# BUILDINGENERGY NYC

# In Hot Water: Key Design Details to Make Efficient e-DHW Attainable for All

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Taitem Engineering

Curated by Joaquin Font and Katelyn Hall

Northeast Sustainable Energy Association (NESEA) | October 16, 2025



Key design details for effective & efficient DHW systems

2025 NESEA BuildingEnergy NYC Conference







# Meet the team



**George Aiken**Project Engineer



**Brendan Mangino**Senior Engineer



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During 30 years of continuous operation, Taitem has continued to expand its offerings in energy efficiency and net-zero energy, leading the market, while maintaining its commitment to its mission as reflected in its name —

**Technology As If The Earth Mattered.** 

# ...and the people who depend on them

Taitem is a mission-driven, certified B-Corp, committed to a triple bottom line — people, planet, prosperity.













# What we'll cover

### **Project overview**

- Building info
- System design details
- M&V The plan

### **Measurement & Verification Results**

- Effectiveness
- Usage rates
- Operating costs
- Efficiency

### **Lessons Learned**

- Piping matters!
- Standby losses
- Balancing & Commissioning are CRITICAL
- Contractor buy-in is not the default

### **Ultimate HP DHW Design**

• Revised approach to Ironworks DHW plant





# Project overview



### **Project overview**

# Building details

### **Ithaca Arthaus**

- Low to Moderate Income (LMI) Multifamily
- 124 Apartments
- 264 Occupancy
- Started design in 2019

### Ironworks Ithaca

- Market Rate (MR) Multifamily
- 129 Apartments
- 242 Occupancy
- Started design in 2020







# System sizing

Traditional DHW calculator

(ASHRAE HVAC Applications handbook)

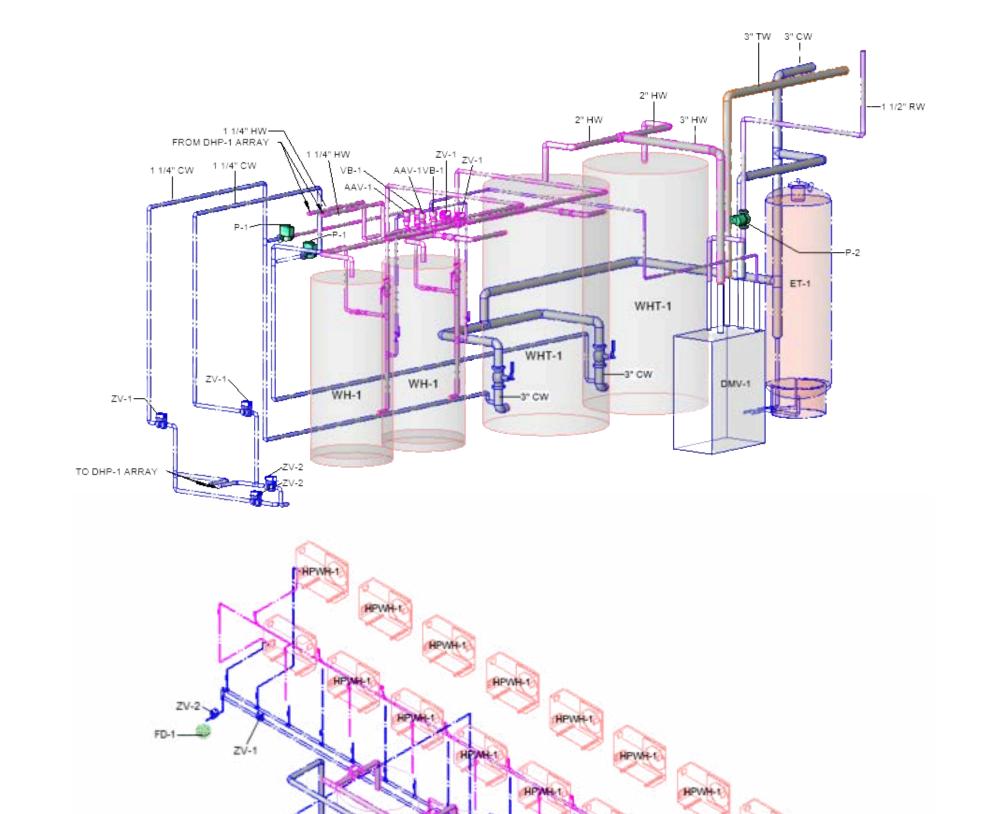
Ithaca Arthaus (LMI)

Hourly peak load: 1248 gph

### Ironworks Ithaca (MR)

Hourly peak load: 1961 gph

- Storage capacity to deliver full peak load
- Recovery rate (heat pump capacity)
  - recover peak in 4hr rated, 6hr rated
- Derated heat pump capacity
  - deliver total daily peak load in 16 hrs max



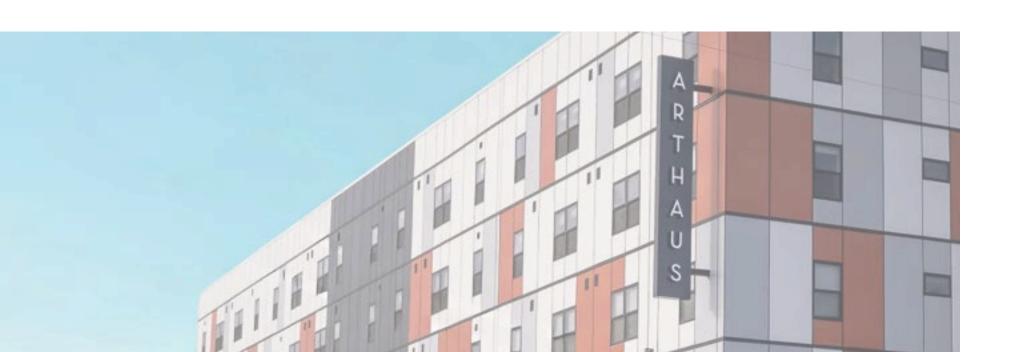
# Ithaca Arthaus (LMI)

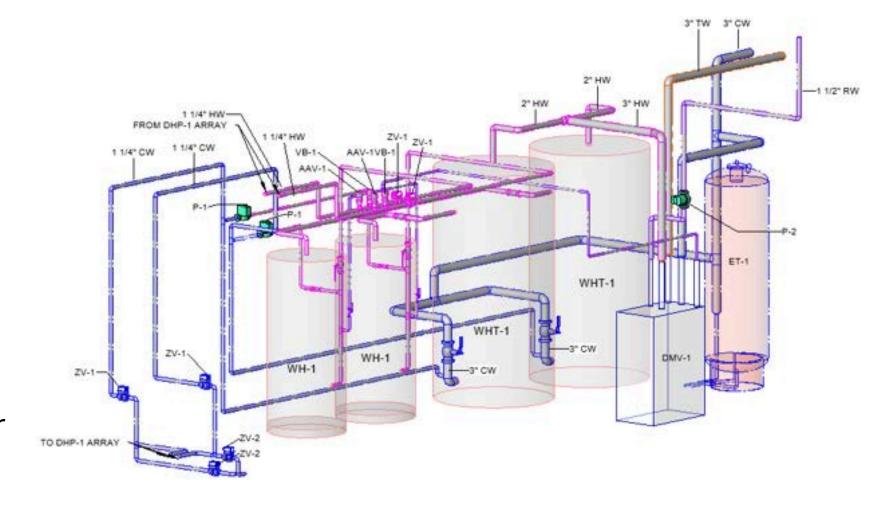
### Selected system

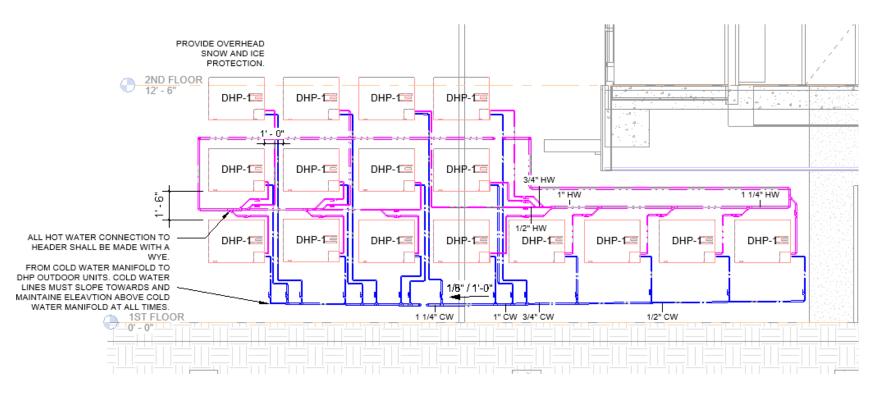
**STORAGE** 1240 gallons stored at 140 °F mixed down to 125 °F out to building

**PRIMARY HW** 16 SanCO2 heat pumps 245,600 btu/hr rated, 191,000 btu/hr derated at -5 °F

**BACKUP HW** (2) 36 KW electric resistance water heaters, de-energized

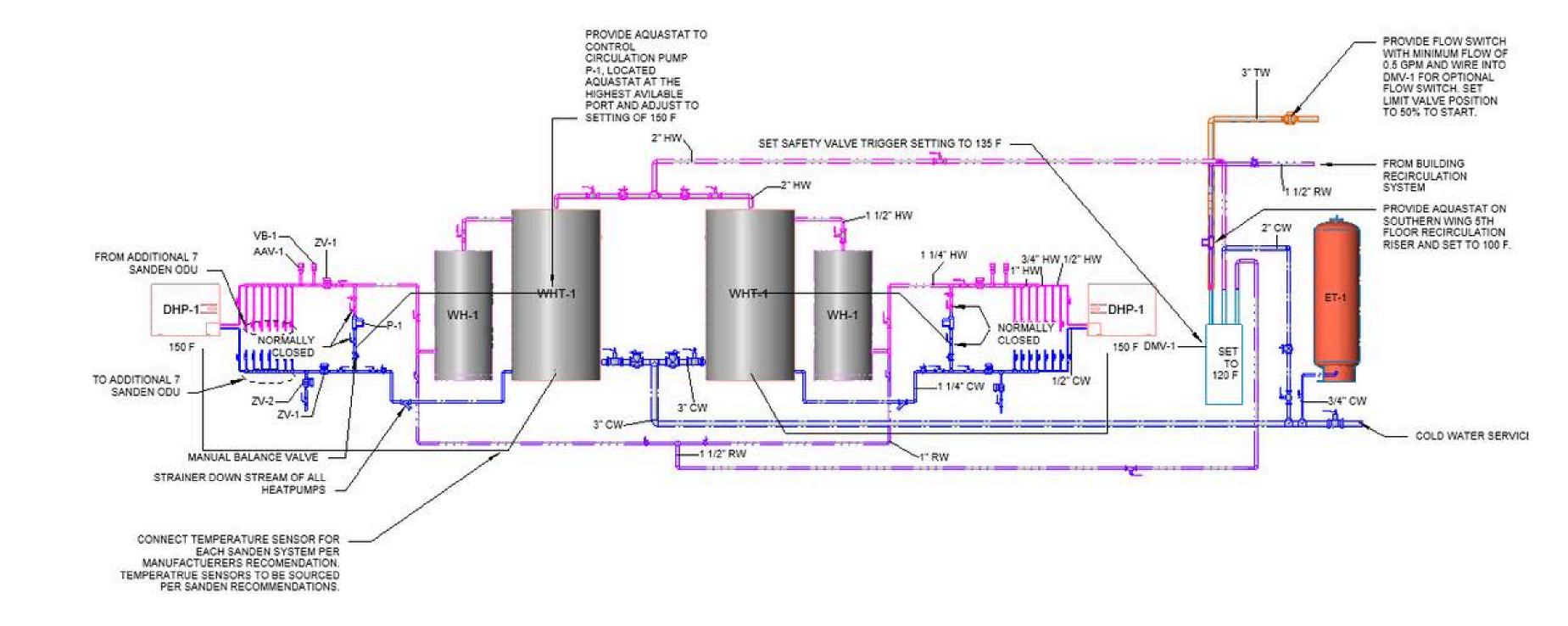






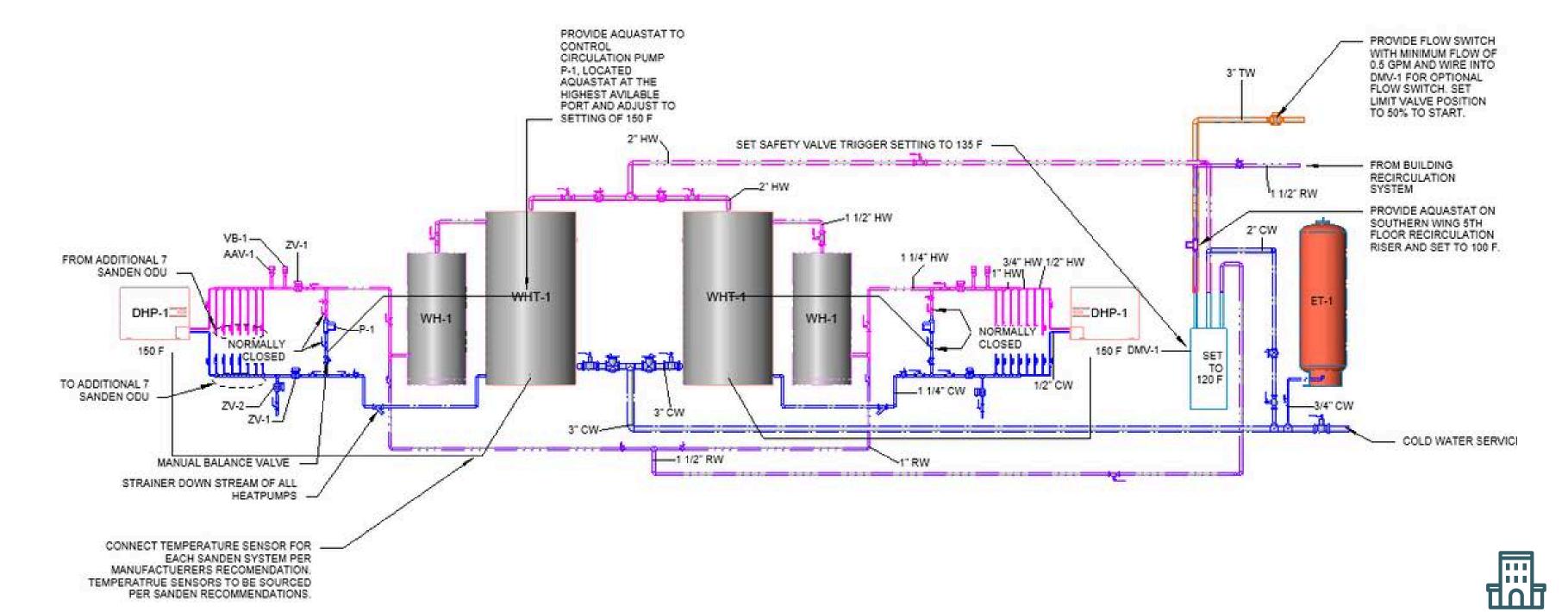
### Design elements

Two parallel systems with storage tanks in series



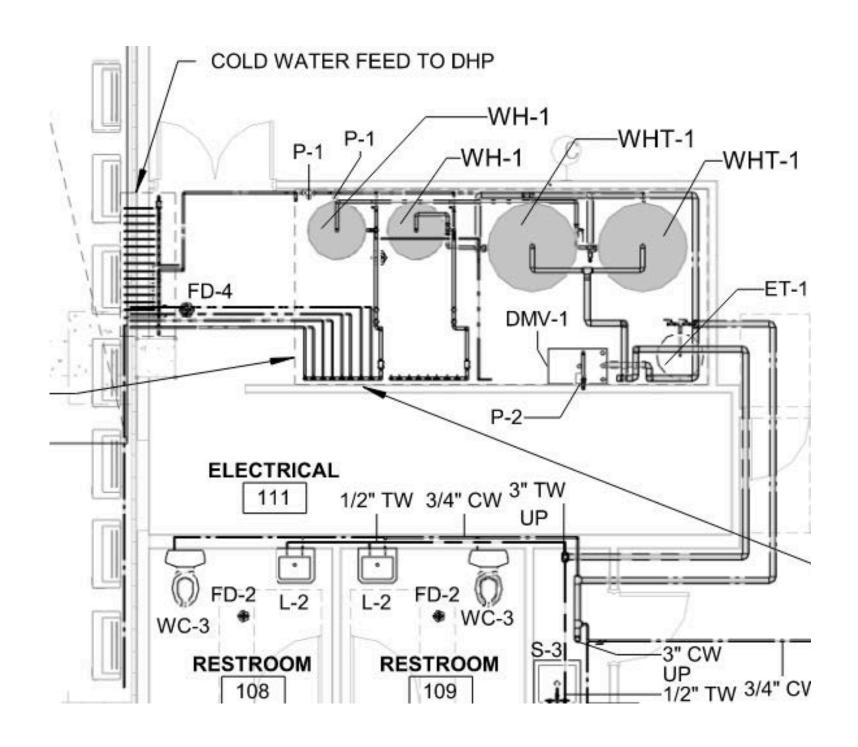
### Design elements

- De-energized back up electric resistance integrated into heat pump plant
- Buffer tank on hot return side of heat pumps in place of swing tank



### **Design limitations**

- Small boiler room
- Limited exterior wall space



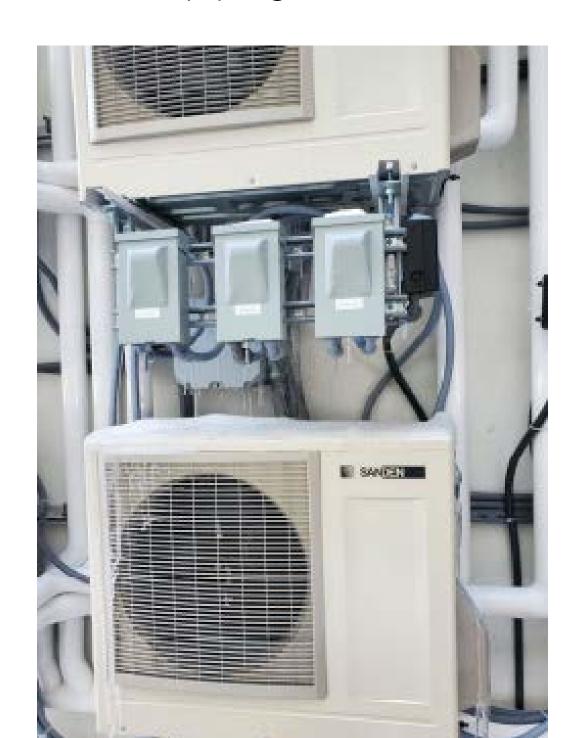






### Design limitations and areas for improvement

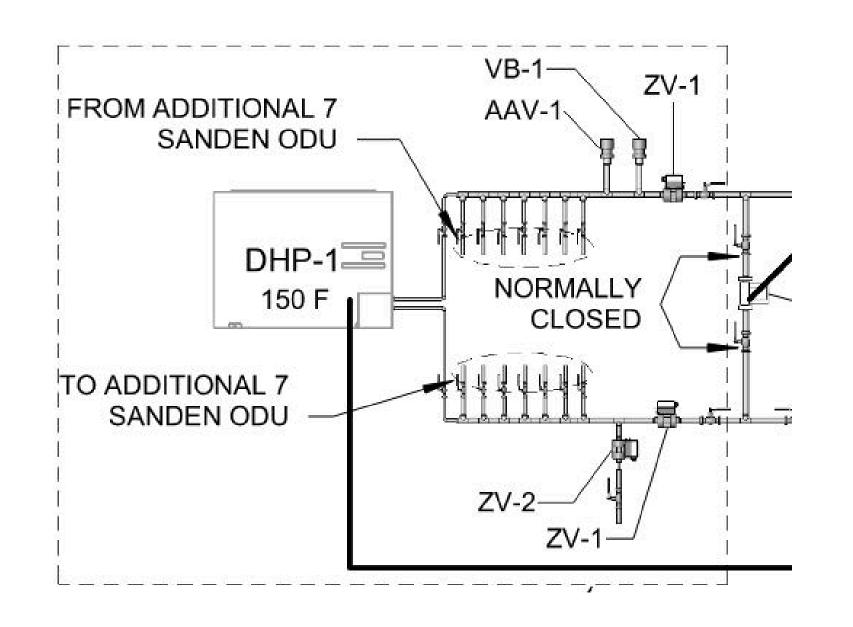
- Stacked heat pump array on exterior wall
- Exterior piping manifold

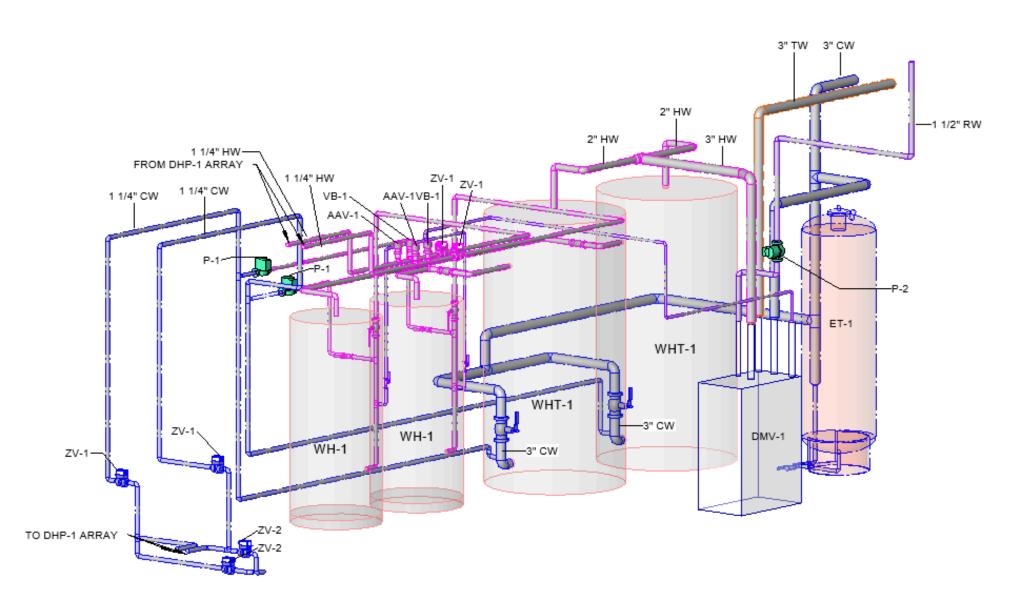




### Design limitations and areas for improvement

• Automatic drain back system 1.0





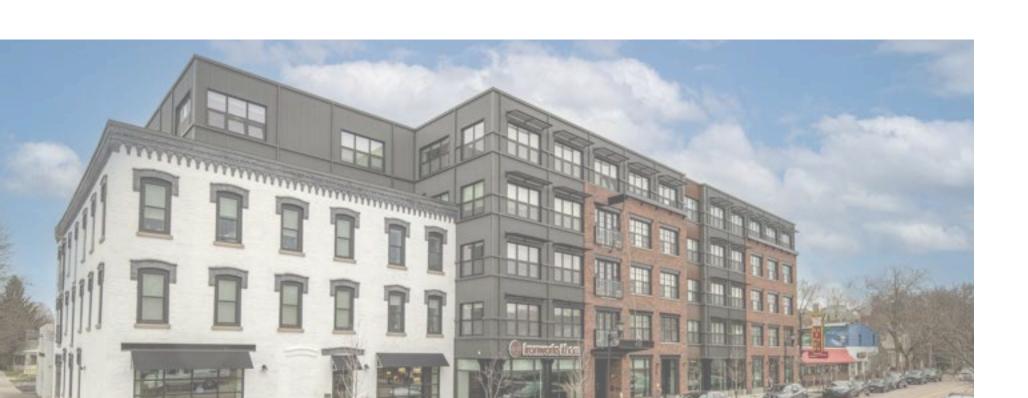
# Ironworks Ithaca (MR)

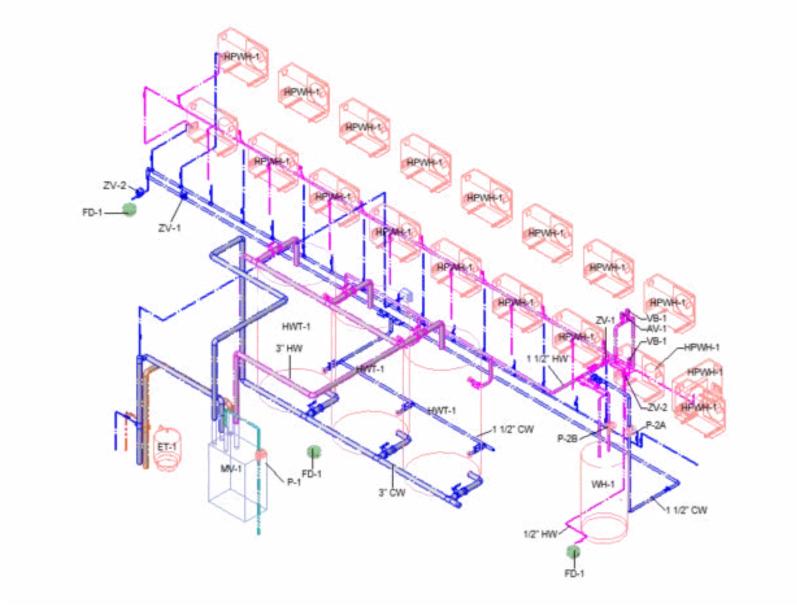
### Selected system

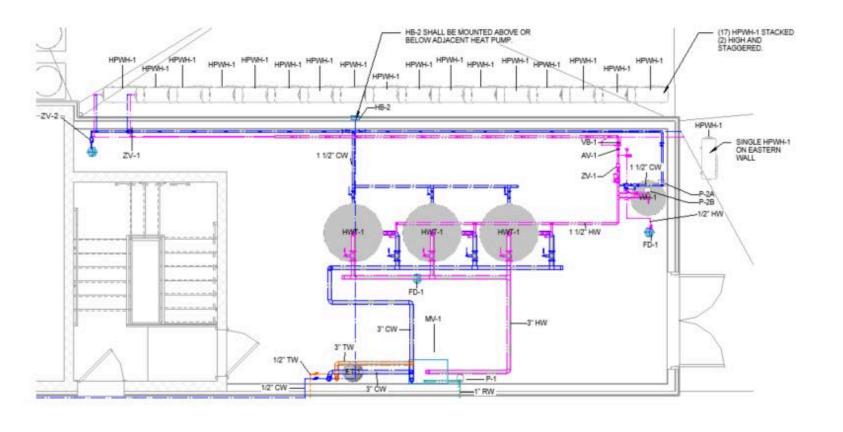
**STORAGE** 1500 gallons stored at 140 °F mixed down to 125 °F out to building

**PRIMARY HW** 18 SanCO2 heat pumps 276,000 btu/hr rated, 215,000 btu/hr derated at -5 °F

**BACKUP HW** 72 KW electric resistance boiler



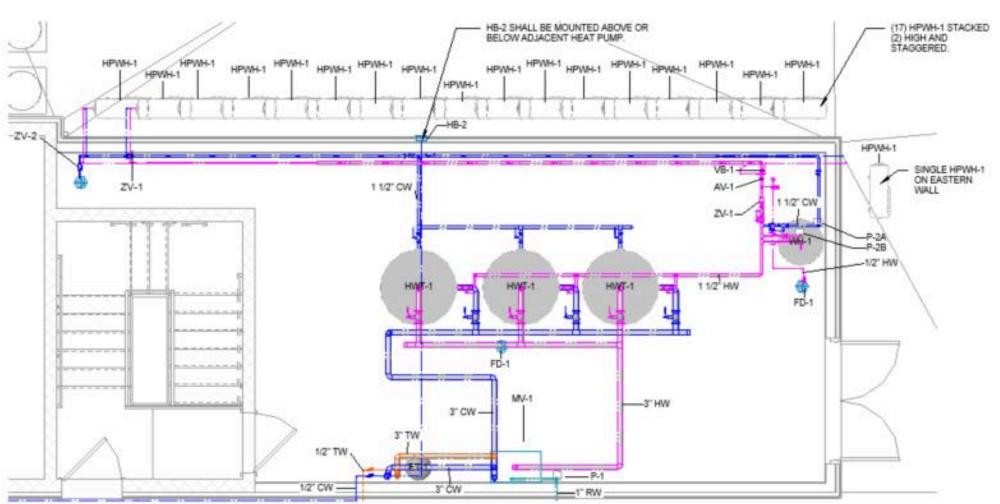




# Ironworks Ithaca

### Design elements

- Staggered heat pump array on exterior wall
- Boiler room purpose built for the DHW plant
- Heat pump piping manifold within building envelope



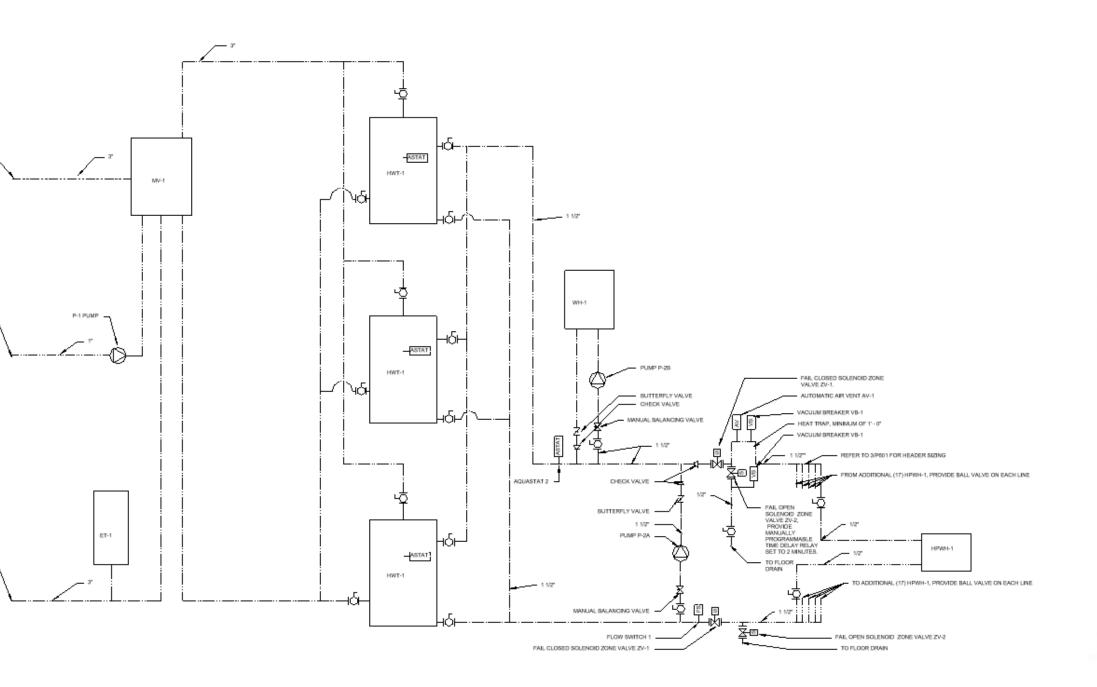


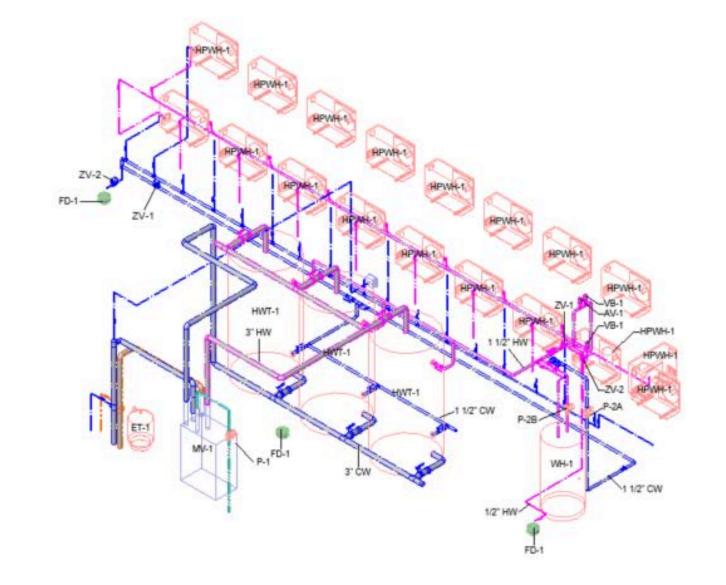


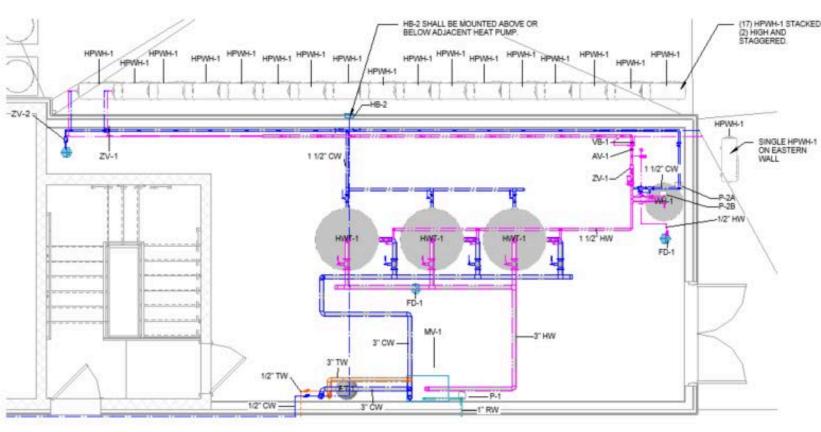
# Ironworks Ithaca

### Design elements

- Single heat pump array and supplemental electric boiler in parallel
- Storage tanks in parallel
- Omitted swing tank or buffer tank for recirculation water



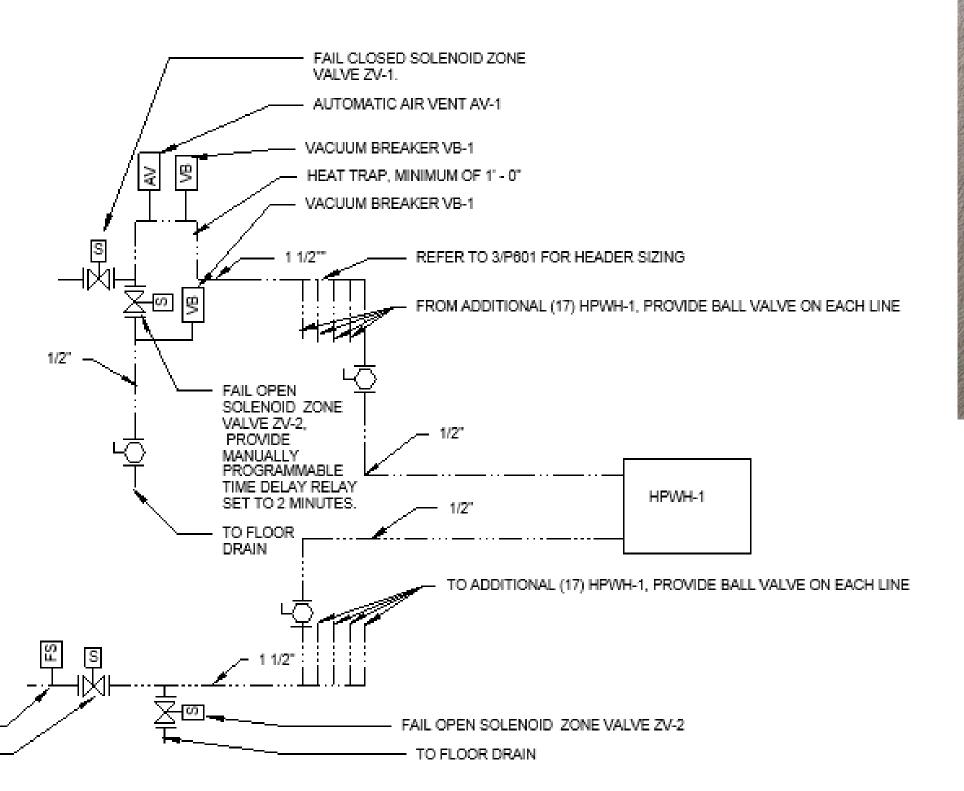




# Ironworks Ithaca

### Design elements

Automatic drain back system 2.0





# Contractor support

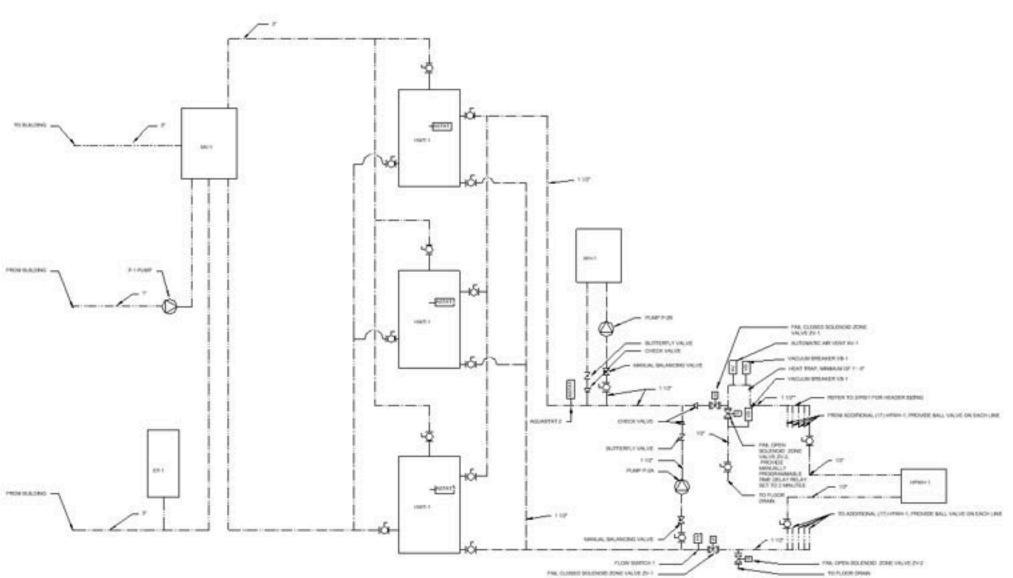


**DRAWINGS** of detailed system schematics and sequence



and a lot of

**DISCUSSION** about system operation



### SEQUENCE OF OPERATION

### Title-DOMESTIC HOT WATER PLANT SEQUENCE OF OPERATIONS:

### 1. HOT WATER PLANT HPWH-1 SYSTEM PRIMARY HEATING PROTOCOL

A. HPWH-1 ECO2 SYSTEM HAS INTEGRAL CONTROLS. THE SYSTEM SHALL BE SET TO 150°F AND INTERNAL CONTROLS WILL DETERMINE STAGING OPERATIONS.

Change to 95 F

### 2. HOT WATER PLANT HPWH-1 SYSTEM PRIMARY WH-1 SUPPLEMENTARY HEATING PROTOCOL

- A. IF ANY STORAGE TANK TEMPERATURE DETECTS TEMPERATURE BELOW (110°F, ADJ.) TURN ON P-2A.
- B. TURN ON P-2B 30 SECONDS (ADJ.) AFTER P-2B PROVES RUNNING STATUS.
- C. ENABLE WH-1 AND IT SHALL STAGE ELEMENTS DEPENDENT ON INLET TEMPERATURE BASED ON ITS INTERNAL CONTROLS.
- D. ONCE ALL TANK TEMPS ARE ABOVE 130°F (ADJ.), DISABLE WH-1, P-2A, AND P-2B.

Change to 115 F

### 3. HOT WATER PLANT WH-1 EMERGENCY BACK UP HEATING PROTOCOL

A. IF ANY STORAGE TANK TEMPERATURE SENSES HWT-1, 2, OR 3 IS BELOW TARGET TEMPERATURE (110 °F, ADJ.) AND THERE IS A "NO-HEAT CALL", P-2A TO TURN ON.

B.TURN ON P-2B 30 SECONDS (ADJ.) AFTER P-2B PROVES RUNNING STATUS.

C. ENABLE WH-1 AND IT SHALL STAGE ELEMENTS DEPENDENT ON INLET TEMPERATURE BASED ON TESTITERNAL CONTROLS.

D. IF TANK TEMP REACHES 130°F (ADJ.) AND A "HEAT CALL" IS DETECTED.
TURN OFF WH-1, P-2A, AND P-2B.

### 4. POWER OUTAGE DURING HPWH-1 SYSTEM OPERATION

A. DURING A POWER OUTAGE EVENT, THE SYSTEM IS DESIGNED TO AUTOMATICALLY PURGE HPWH-1 ECO2 SYSTEM OF ALL WATER. ZONE VALVES ZV-1A/B (NORMALLY CLOSED WHEN DE-ENERGIZED) AND ZV-2A/B (NORMALLY OPEN WHEN DE-ENERGIZED) WILL OPEN OR CLOSE TO THEIR







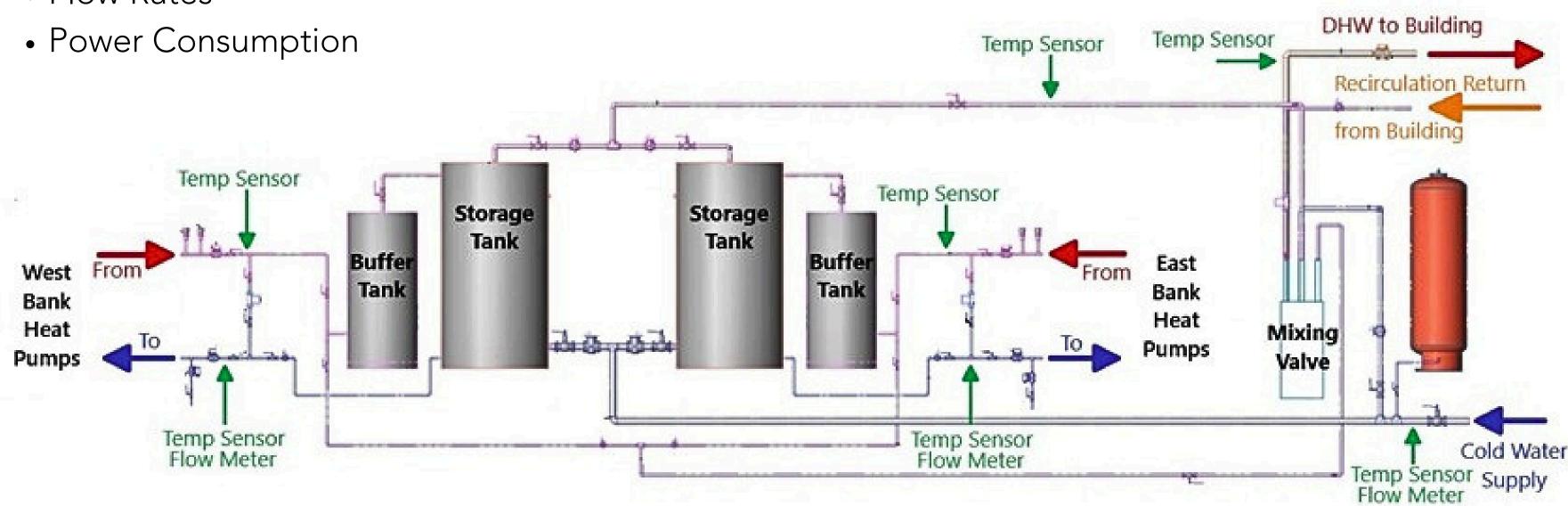
# Ithaca Arthaus (LMI)

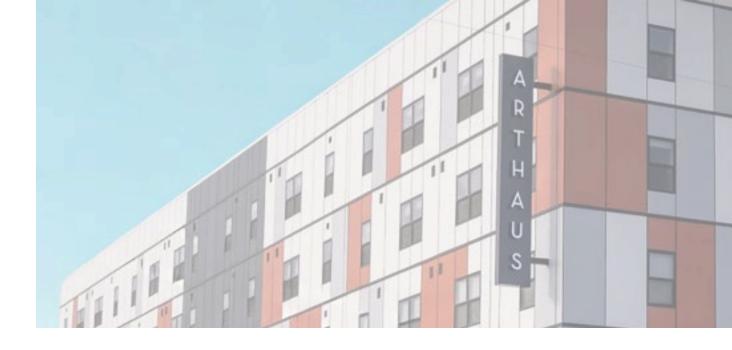
### **MEASUREMENT & VERIFICATION RESULTS**

15 months — Sept. 2022-Nov 2023

eGauge based monitoring system

- Temperatures
- Flow Rates







# Ironworks Ithaca (MR)

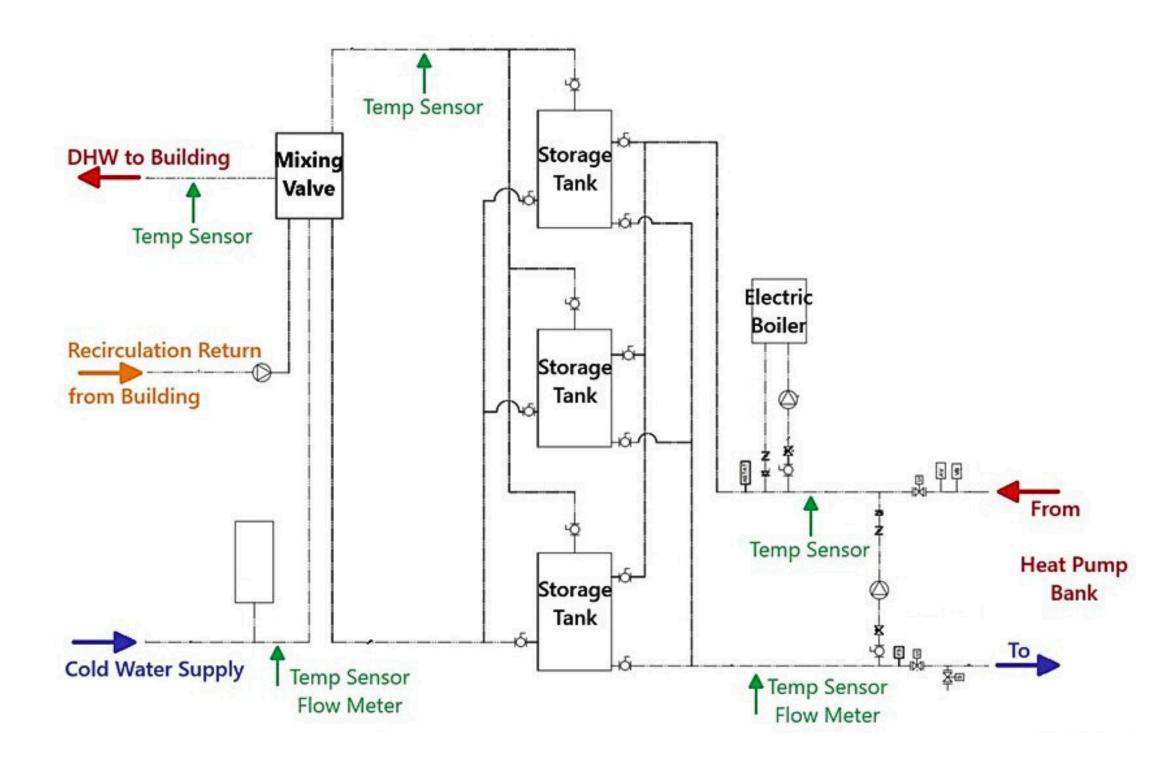
### **MEASUREMENT & VERIFICATION RESULTS**

### 12 months — Feb 2024-Feb 2025

eGauge based monitoring system

- Temperatures
- Flow Rates
- Power Consumption



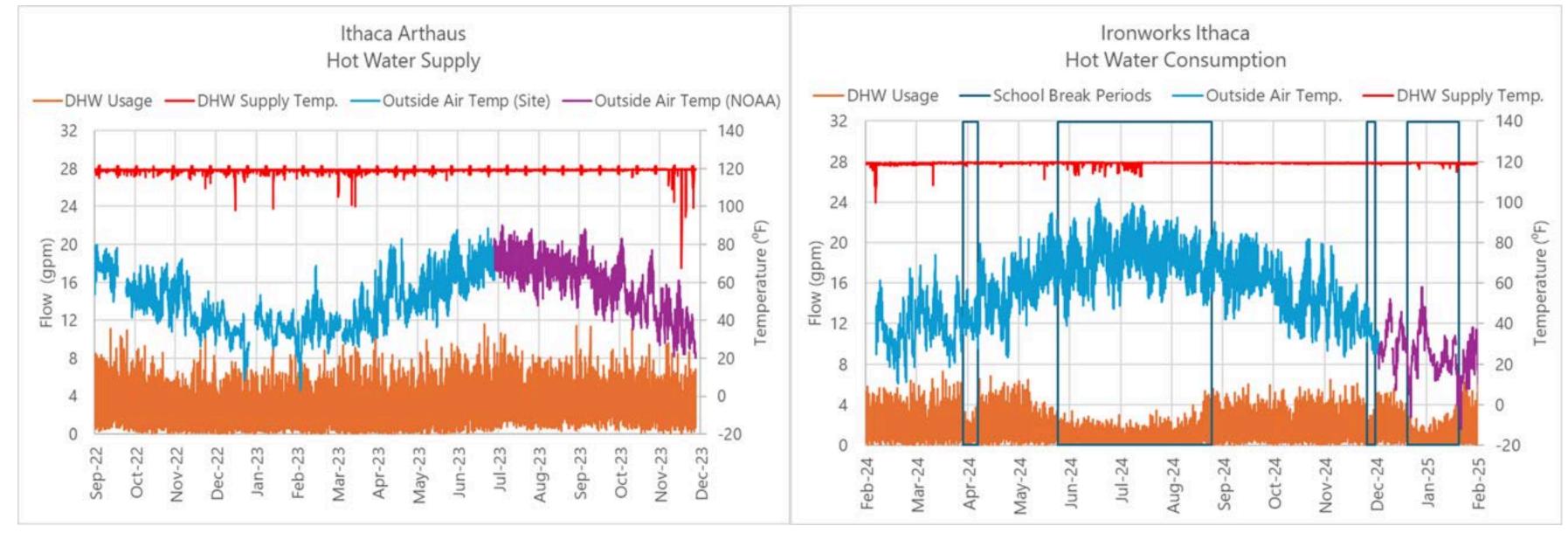


# Effectiveness

### Both systems proved extremely reliable – WITH NO ELECTRIC RESISTANCE

Arthaus: 99.6% Uptime\*

Ironworks: 99.99% Uptime\*



<sup>\*</sup>Fraction of time system provided at least 110 °F water to building loop



# Usage Rates

Both buildings had significantly lower DHW usage than ASHRAE Guidelines

Actual Measured Hot Water  Consumption (Per Occupant)							
Period	Arthaus	Ironworks					
15 Min Peak	1.0 gal	0.7 gal					
1 Hr Peak	2.9 gal	1.8 gal					
1 Day Peak	33.1 gal	15.5 gal					
1 Day Avg	16.1 gal	9.6 gal					

ASHRAE Handbook Hot Water Consumption										
(Per Occupant)										
Period	Low	Med	High							
15 Min Peak	1.0	1.7	3.0	gal						
1 Hr Peak	2.8	4.8	8.5	gal						
1 Day Peak	20.0	49.0	90.0	gal						
1 Day Avg	14.0	30.0	54.0	gal						

Design guidelines based on 2019 ASHRAE Handbook HVAC Applications Ch. 51, Table 7



# **Operating Costs**

Arthaus was cost competitive with theoretical natural gas boiler system\*

Ithaca Arthaus DHW Plant Operating Cost Comparisons												
Heat Pump						Electric Re	esistance	Natural Gas				
	(Actual Values)					(Theoretical Values)				(Theoretical Values)		
	Peak Avg				Peak		Relative					
Month	kWh	kW	Cost	COP	kWh	kW	Cost	Cost	Therm	Cost	Cost	
Nov-22	9,684	30.9	\$1,257	2.9	28,766	85.0	\$3,651	290%	1,012	\$1,012	81%	
Dec-22	13,216	36.0	\$1,640	2.5	33,423	86.5	\$4,090	249%	1,176	\$1,176	72%	
Jan-23	13,180	31.3	\$1,578	2.7	35,447	91.3	\$4,331	274%	1,247	\$1,247	79%	
Feb-23	12,191	37.2	\$1,562	2.7	33,780	104.5	\$4,347	278%	1,189	\$1,189	76%	
Mar-23	13,100	31.3	\$1,570	2.9	38,758	101.2	\$4,754	303%	1,364	\$1,364	87%	
Apr-23	9,238	30.3	\$1,211	3.5	32,831	101.5	\$4,223	349%	1,155	\$1,155	95%	
May-23	8,517	26.4	\$1,097	3.7	31,616	86.2	\$3,923	358%	1,112	\$1,112	101%	
Jun-23	6,800	19.3	\$854	4.0	27,245	91.1	\$3,591	421%	959	\$959	112%	
Jul-23	5,844	19.3	\$767	3.9	23,264	90.5	\$3,225	420%	819	\$819	107%	
Aug-23	5,963	17.7	\$758	3.8	22,900	72.9	\$2,972	392%	806	\$806	106%	
Sep-23	6,223	18.1	\$786	3.6	22,712	77.3	\$3,010	383%	799	\$799	102%	
Oct-23	8,059	23.8	\$1,023	3.4	27,333	79.3	\$3,451	337%	962	\$962	94%	
Annual	108,103	316.9	\$13,691	3.2	349,415	1,060.6	\$44,705	327%	12,295	\$12,295	90%	

# **Operating Costs**

### Ironworks was more costly due to lower efficiency

	Ironworks Ithaca DHW Plant Operating Cost Comparisons												
		Heat P				esistance	Natural Gas						
	(Actual Values)					(Theoretical Values)				(Theoretical Values)			
				Avg				Relative			Relative		
Month	kWh	Peak kW	Cost	COP	kWh	Peak kW	Cost	Cost	Therm	Cost	Cost		
Feb-24	15,597	38.0	\$1,879	1.9	30,434	94.6	\$3,922	209%	1,071	\$1,071	57%		
Mar-24	12,993	34.4	\$1,599	2.1	27,951	87.5	\$3,610	226%	983	\$983	62%		
Apr-24	9,299	33.0	\$1,249	3.0	28,151	79.3	\$3,524	282%	991	\$991	79%		
May-24	5,886	21.7	\$801	3.2	19,314	77.2	\$2,703	337%	680	\$680	85%		
Jun-24	4,156	20.4	\$629	3.3	13,676	73.2	\$2,146	341%	481	\$481	76%		
Jul-24	3,653	16.8	\$539	3.4	12,489	71.2	\$2,013	374%	439	\$439	82%		
Aug-24	5,349	20.4	\$736	3.3	18,056	75.0	\$2,563	348%	635	\$635	86%		
Sep-24	6,320	21.6	\$839	3.2	20,619	76.3	\$2,809	335%	726	\$726	86%		
Oct-24	8,908	32.0	\$1,202	2.7	24,199	77.7	\$3,149	262%	851	\$851	71%		
Nov-24	12,474	35.9	\$1,572	2.1	26,636	82.5	\$3,428	218%	937	\$937	60%		
Dec-24	14,422	41.7	\$1,819	1.5	21,956	77.5	\$2,944	162%	773	\$773	42%		
Jan-25	20,067	46.0	\$2,381	1.3	27,178	81.2	\$3,462	145%	956	\$956	40%		
Annual	119,125	361.9	\$15,245	2.2	270,659	953.1	\$36,273	238%	9,523	\$9,523	62%		



# Operating Costs

A theoretical swing tank system came at only a 10% cost increase over Arthaus\*

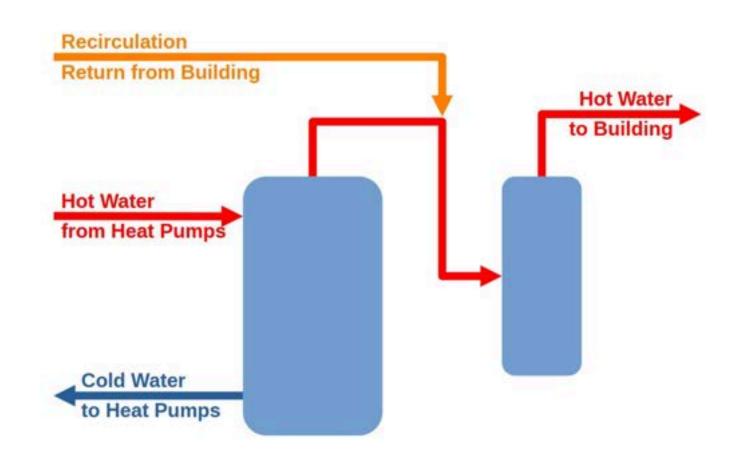
Ithaca Arthaus DHW Plant Operating Cost Comparisons											
		Heat P	ump		Heat Pump w/ Swing Tank						
		(Actual \	/alues)		(Theoretical Values)						
		Peak		Avg		Avg	Relative				
Month	kWh	kW	Cost	COP	kWh	kW	Cost	COP	Cost		
Nov-22	9,684	30.9	\$1,257	2.9	10,528	33.3	\$1,364	2.7	108%		
Dec-22	13,216	36.0	\$1,640	2.5	14,261	41.9	\$1,807	2.3	110%		
Jan-23	13,180	31.3	\$1,578	2.7	14,136	47.8	\$1,870	2.5	118%		
Feb-23	12,191	37.2	\$1,562	2.7	12,922	38.5	\$1,644	2.6	105%		
Mar-23	13,100	31.3	\$1,570	2.9	14,105	43.2	\$1,809	2.7	115%		
Apr-23	9,238	30.3	\$1,211	3.5	10,004	30.3	\$1,280	3.2	106%		
May-23	8,517	26.4	\$1,097	3.7	9,181	28.6	\$1,184	3.4	108%		
Jun-23	6,800	19.3	\$854	4.0	7,185	22.7	\$931	3.8	109%		
Jul-23	5,844	19.3	\$767	3.9	6,111	19.3	\$791	3.8	103%		
Aug-23	5,963	17.7	\$758	3.8	6,242	18.7	\$795	3.6	105%		
Sep-23	6,223	18.1	\$786	3.6	6,451	20.3	\$834	3.5	106%		
Oct-23	8,059	23.8	\$1,023	3.4	8,405	29.7	\$1,128	3.2	110%		
Annual	108,103	316.9	\$13,691	3.2	115,501	367.8	\$14,992	3.0	110%		

<sup>\*</sup>If properly tuned (140 °F storage temp, 125 °F swing tank temp)

## Quick Aside

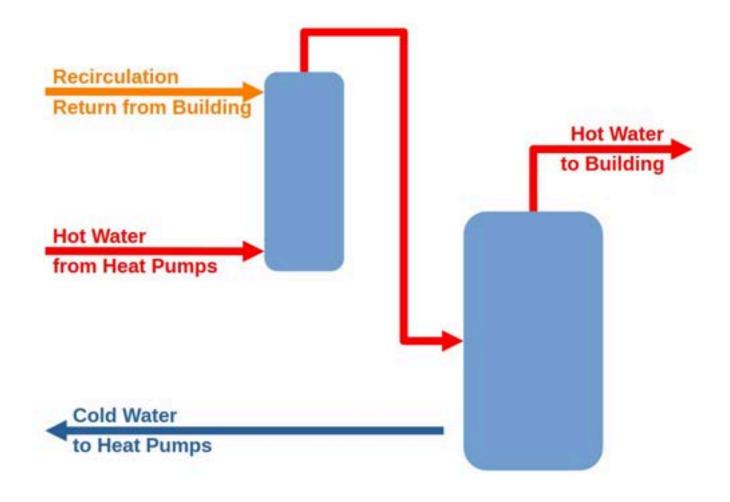
**Tank Terminology** 

### **SWING TANK**



Recirculation water is reheated with electric resistance

### **BUFFER TANK**

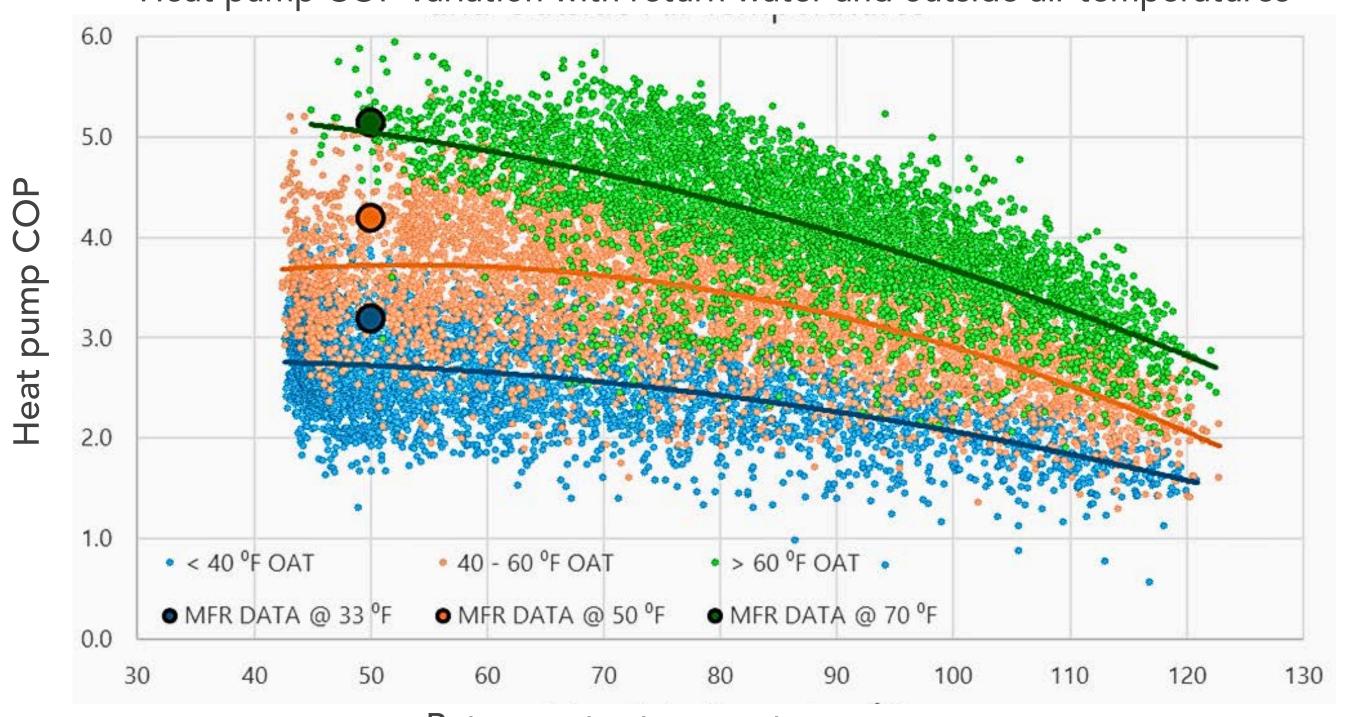


Recirculation water is reheated with heat pump system

# Efficiency

### Arthaus annual average COP: 3.2





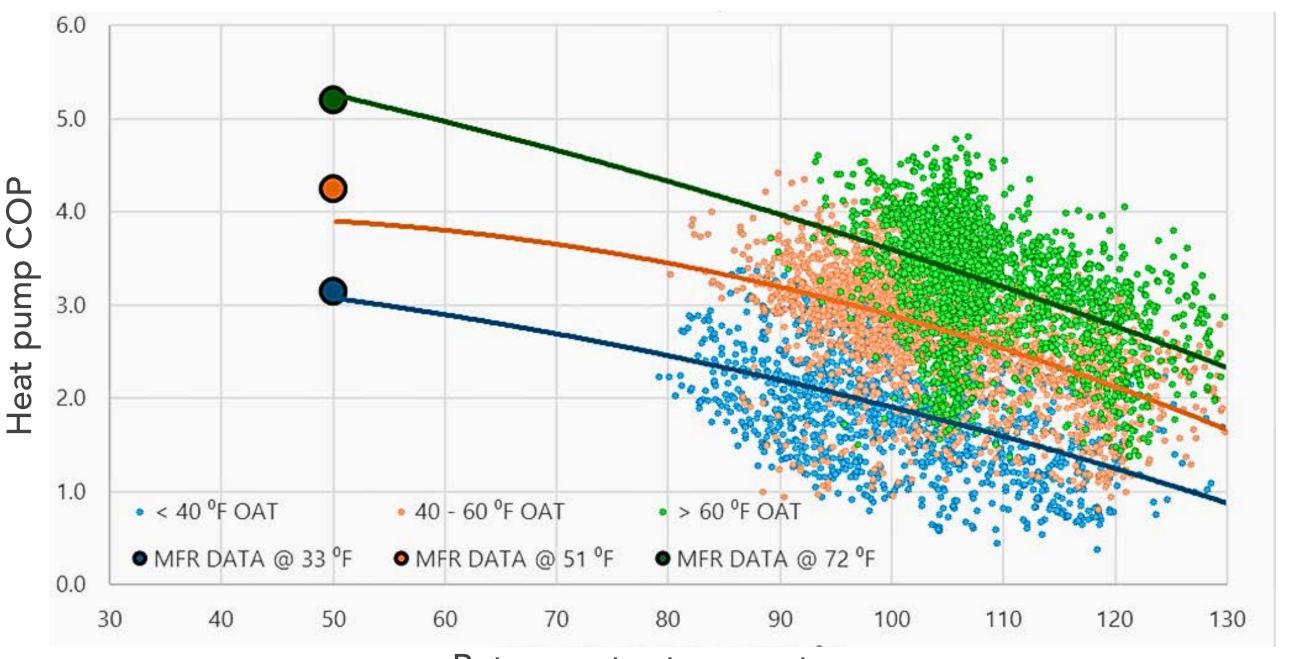




# Efficiency

### Ironworks annual average COP: 2.2

Heat pump COP variation with return water and outside air temperatures







# Efficiency

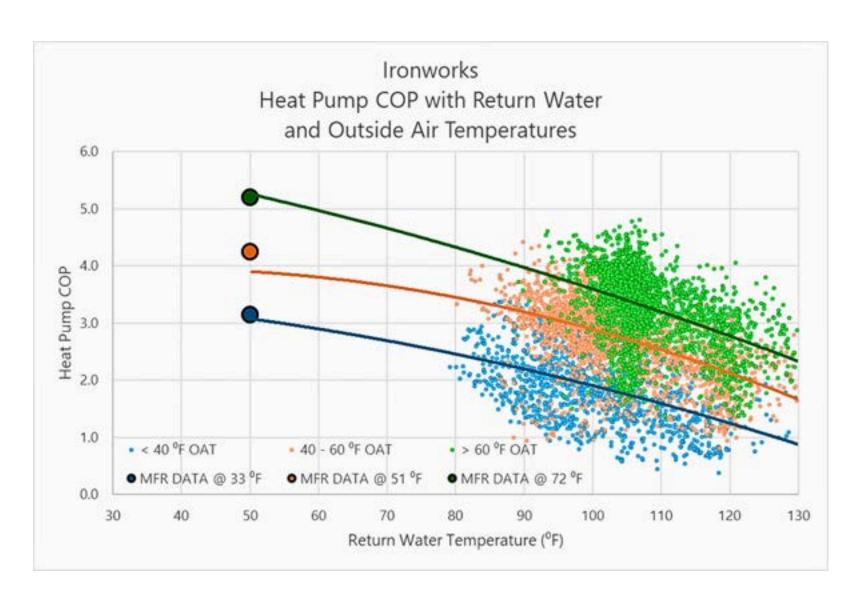
Big difference between system efficiencies is related to RETURN WATER TEMPS

### **Arthaus = Colder return water**

### Ithaca Arthaus Heat Pump COP Variation with Return Water and Outside Air Temperatures 6.0 5.0 Heat Pump COP 3.0 < 40 °F OAT . > 60 °F OAT .

Return Water Temperature (°F)

### Ironworks = Warmer return water







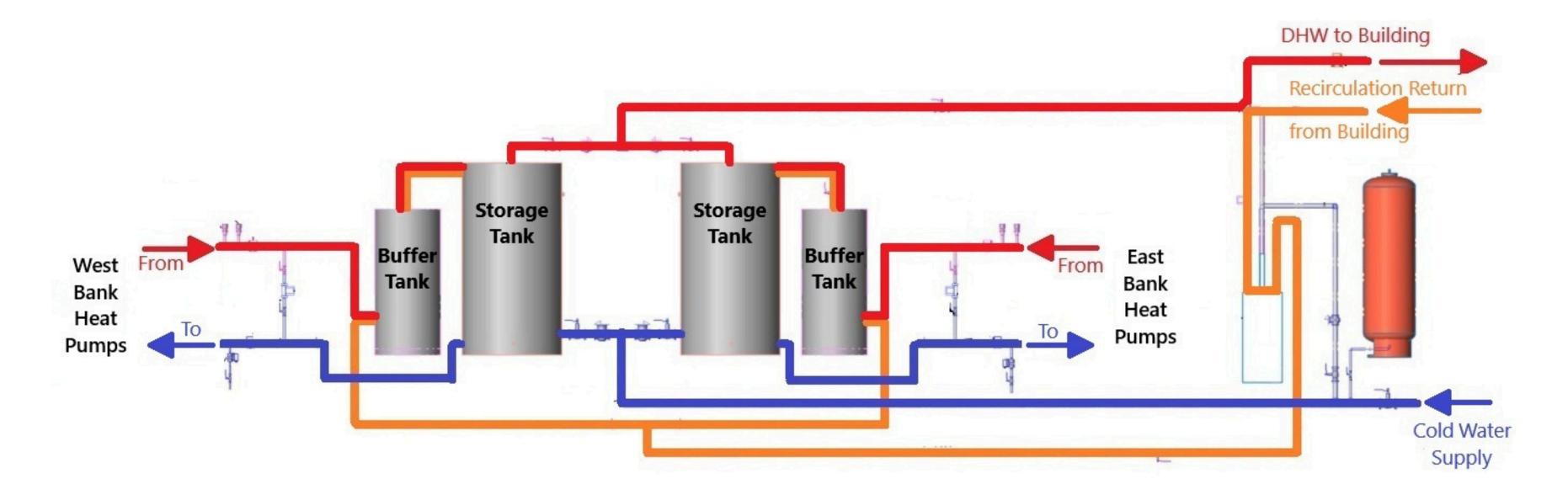


## Lessons Learned



# Piping matters!

Arthaus buffer tank design allowed for colder return water to heat pumps

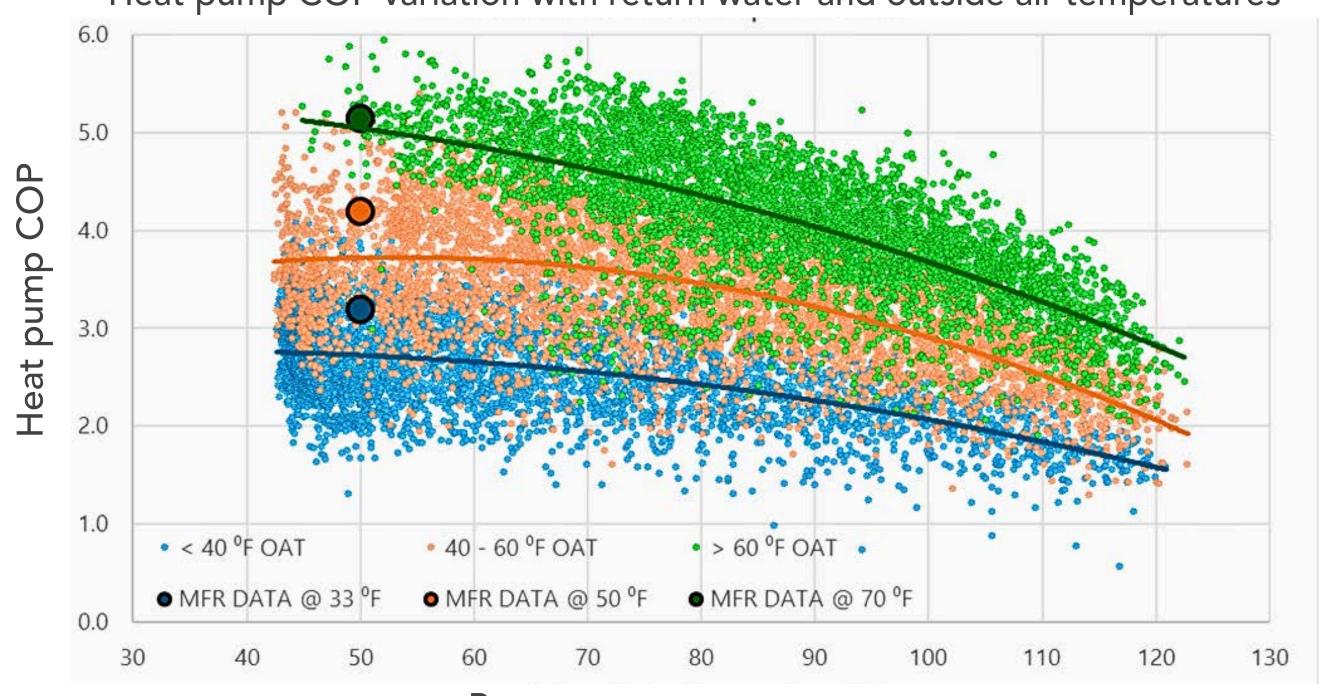




# Piping matters

Arthaus buffer tank design allowed for colder return water to heat pumps

Heat pump COP variation with return water and outside air temperatures

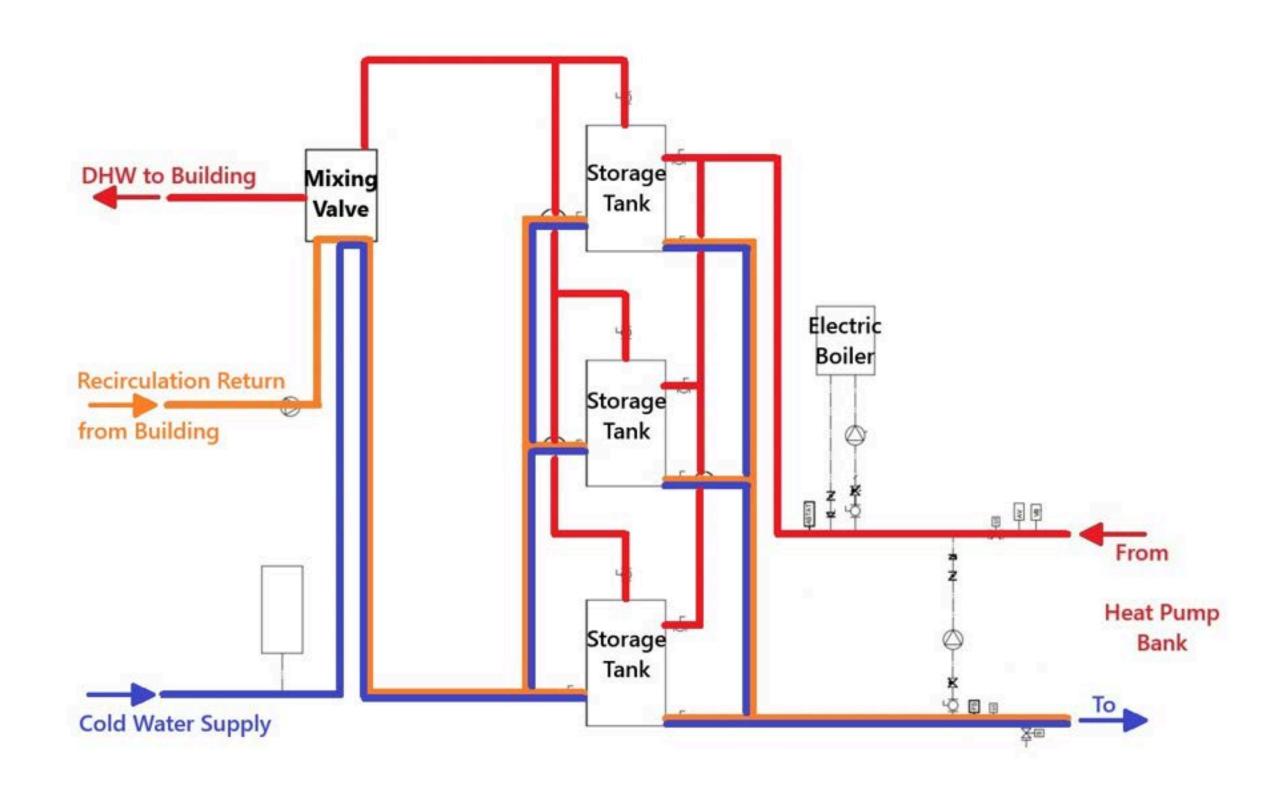


Return water temperature



# Piping matters!

Ironworks design limited return water temps to heat pumps

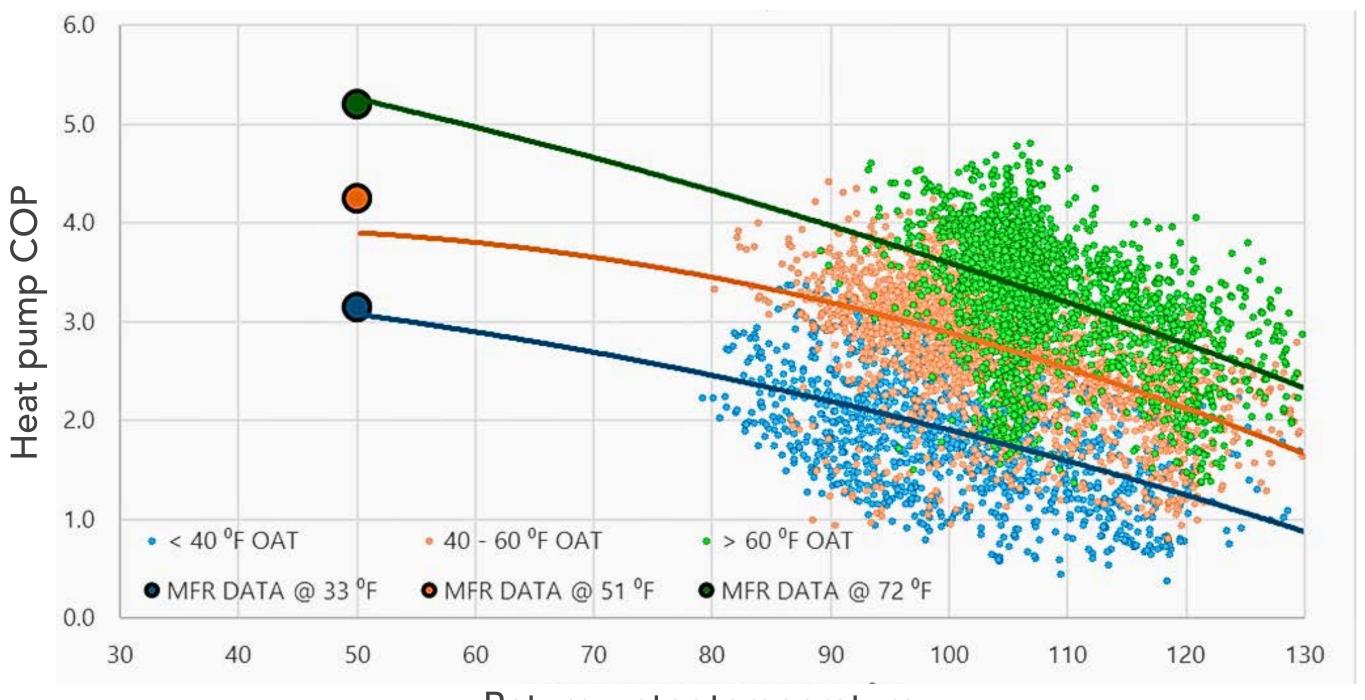




# Piping matters

Ironworks design limited return water temps to heat pumps

Heat pump COP variation with return water and outside air temperatures

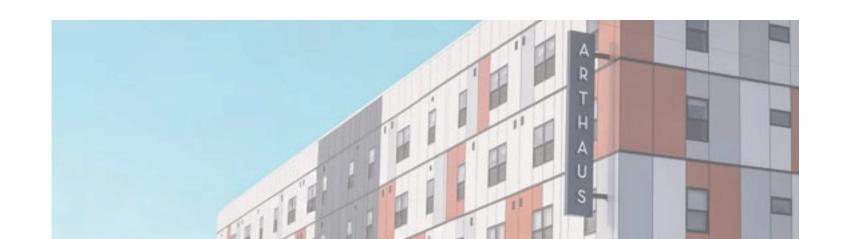


# Standby losses are <u>significant</u>

Heat Loss to surroundings was similar for both buildings

Ithaca Arthaus  DHW Storage/Distribution Losses			
	Whole Building	Per Apartment	
Heat Pump Output	1,196 MMBTU/yr	323 W	
Delivered Heat	746 MMBTU/yr	201 W	
System Losses	450 MMBTU/yr	121 W	
	38% of HP Output		

Ironworks Ithaca Storage/Distribution Losses			
	Whole Building	Per Apartment	
Heat Pump Output	916 MMBTU/yr	238 W	
Delivered Heat	446 MMBTU/yr	116 W	
System Losses	470 MMBTU/yr	122 W	
	51% of HP Output		





## Unique attributes

#### **Ithaca Arthaus**

Tempered water mains on each floor





Complicated building shapes

Balancing valves atop each riser

#### **WATTS PER APARTMENT**

#### **TARGET**

100 Watts/apartment

#### **MEASURED**

121 Watts/apartment



Box & riser design





# Balancing and Cx are CRITICAL

Projects were successful due in large part to EARLY performance monitoring

1. Storage tanks rebalanced: maximized storage capacity + lowest return water temps



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Projects were successful due in large part to EARLY performance monitoring

- 1. Storage tanks rebalanced: maximized storage capacity + lowest return water temps
- 2. Distribution system balanced: ensured hot water for apts at lowest recirc flowrate



# Balancing and Cx are CRITICAL

Projects were successful due in large part to EARLY performance monitoring

- 1. Storage tanks rebalanced: maximized storage capacity + lowest return water temps
- 2. Distribution system balanced: ensured hot water for apts at lowest recirc flowrate
- 3. Recirc pumps run lowest flowrate: improved mixing valve stability and storage tank disruption





Contractors at both sites were skeptical of new, complex systems



Making time to talk about the design and function early on eased jitters



Listening to feedback and concerns helped improve designs and contractor relationships







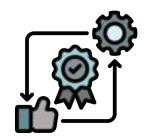




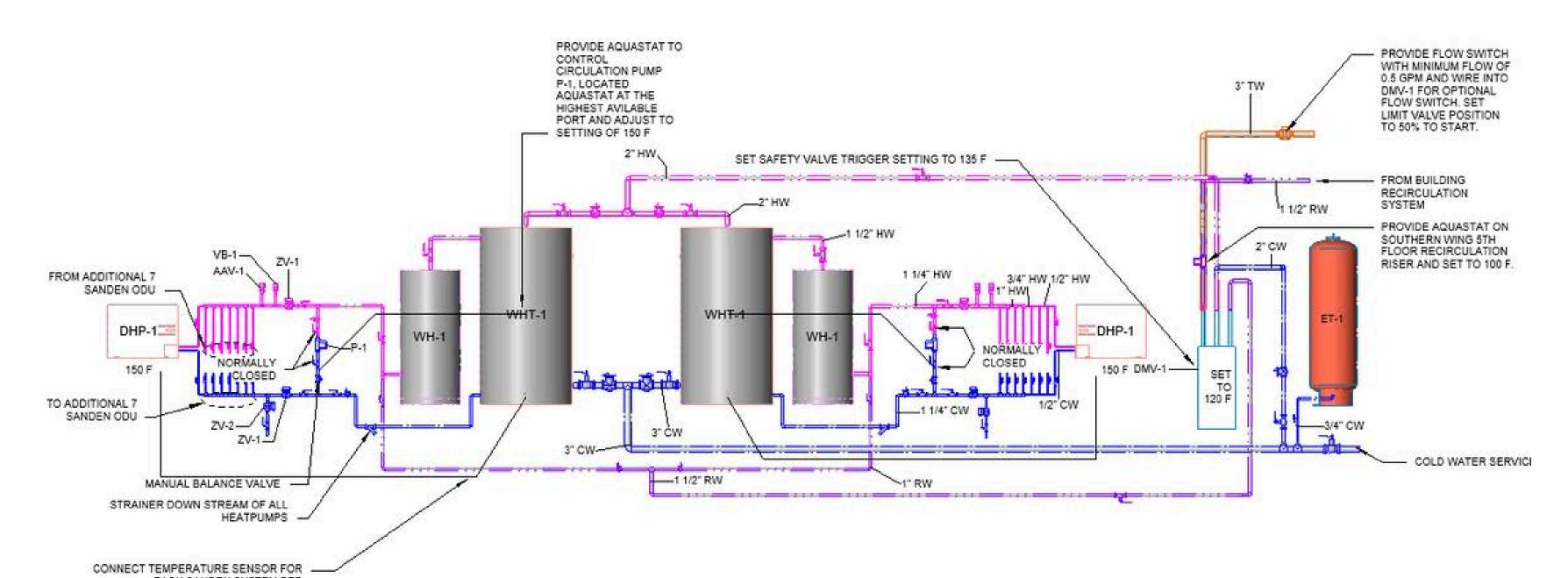
## The Ultimate HP DHW Design



## Ironworks revised



- Split the 18 heat pumps into 3 separate arrays of 6 heat pumps
- $\bullet$  Provide a 119 gallon 24 kw buffer tank on the supply side of the storage tanks set to 120  $^{0}$ F
- Pipe each of the 3 system sub assemblies in parallel, provide circuit setters on supply and return to the building



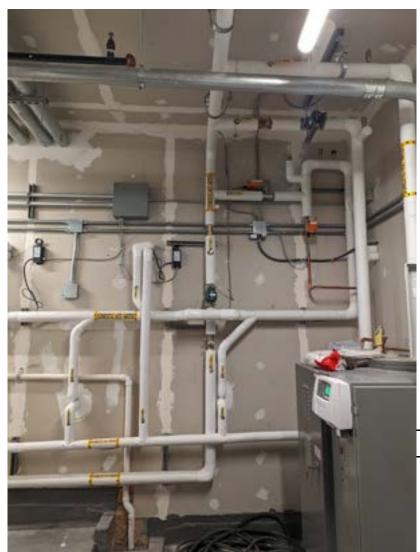
## Ironworks revised

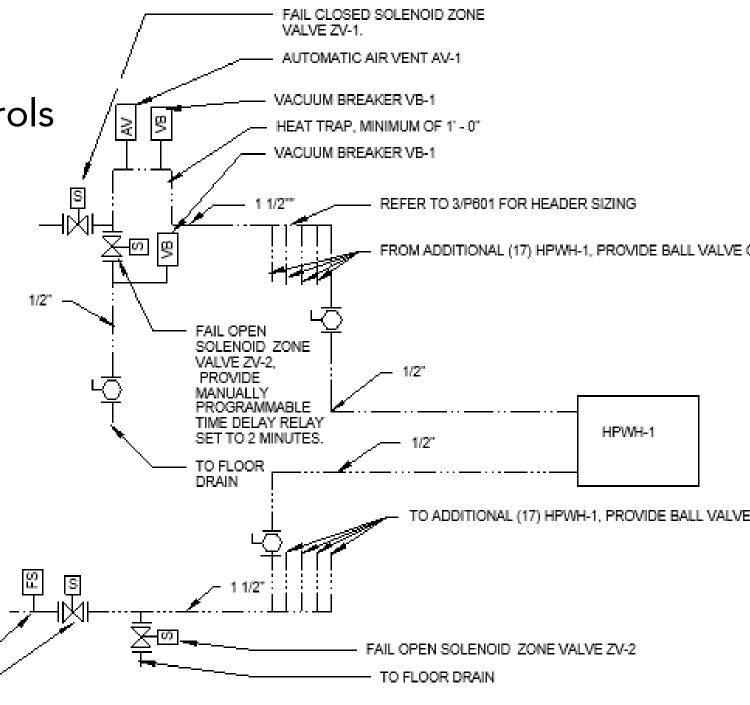
Stagger heat pumps on exterior wall

• Provide automatic drain back system 2.0

• Reduce size of recirc pump, provide better balancing controls





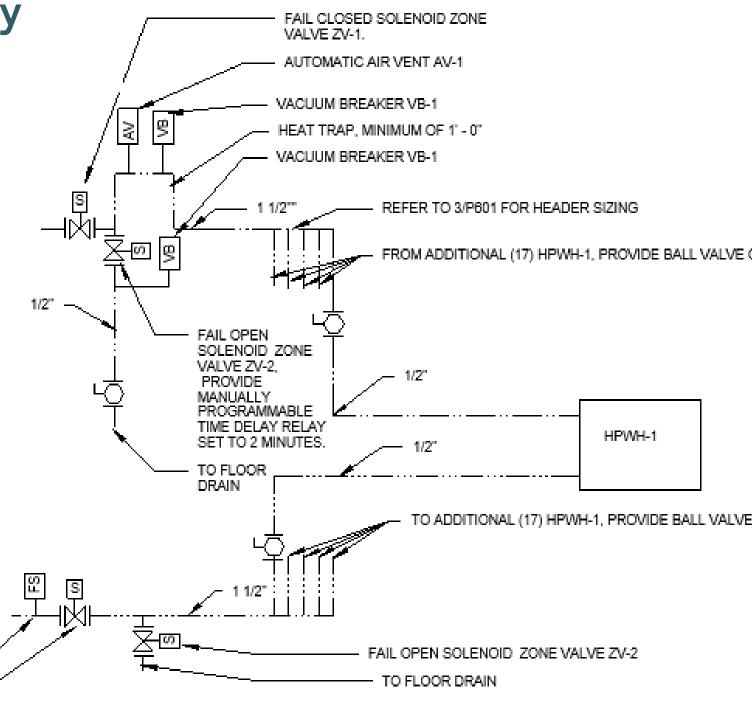




Provide balancing and measurement points within key points of the hot water plant



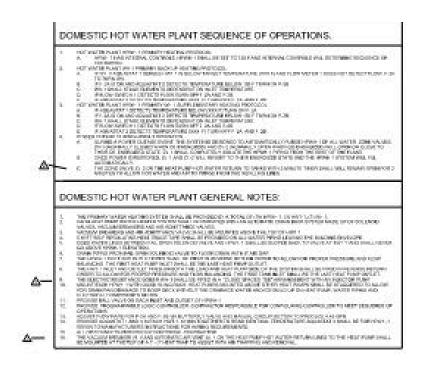


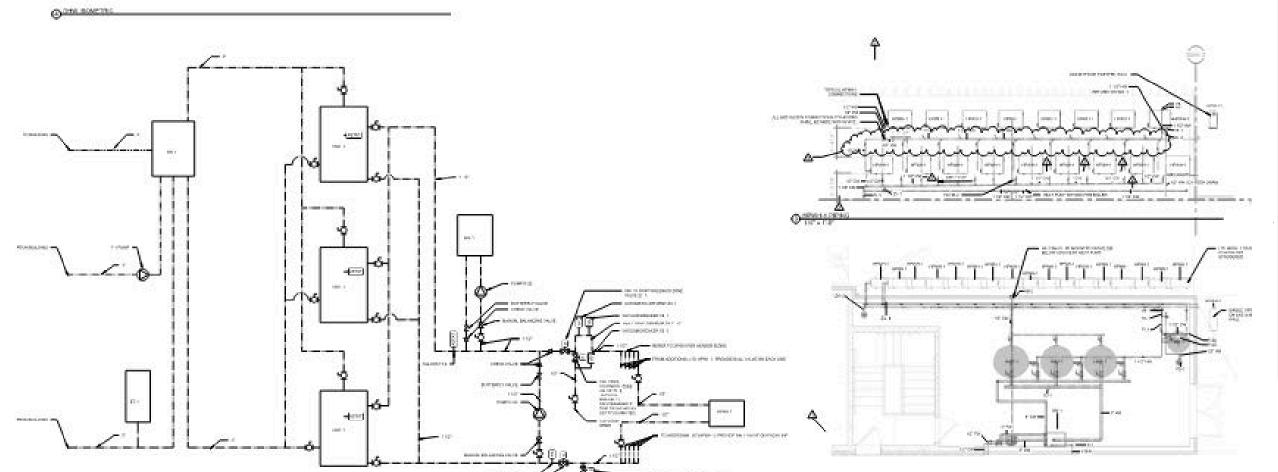


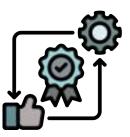
# Contractor support

### **Drawings**

- Detailed system schematics
- Describe
  - system operation in each modehow it differs from traditional
  - systems







#### DOMESTIC HOT WATER PLANT SEQUENCE OF OPERAT

- HOT WATER PLANT HPWH-1 PRIMARY HEATING PROTOCOL
  - HPWH-1 HAS INTEGRAL CONTROLS. HPWH-1 SHALL BE SET TO 150 F AND INTERNAL CONTROL

- IF AQUASTAT 1 DETECTS TEMPERATURE BELOW (XXX F) TURN ON P-2A

  - IF FLOW SWITCH 1 DETECTS FLOW TURN OFF P-2A AND P-2B
- IF AQUASTAT 2 DETECTS TEMPERATURE (XXX F) TURN OFF P-2A AND P-2B
- - ZV-1 (NORMALLY CLOSED WHEN DE-ENERGIZED) AND ZV-2 (NORMALLY OPEN WHEN GE-ENER THEIR DE-ENERGIZED STATE. ZV-1 SHALL COMPLETELY ISOLATE THE HPWH-1 PIPING FROM

  - THE ZONE VALVE ZV-2 ON THE HEAT PUMP HOT WATER RETURN TO TANKS WITH 2 MINUT MINUTES TO ALLOW FOR WATER AND AIR TO PURGE FROM THE REFILLING LINES

#### DOMESTIC HOT WATER PLANT GENERAL NOTES:

- EACH HEAT PUMP WATER HEATER SYSTEM SHALL BE PROVIDED WITH AN AUTOMATIC DRAIN BACK
- VACUUM BREAKERS AND AIR ADMITTANCE VALVE SHALL BE MOUNTED ABOVE THE TOP OF HWT-
- 5 W/FT SELF REGULATING HEAT-TRACE TAPE SHALL BE PROVIDED ON ALL WATER PIPING LEAVING

- REFER TO MANUFACTURERS INSTRUCTIONS FOR WIRING REQUIREMENTS
- ALL DISCONNECTS PROVIDED BY ELECTRICAL CONTRACTOR
- THE VACUUM BREAKER VB-1 AND AUTOMATIC AIR VENT AV-1 ON THE HEAT PUMP HOT WATER RETU BE MOUNTED AT THE TOP OF A 1' - 0" HEAT TRAP TO ASSIST WITH AIR TRAPPING AND REMOVAL

# Contractor support

#### **Discussion**

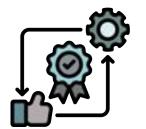
- Preconstruction meeting with contractor leading the hot water plant work
  - Discuss how system operation differs from traditional systems
- Early attentions to bottle necks (control systems, coordination with trades/mfr.)
- Discuss pinch points and areas of complexity



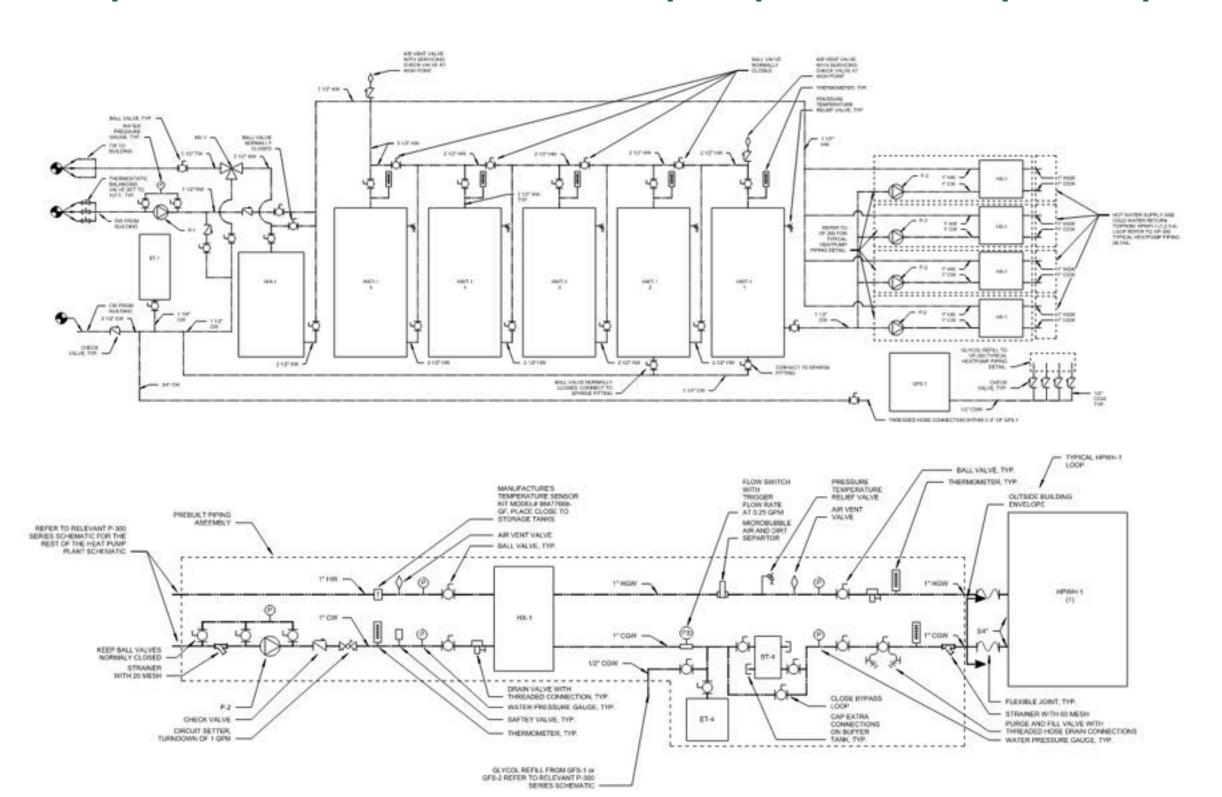




# Ironworks large capacity CO2

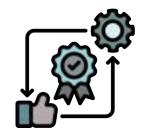


Explore different central heat pump hot water plant options

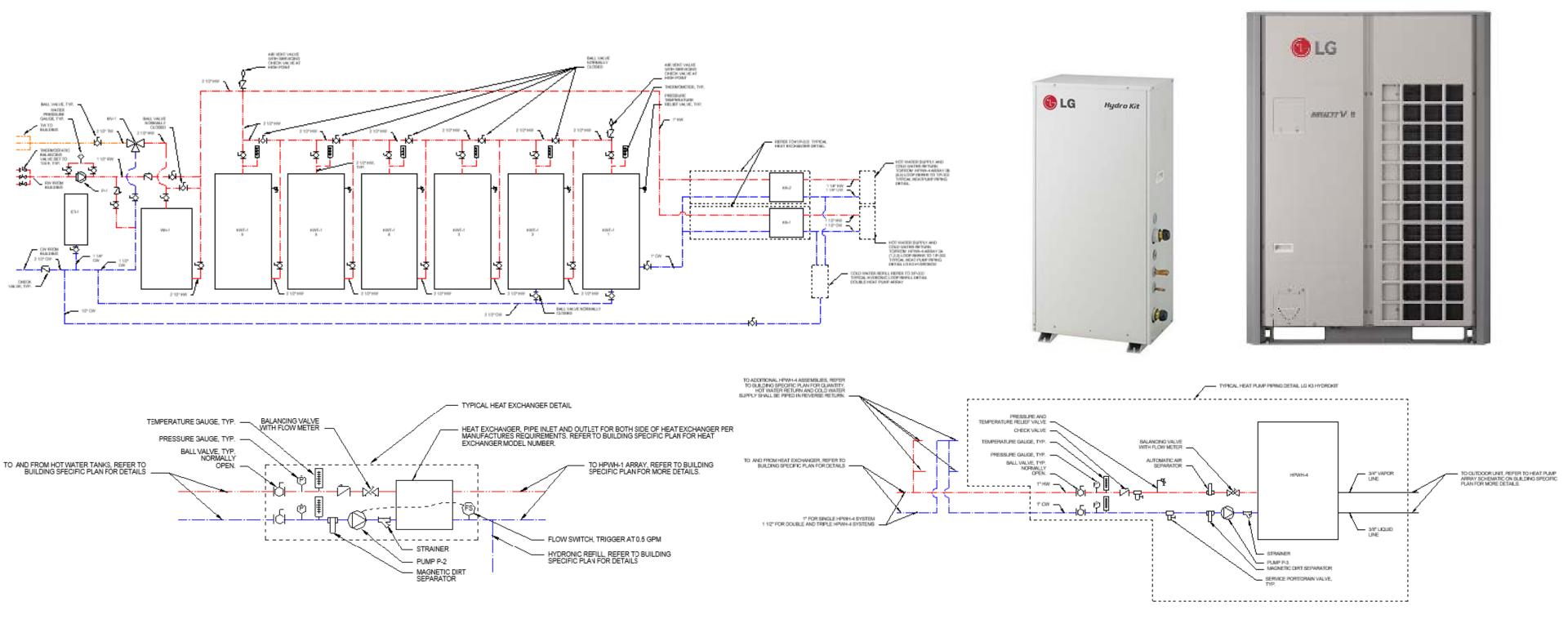




## Ironworks Cascade



Explore different central heat pump hot water plant options



# In Hot Water Key design details for effective & efficient DHW systems Let's talk about it...



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Northeast Sustainable Energy Association (NESEA) | October 16, 2025