.20	3.01	3.87	31%	863.3	96%
5/29/2023	1,317.2	633.7	260.4	3.41	2.42	3.02	3.89	29%	886.2	101%
5/30/2023	1,195.2	567.2	265.8	3.18	2.17	2.99	3.82	32%	873.8	95%
5/31/2023	1,270.3	597.9	262.1	3.24	2.25	3.01	3.82	30%	891.9	96%

Table B-33 Daily DHW Heat, Efficiency and Energy Use – June 2023

Date	HW Use (gal/day)	QHW (MBtu/day)	QR (MBtu/day)	Gross COP (-)	Net COP (-)	Predicted COP WWHP1 (-)	Predicted COP WWHP2 (-)	Recirc Losses (%)	Q Predicted (MBtu/day)	Heat Balance (%)
6/1/2023	1,233.5	578.2	259.6	3.36	2.32	3.04	3.89	31%	842.1	99%
6/2/2023	1,113.9	513.9	254.7	3.19	2.13	3.08	3.93	33%	826.2	93%
6/3/2023	899.0	412.8	259.0	3.22	1.98	3.06	3.87	39%	700.7	96%
6/4/2023	1,183.4	541.4	258.3	3.26	2.20	3.01	3.80	32%	816.9	98%
6/5/2023	1,140.2	518.3	260.8	3.21	2.14	3.00	3.80	33%	804.8	97%
6/6/2023	1,129.7	518.3	263.1	3.24	2.15	2.99	3.77	34%	796.9	98%
6/7/2023	1,049.9	482.2	260.8	3.13	2.03	2.99	3.78	35%	783.1	95%
6/8/2023	1,332.9	614.5	264.4	3.26	2.28	2.99	3.79	30%	897.2	98%
6/9/2023	1,084.0	499.9	260.8	3.08	2.02	3.00	3.79	34%	820.6	93%
6/10/2023	1,360.3	637.0	261.8	3.31	2.34	3.00	3.83	29%	909.2	99%
6/11/2023	1,153.1	536.9	261.6	3.19	2.15	3.02	3.82	33%	839.1	95%
6/12/2023	1,074.1	498.9	256.0	3.28	2.17	3.04	3.86	34%	772.5	98%
6/13/2023	1,041.7	478.9	261.8	3.26	2.11	3.04	3.86	35%	762.7	97%
6/14/2023	1,241.3	575.2	254.6	3.26	2.26	3.02	3.81	31%	852.9	97%
6/15/2023	1,218.2	560.3	255.0	3.21	2.21	3.02	3.86	31%	853.7	96%
6/16/2023	934.6	428.8	257.5	3.15	1.97	3.03	3.83	38%	726.3	94%
6/17/2023	1,056.4	487.1	256.1	3.34	2.19	3.03	3.83	34%	741.0	100%
6/18/2023	1,113.1	512.0	252.7	3.17	2.12	3.04	3.85	33%	811.6	94%
6/19/2023	1,383.8	634.0	255.7	3.32	2.37	3.05	3.89	29%	915.8	97%
6/20/2023	1,066.7	480.9	261.5	3.35	2.17	3.07	3.88	35%	747.9	99%
6/21/2023	1,119.1	503.0	257.2	3.19	2.11	3.07	3.89	34%	812.5	94%
6/22/2023	1,087.4	488.7	255.1	3.29	2.16	3.07	3.87	34%	765.6	97%
6/23/2023	1,169.4	523.9	255.1	3.33	2.24	3.09	3.92	33%	799.0	98%
6/24/2023	1,315.0	587.7	258.9	3.42	2.37	3.10	3.95	31%	857.4	99%
6/25/2023	1,235.8	551.2	256.0	3.43	2.34	3.13	3.98	32%	819.4	99%
6/26/2023	1,364.9	603.2	255.9	3.38	2.37	3.12	3.98	30%	884.4	97%
6/27/2023	1,006.7	440.6	262.9	3.26	2.04	3.09	3.90	37%	734.0	96%
6/28/2023	1,169.7	514.6	256.1	3.39	2.26	3.11	3.94	33%	781.4	99%
6/29/2023	1,168.2	517.8	260.1	3.34	2.22	3.10	3.94	33%	803.1	97%
6/30/2023	1,093.4	485.4	254.7	3.38	2.22	3.12	3.96	34%	751.1	99%

Table B-34 Daily DHW Heat, Efficiency and Energy Use – July 2023

Date	HW Use (gal/day)	QHW (MBtu/day)	QR (MBtu/day)	Gross COP (-)	Net COP (-)	Predicted COP WWHP1 (-)	Predicted COP WWHP2 (-)	Recirc Losses (%)	Q Predicted (MBtu/day)	Heat Balance (%)
7/1/2023	1,186.3	524.2	254.3	3.39	2.28	3.12	3.97	33%	795.0	98%
7/2/2023	1,093.7	482.3	253.1	3.45	2.26	3.14	3.97	34%	739.8	99%
7/3/2023	991.4	433.1	256.6	3.35	2.11	3.17	4.01	37%	718.0	96%
7/4/2023	962.1	417.8	262.3	3.34	2.05	3.17	4.02	39%	709.8	96%
7/5/2023	1,030.7	446.0	266.0	3.52	2.21	3.17	4.01	37%	705.8	101%
7/6/2023	1,245.6	534.1	263.2	3.66	2.45	3.21	4.07	33%	774.9	103%
7/7/2023	1,097.8	469.3	255.2	3.58	2.32	3.21	4.08	35%	715.8	101%
7/8/2023	1,253.7	534.6	256.4	3.52	2.38	3.21	4.06	32%	801.6	99%
7/9/2023	1,156.1	488.6	253.4	3.57	2.35	3.20	4.03	34%	734.9	101%
7/10/2023	1,053.9	442.0	255.9	3.48	2.20	3.17	4.01	37%	696.6	100%
7/11/2023	955.8	398.3	259.0	3.36	2.04	3.15	3.97	39%	671.9	98%
7/12/2023	1,133.4	474.3	256.5	3.50	2.27	3.18	4.01	35%	733.5	100%
7/13/2023	980.8	409.1	257.5	3.45	2.12	3.20	4.05	39%	679.6	98%
7/14/2023	1,219.9	512.5	253.4	3.44	2.30	3.19	4.03	33%	784.8	98%
7/15/2023	918.7	379.7	258.4	3.51	2.09	3.21	4.04	40%	635.9	100%
7/16/2023	1,428.1	590.6	252.2	3.69	2.58	3.23	4.09	30%	819.2	103%
7/17/2023	1,241.7	509.2	258.0	3.47	2.31	3.21	4.04	34%	785.1	98%
7/18/2023	1,189.7	485.1	258.4	3.63	2.37	3.19	4.03	35%	717.8	104%
7/19/2023	1,196.7	490.4	260.1	3.43	2.24	3.18	4.01	35%	766.4	98%
7/20/2023	1,158.6	474.5	258.8	3.59	2.32	3.19	4.02	35%	713.5	103%
7/21/2023	1,328.6	544.1	256.0	3.59	2.44	3.19	4.02	32%	785.0	102%
7/22/2023	1,259.5	514.7	251.7	3.58	2.41	3.19	4.01	33%	751.3	102%
7/23/2023	1,392.1	567.3	253.9	3.45	2.38	3.18	4.00	31%	836.7	98%
7/24/2023	1,158.4	469.7	255.8	3.60	2.33	3.18	3.99	35%	700.9	103%
7/25/2023	1,088.3	441.6	261.9	3.33	2.09	3.19	4.00	37%	737.6	95%
7/26/2023	1,076.0	435.6	259.4	3.56	2.23	3.18	3.99	37%	678.8	102%
7/27/2023	1,214.1	494.0	254.1	3.56	2.35	3.21	4.05	34%	741.6	101%
7/28/2023	1,213.4	493.1	252.5	3.55	2.35	3.23	4.08	34%	748.1	100%
7/29/2023	1,051.3	424.5	271.3	3.60	2.20	3.24	4.08	39%	684.2	102%
7/30/2023	1,118.7	449.4	268.2	3.52	2.20	3.18	3.98	37%	707.3	101%
7/31/2023	1,144.9	460.1	256.3	3.45	2.22	3.16	3.96	36%	717.3	100%

Table B-35 Daily DHW Heat, Efficiency and Energy Use – Aug 2023

Date	HW Use (gal/day)	QHW (MBtu/day)	QR (MBtu/day)	Gross COP (-)	Net COP (-)	Predicted COP WWHP1 (-)	Predicted COP WWHP2 (-)	Recirc Losses (%)	Q Predicted (MBtu/day)	Heat Balance (%)
8/1/2023	1,087.0	434.0	261.2	3.37	2.10	3.14	3.91	38%	707.2	98%
8/2/2023	1,202.5	488.4	258.5	3.43	2.24	3.13	3.92	35%	747.5	100%
8/3/2023	1,189.5	483.0	256.7	3.44	2.25	3.13	3.92	35%	735.9	101%
8/4/2023	1,157.2	474.1	257.1	3.46	2.24	3.15	3.96	35%	732.0	100%
8/5/2023	1,276.2	524.4	258.0	3.44	2.31	3.16	3.96	33%	791.7	99%
8/6/2023	1,037.8	429.9	256.8	3.45	2.16	3.17	3.98	37%	690.7	99%
8/7/2023	1,178.9	488.2	256.3	3.54	2.32	3.17	3.99	34%	731.9	102%
8/8/2023	1,002.2	412.4	261.5	3.36	2.06	3.15	3.95	39%	690.1	98%
8/9/2023	977.1	404.1	255.0	3.51	2.15	3.16	3.97	39%	646.1	102%
8/10/2023	1,151.8	475.0	254.7	3.39	2.21	3.17	3.96	35%	748.6	97%
8/11/2023	1,516.2	623.3	257.3	3.60	2.55	3.15	3.97	29%	853.2	103%
8/12/2023	1,104.1	452.6	254.5	3.48	2.23	3.16	3.97	36%	705.0	100%
8/13/2023	1,175.4	483.5	255.3	3.55	2.32	3.19	4.02	35%	728.8	101%
8/14/2023	1,157.6	473.1	257.4	3.52	2.28	3.17	4.00	35%	722.9	101%
8/15/2023	944.9	383.5	263.3	3.32	1.97	3.17	3.97	41%	672.7	96%
8/16/2023	1,214.9	499.0	253.5	3.44	2.28	3.18	3.99	34%	765.1	98%
8/17/2023	1,233.6	513.8	260.6	3.62	2.40	3.18	4.00	34%	746.8	104%
8/18/2023	1,041.4	431.3	255.4	3.48	2.18	3.17	3.99	37%	686.9	100%
8/19/2023	1,166.3	484.6	257.6	3.50	2.29	3.14	3.95	35%	730.5	102%
8/20/2023	1,141.2	474.4	254.6	3.39	2.20	3.15	3.95	35%	746.4	98%
8/21/2023	1,245.0	522.0	255.3	3.52	2.37	3.17	4.00	33%	772.0	101%
8/22/2023	1,121.0	466.1	287.1	3.52	2.18	3.15	3.95	38%	734.3	103%
8/23/2023	1,161.2	486.6	267.2	3.47	2.24	3.13	3.94	35%	745.3	101%
8/24/2023	1,112.5	466.1	255.6	3.37	2.18	3.13	3.94	35%	736.9	98%
8/25/2023	1,112.5	462.3	252.4	3.47	2.24	3.15	3.96	35%	710.3	101%
8/26/2023	981.6	408.4	253.8	3.42	2.11	3.18	4.00	38%	674.9	98%
8/27/2023	1,282.2	534.5	253.0	3.57	2.42	3.18	3.97	32%	772.0	102%
8/28/2023	1,074.9	445.5	255.0	3.37	2.14	3.14	3.94	36%	714.0	98%
8/29/2023	1,135.6	470.0	258.7	3.61	2.33	3.16	3.99	35%	698.8	104%
8/30/2023	1,340.7	553.9	252.3	3.52	2.42	3.17	4.00	31%	802.0	101%
8/31/2023	1,181.3	484.9	252.1	3.49	2.30	3.14	3.92	34%	728.7	101%

Table B-36 Daily DHW Heat, Efficiency and Energy Use – Sep 2023

Date	HW Use (gal/day)	QHW (MBtu/day)	QR (MBtu/day)	Gross COP (-)	Net COP (-)	Predicted COP WWHP1 (-)	Predicted COP WWHP2 (-)	Recirc Losses (%)	Q Predicted (MBtu/day)	Heat Balance (%)
9/1/2023	1,290.2	526.3	255.1	3.42	2.30	3.12	3.91	33%	784.4	100%
9/2/2023	1,167.9	477.7	257.0	3.32	2.16	3.12	3.91	35%	758.7	97%
9/3/2023	1,035.5	425.1	248.2	3.51	2.21	3.17	4.00	37%	665.7	101%
9/4/2023	1,201.1	491.4	250.7	3.47	2.30	3.20	4.03	34%	754.8	98%
9/5/2023	1,184.1	475.9	261.2	3.62	2.34	3.22	4.04	35%	718.3	103%
9/6/2023	1,442.0	578.3	247.4	3.62	2.53	3.24	4.08	30%	819.6	101%
9/7/2023	1,335.6	514.1	225.7	3.98	2.77	3.26	4.10	31%	676.0	109%
9/8/2023	1,442.4	536.8	228.9	3.64	2.55	3.29	4.17	30%	794.0	96%
9/9/2023	1,215.1	460.8	240.0	3.70	2.43	3.28	4.05	34%	680.7	103%
9/10/2023	1,229.6	464.4	239.8	3.71	2.45	3.27	4.05	34%	683.3	103%
9/11/2023	1,199.5	448.2	243.5	3.67	2.38	3.25	4.02	35%	670.1	103%
9/12/2023	1,208.1	454.7	248.3	3.63	2.35	3.22	3.98	35%	683.4	103%
9/13/2023	1,237.0	469.3	238.8	3.60	2.39	3.21	3.96	34%	691.8	102%
9/14/2023	1,320.8	503.3	243.6	3.52	2.37	3.19	3.95	33%	743.9	100%
9/15/2023	1,305.7	500.0	246.8	3.53	2.36	3.15	3.88	33%	729.4	102%
9/16/2023	1,150.3	445.6	242.6	3.37	2.18	3.14	3.86	35%	703.2	98%
9/17/2023	1,254.6	490.5	241.7	3.56	2.38	3.13	3.87	33%	706.0	104%
9/18/2023	1,284.6	503.2	246.3	3.35	2.25	3.13	3.85	33%	769.9	97%
9/19/2023	1,192.4	474.6	250.4	3.42	2.24	3.12	3.85	35%	723.2	100%
9/20/2023	1,188.8	480.9	247.5	3.37	2.22	3.10	3.84	34%	736.0	99%
9/21/2023	1,290.7	529.8	246.1	3.43	2.34	3.10	3.84	32%	773.3	100%
9/22/2023	1,223.7	503.9	250.9	3.46	2.31	3.11	3.84	33%	743.1	102%
9/23/2023	1,113.0	460.6	246.2	3.38	2.20	3.08	3.81	35%	705.9	100%
9/24/2023	1,228.9	513.3	251.5	3.27	2.19	3.09	3.83	33%	798.3	96%
9/25/2023	1,255.8	530.8	252.0	3.47	2.36	3.08	3.84	32%	766.4	102%
9/26/2023	1,126.0	484.9	276.5	3.37	2.15	3.07	3.81	36%	758.5	100%
9/27/2023	1,384.5	610.4	267.5	3.34	2.32	3.06	3.82	30%	895.9	98%
9/28/2023	1,334.8	594.5	254.5	3.53	2.47	3.05	3.82	30%	814.9	104%
9/29/2023	1,261.7	558.3	247.1	3.36	2.33	3.07	3.81	31%	813.6	99%
9/30/2023	1,417.3	635.5	248.4	3.46	2.49	3.07	3.84	28%	876.2	101%

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