GETTING PUMPED

AN ANALYSIS OF CENTRAL HEAT PUMP DOMESTIC HOT WATER SYSTEMS

PRESENTED BY:

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ITHACA, NY

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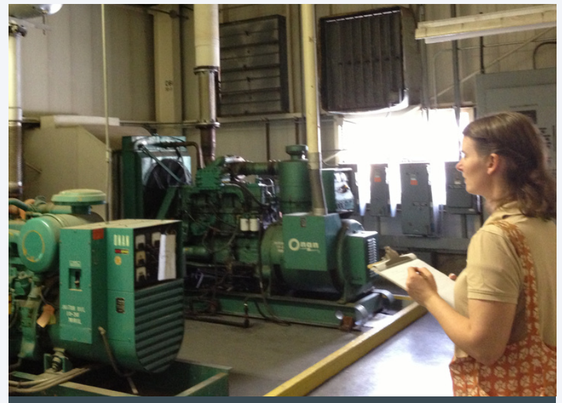
- Construction oversight
- On-site Energy Mgmt
- Energy Research
- Utility Consulting

PROGRAM COMPLIANCE

- Passive House
- NYSERDA
- Utilities
- LEED



QUALITY ASSURANCE

- QA Contractor for NYSERDA's MF Energy Performance Portfolio since 2007
- Training, tech tips, etc.

Presentation Summary

What we'll cover

Introduction
- Why Heat Pumps for DHW?
- System Options and Refrigerant Types

Project Case Studies
- System Design and M&V Results

Lessons Learned

Discussion

If you haven't heard,
ELECTRIFICATION IS HOT!

Tartem

Heat pumps are the primary path to building electrification

Replacing fossil fuel-powered systems with electric zero-carbon alternatives is a necessary step to achieve statewide and carbon emission reduction goals.

System Options for DHW

COMPARING SYSTEM OPTIONS AND REFRIGERANT TYPES

TAITEM ENGINEERING

SYSTEM OPTIONS FOR DHW

ELECTRIC RESISTANCE

AIR SOURCE HEAT PUMP

GROUND SOURCE HEAT PUMP

Electric Resistance

TANK TYPE

Uniform Energy Factor UEF = 0.89 to 0.94

PROS

- Relatively cost-effective
- Small electrical demand (vs. tankless)

CONS

- Low efficiency
- Standby losses
- Not great for commercial (heating element)

TANKLESS

Uniform Energy Factor UEF = 0.95 to 0.99

PROS

- Relatively cost-effective
- No standby losses
- Good for point of use

CONS

- Large electrical requirement
- Delicate heat exchanger (not great for hard water)

Air Source Heat Pump

PROS

- More efficient
- Contractor familiarity
- Relatively cost-effective

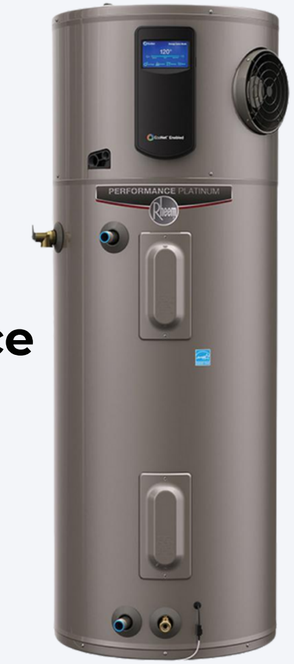
CONS

- Complex systems
- Space constraints
- Recovery time
- Freeze protection

Hybrid

COP = 3.0-3.5

Steals heat from space



Split system

COP = 2.0-4.0

Ground Source Heat Pump

COP = 2.2-3.5

PROS

- Minimally effected by seasonal changes (outdoor ambient temp has no effect)
- No visible outdoor equipment

CONS

- High cost
- Lack of contractor familiarity
- Complex systems
- Space constraints
- Thermal drift (if it's just for DHW)

Design considerations

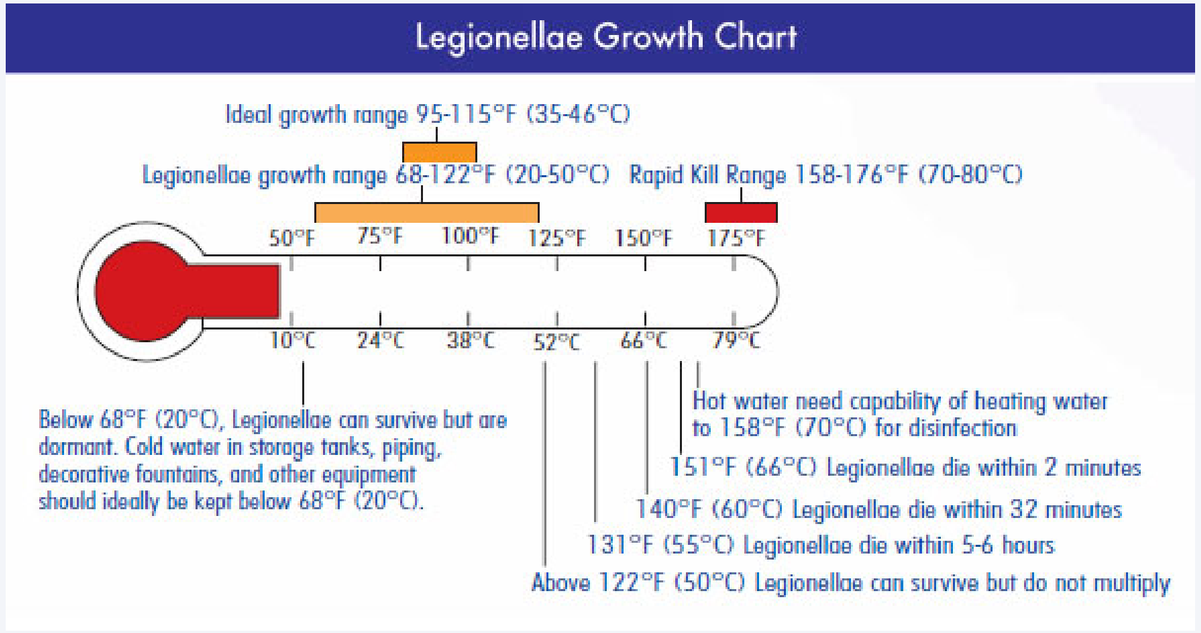
LEGIONAIRES DISEASE
Grows below 122 F, Dies above 140 F

STORING AT 140F
Kills Legionella and increases effective tempered water volume when mixed down.

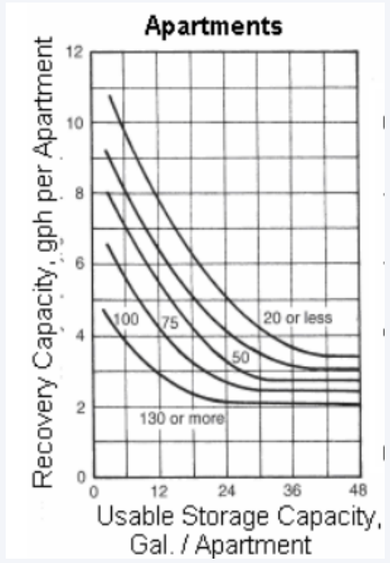
SLOWER RECOVERY RATE
Heat pumps water heaters known to have a slower recovery rate when compared to traditional water heater methods.

BALANCE GENERATION VS. STORAGE
Find balance between reasonable amount of water storage and number/ size of pumps.

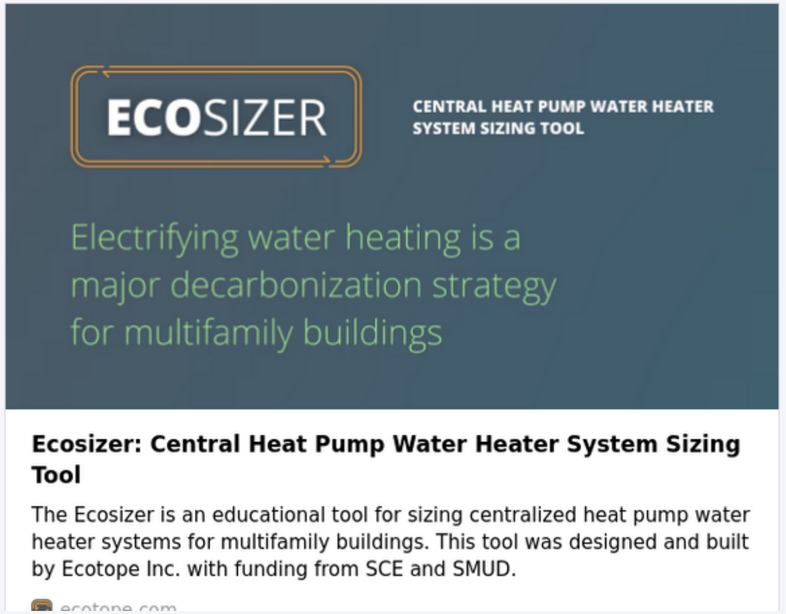
LIMIT USE OF ELECTRIC RESISTANCE
Use staged electric resistance only if other options not available.
Reserve back up electric resistance for emergency use only.



* Image courtesy of Powers



* Image courtesy of 2015 ASHRAE HVAC APPLICATIONS HANDBOOK



Identifying
REFRIGERANT TYPES

	OPERABLE DOWN TO	PRODUCES H2O TEMP UP TO	GLOBAL WARMING POTENTIAL
 R134A	40F	170F	1300 GWP
 R-410A	-5F	140F	2088 GWP
 R-744 (CO2)	-20F	170F	1 GWP*

AND OTHERS...

*May not require double wall heat exchanger

Project Examples

DESIGNING CENTRAL HEAT PUMPS FOR DHW

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MULTIFAMILY

LOCATION

Ithaca, New York

ITHACA ARTHAUS

ITHACA, NEW YORK

PROJECT SIZE

100,000 SF, 124 affordable housing units, 5-story

SERVICES PROVIDED

MEPS+FP design services; energy consulting, energy modeling, commissioning; testing & verification

PROJECT HIGHLIGHTS

- All-electric building, utilizing heat pumps for space heating/cooling and domestic hot water
- Envelope system with significantly better-than-code R-values
- Projected to achieve over 50% site energy savings over a code baseline building; projected site EUI of 25.6 kBtu/SF/yr
- Energy Star Multifamily High Rise Certified
- Incentives through NYSERDA's Multifamily New Construction Program and NYS Clean Heat, over $300,000 of incentives secured for project

OCCUPIED SINCE OCTOBER 2021

DHW SYSTEM OPTIONS

MULTIFAMILY

1

Central GSHP

3

Central CO2 ASHP

2

Central R-410A ASHP

4

Semi-Central Hybrid Water Heater

DHW SYSTEM DESIGN
MULTIFAMILY

Total storage:
Peak usage @ 125 F

Number of heat pumps:
Capacity to recover max daily usage at 16 hour maximum to allow for heat pump rest and defrost

Sized with the following assumptions

- 1.5 GPM shower head flow
- 104 1-bathroom units, 1.8 ppl/apt
- 20 2-bathroom units, 2.5 ppl/apt
- 8 commercial clothes washers

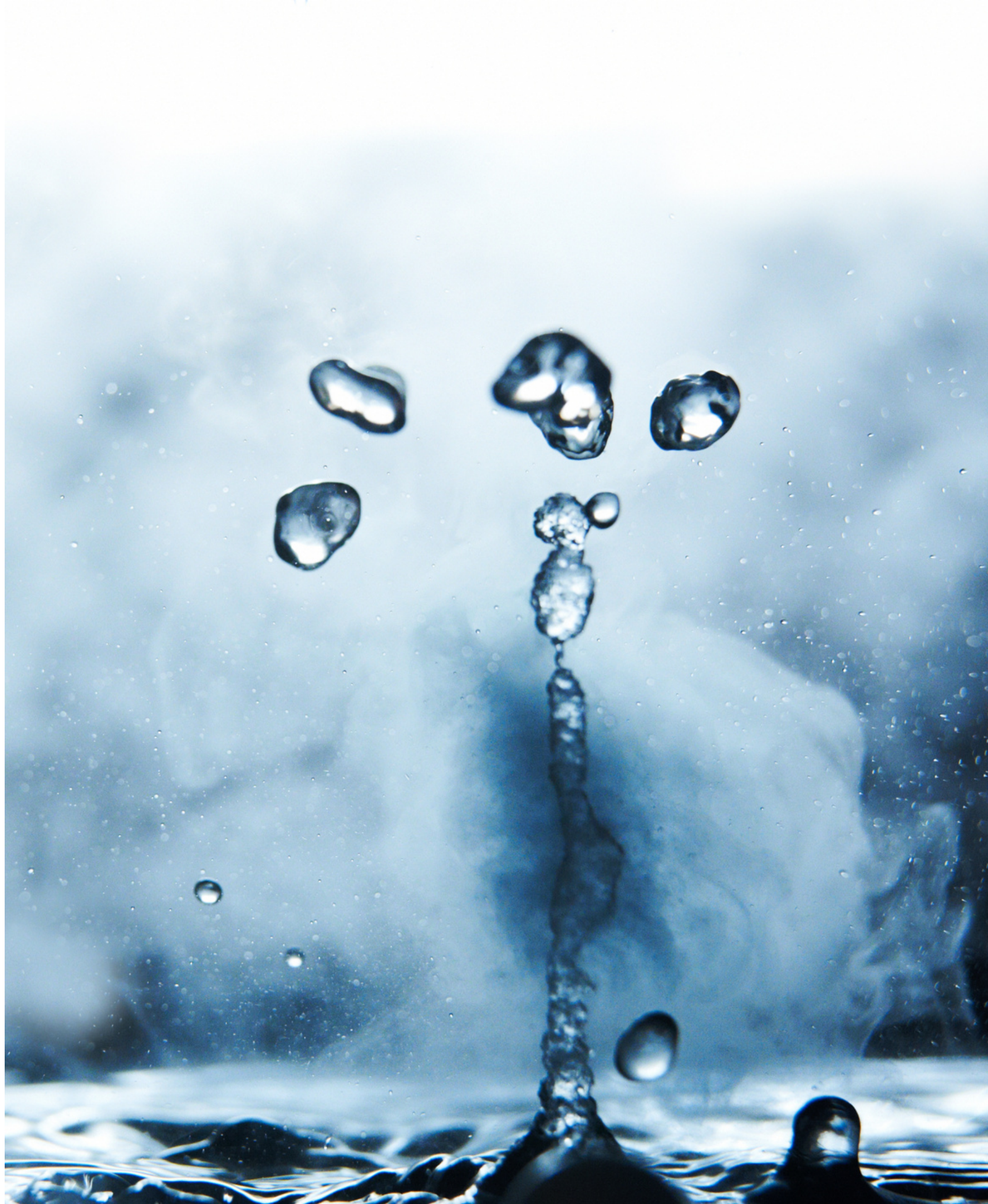
Peak hourly usage
1248 GPH

Max daily usage
4740 Gallons

Design challenges

DOMESTIC HOT WATER DESIGN

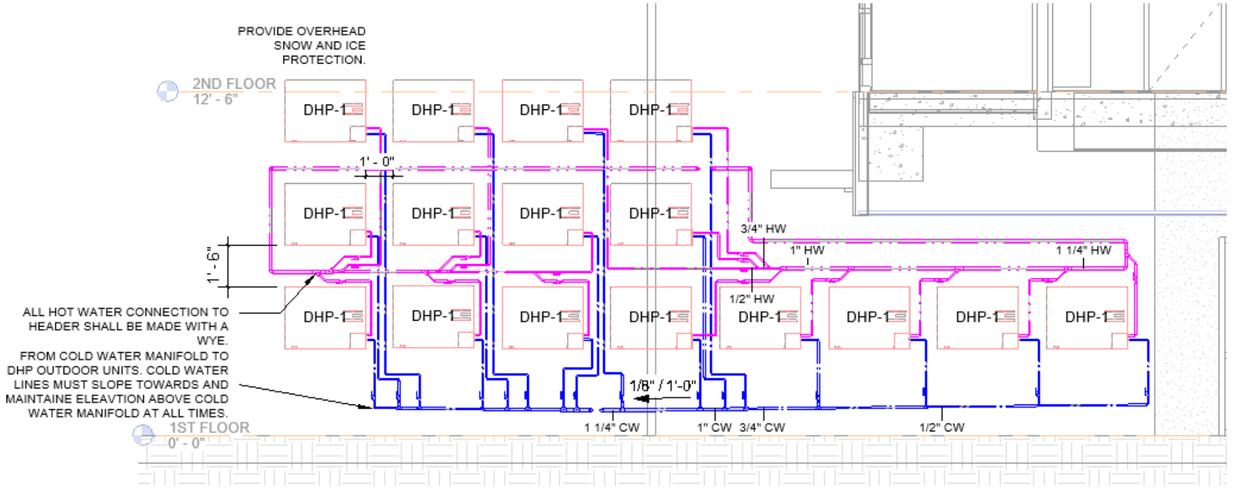
- Freeze protection of water
- 100% back up system
- Space limitation, large hot water storage requirement

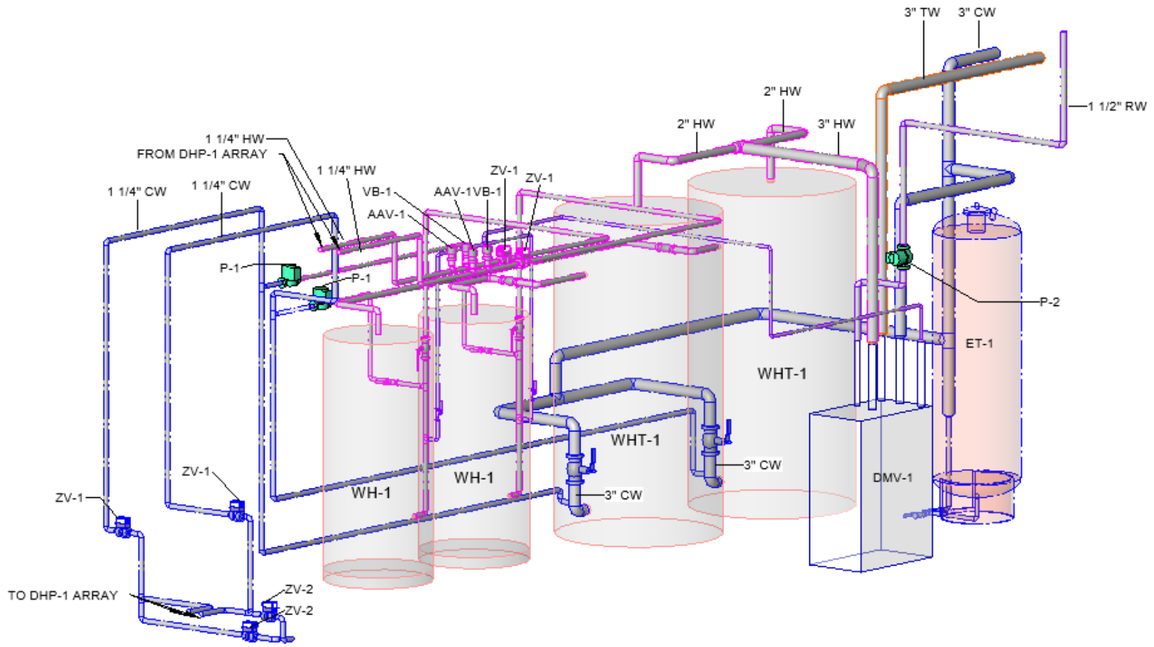


Freeze protection of water

DOMESTIC HOT WATER DESIGN

- Water exits building envelope, which presents risk of freezing during a power outage
- Automatic drain back and refill system
- 6 W/ft self regulating heat trace tape

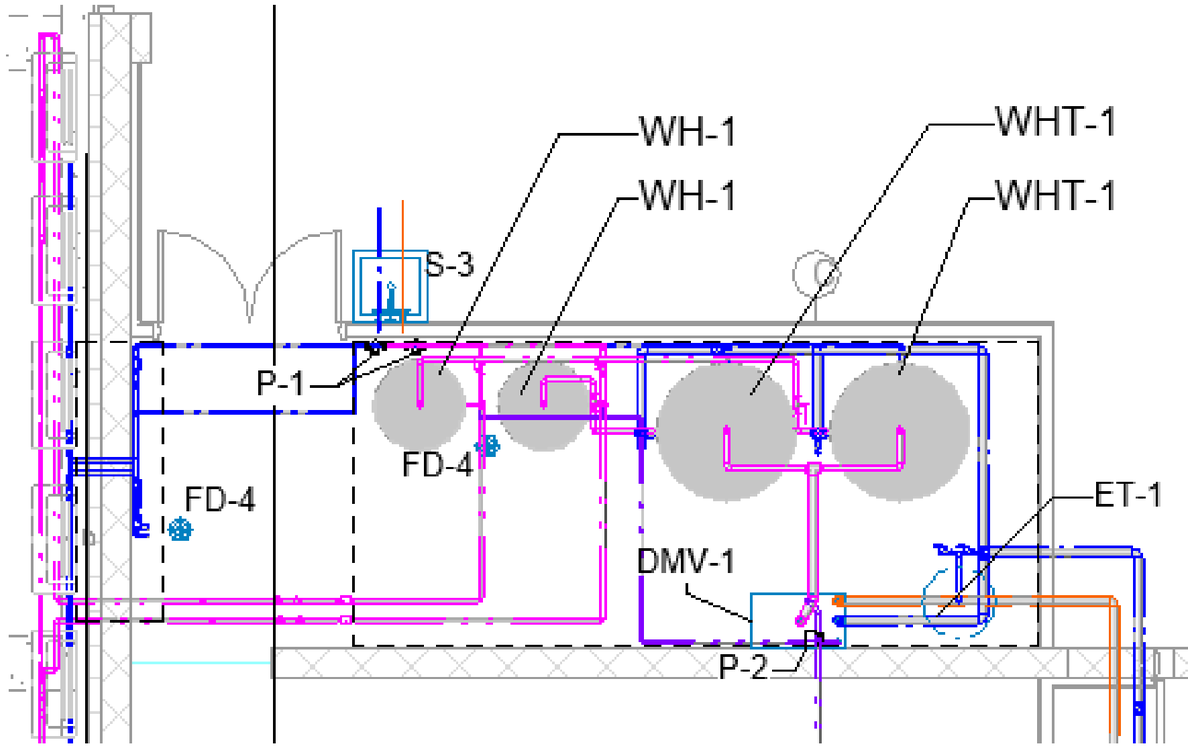




Space limitation

DOMESTIC HOT WATER DESIGN

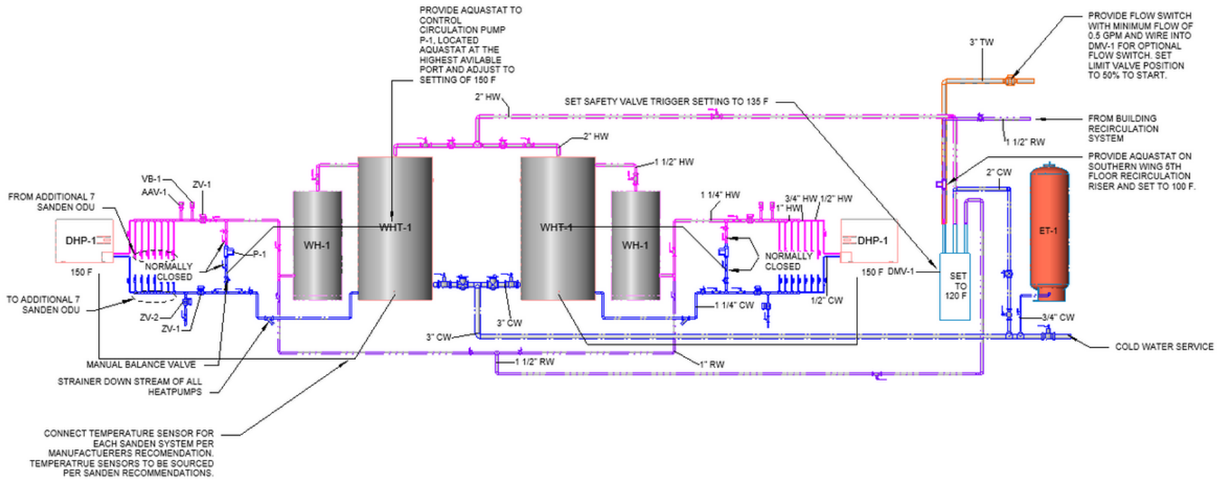
- Limited space in hot water room
- 1248 gallons of 125F water required
- Combined extra storage of 120 Gallon electric resistance tanks
- "Charge" tanks to 150F to allow for 30% more capacity



100% back up

DOMESTIC HOT WATER DESIGN

- 100% electric resistance
- (2) 36 KW 120 Gallon water heaters in series between heat pumps and storage tanks
- Manual switch over to limit reliance on electric resistance

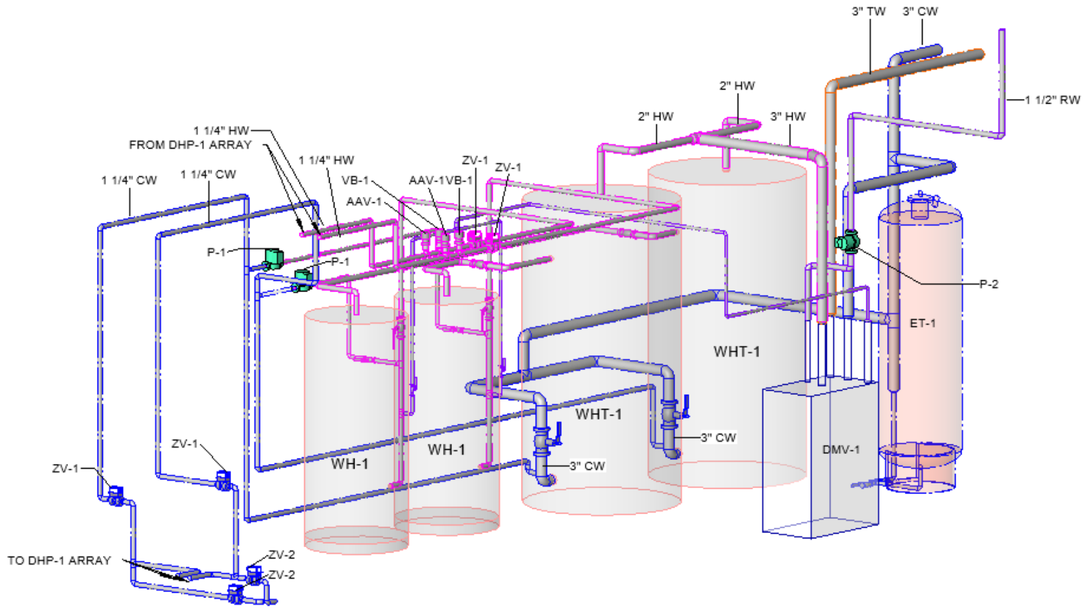


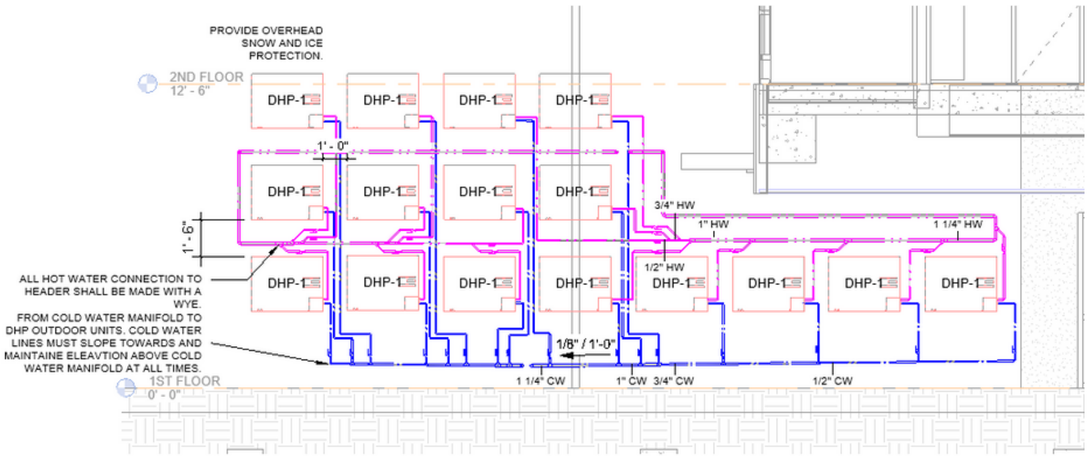
Final System Selection

Central CO2 ASHP
with 100% electric resistance back up

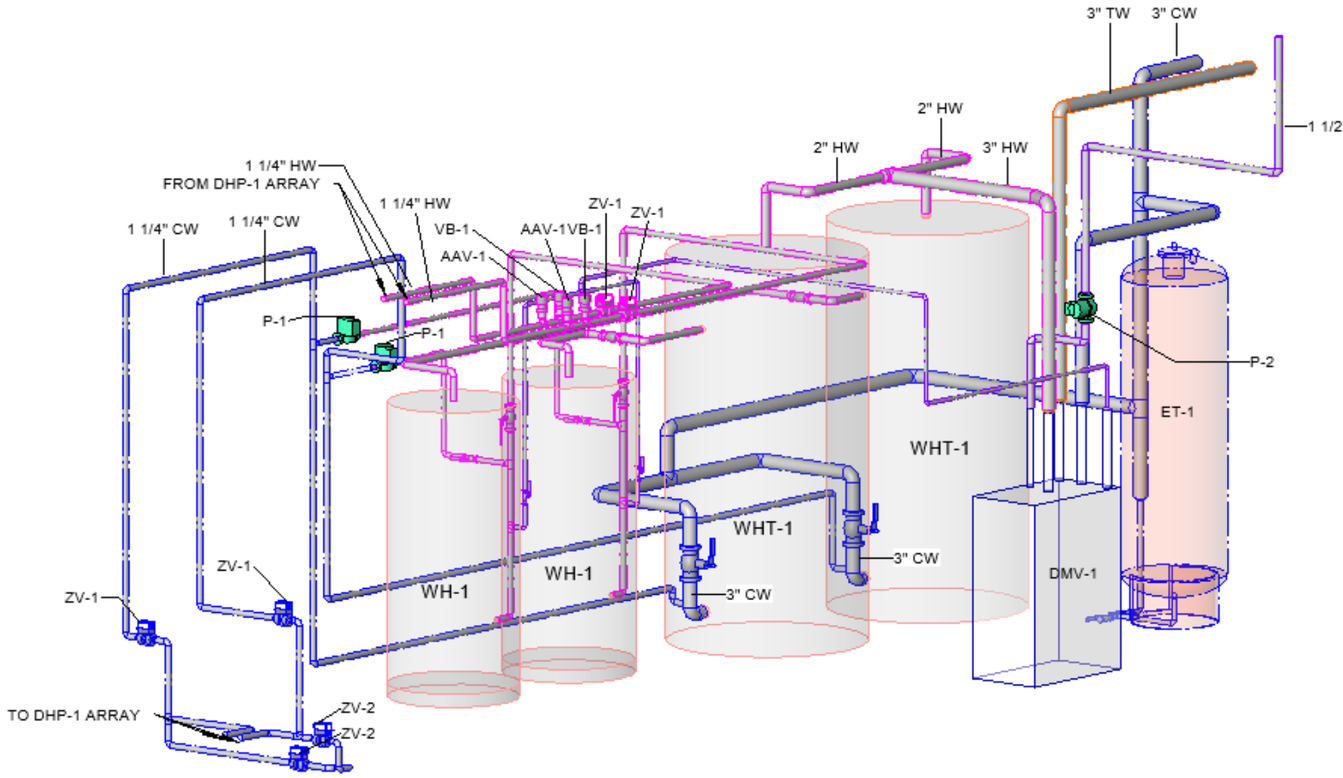
- **Primary** Two parallel systems made up of (8)HP WHs in parallel (piped reverse return) (1) electric resistance water heater and (1) 500 gallon storage tank with target temp 150F
  - Total of (16) 15,400 BTU/ hr HP WHs; auto drain back; 1248 gallons of storage

- **Secondary** (2) 36 kw electric resistance water heaters and (2) 500 gallon storage tanks

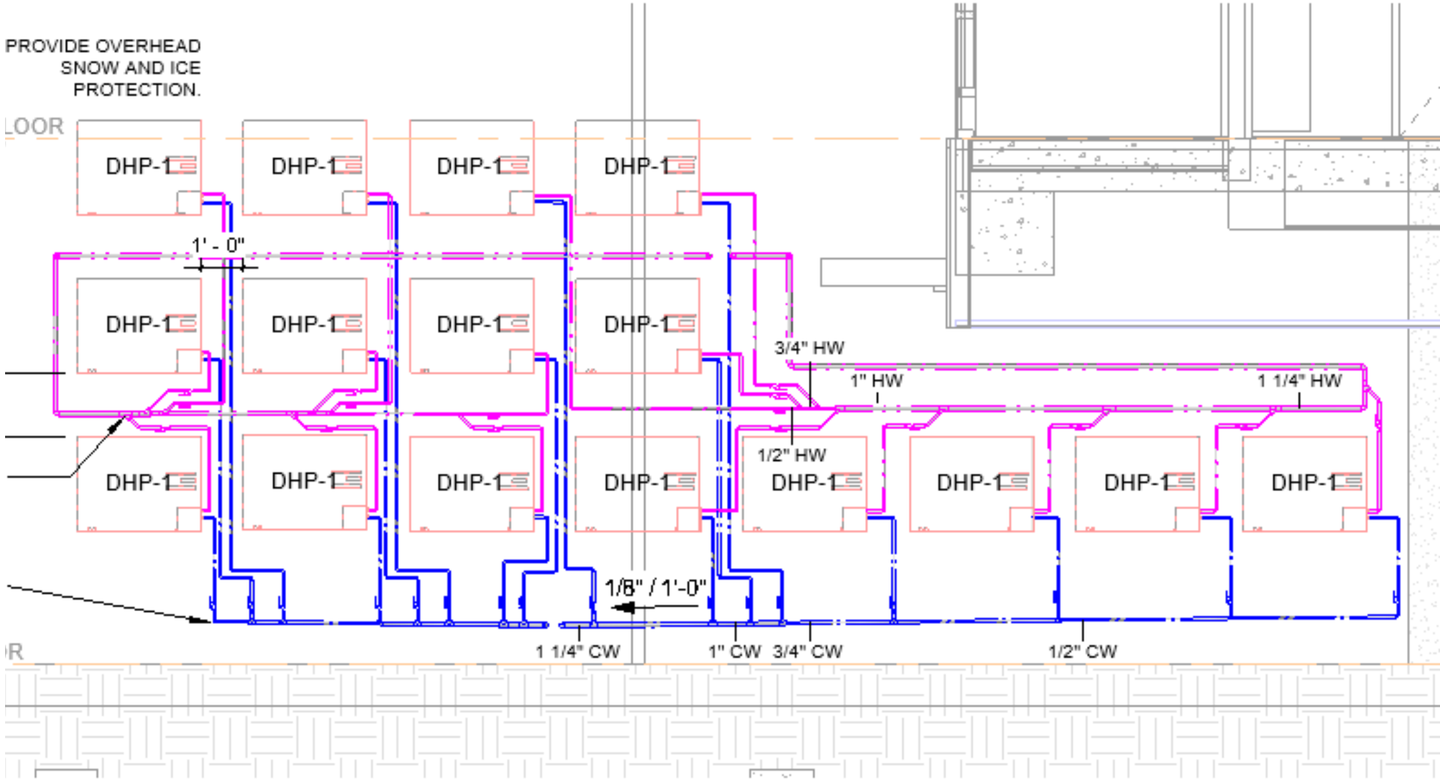




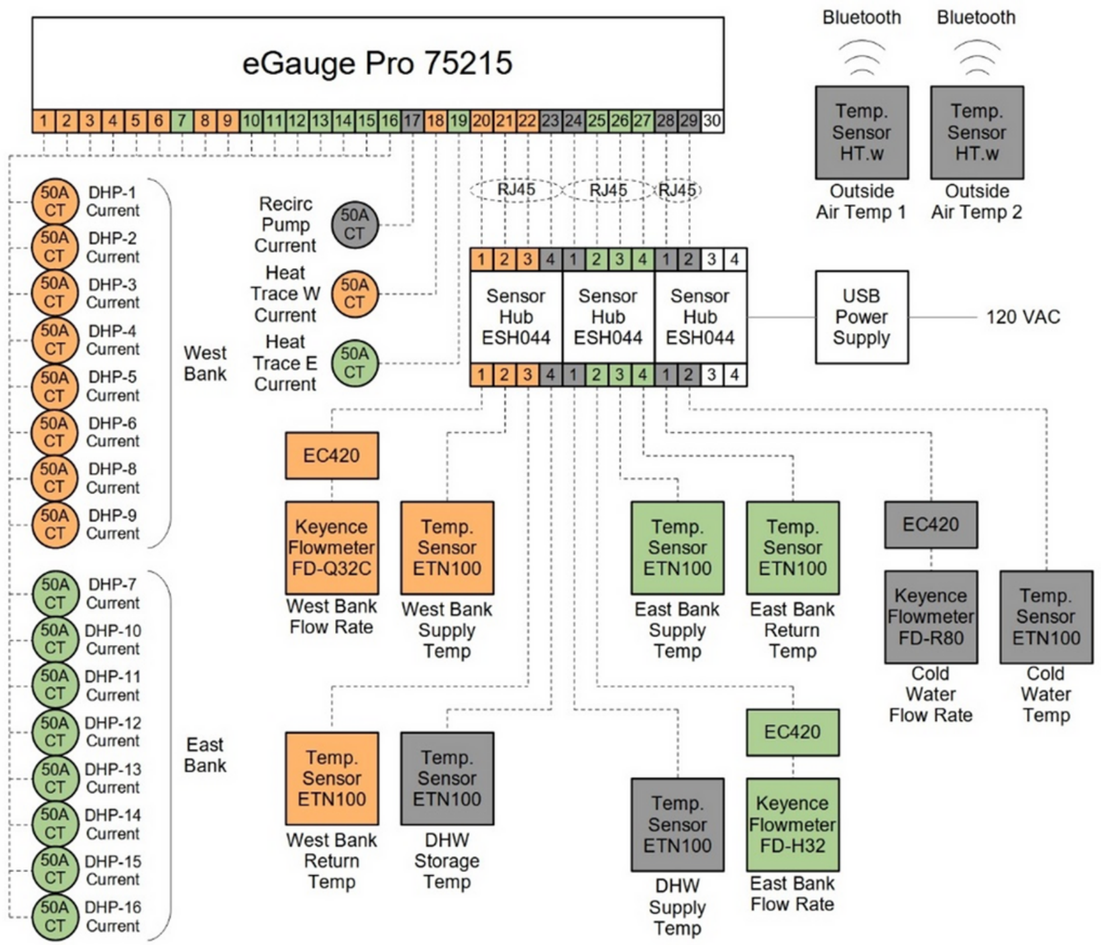
Final System Selection



Final System Selection

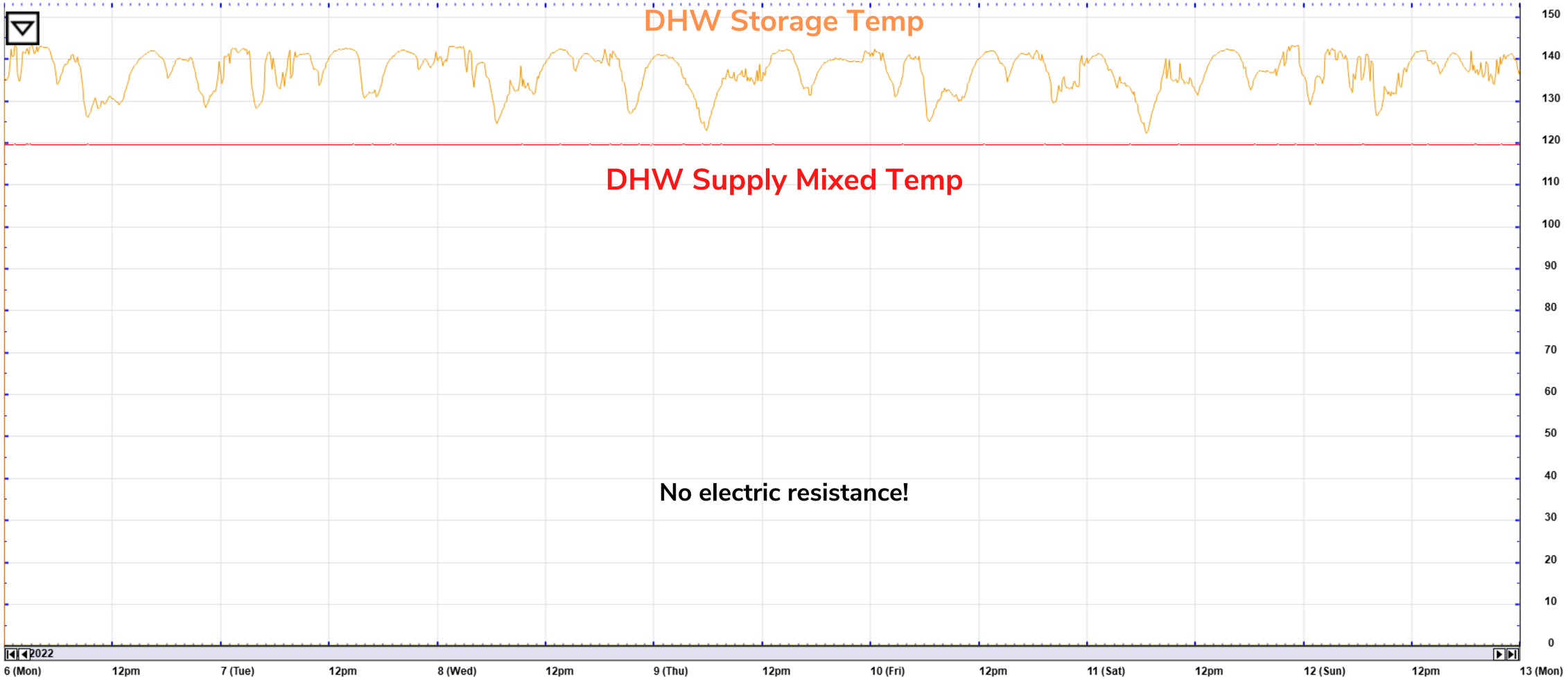


Measurement & Verification



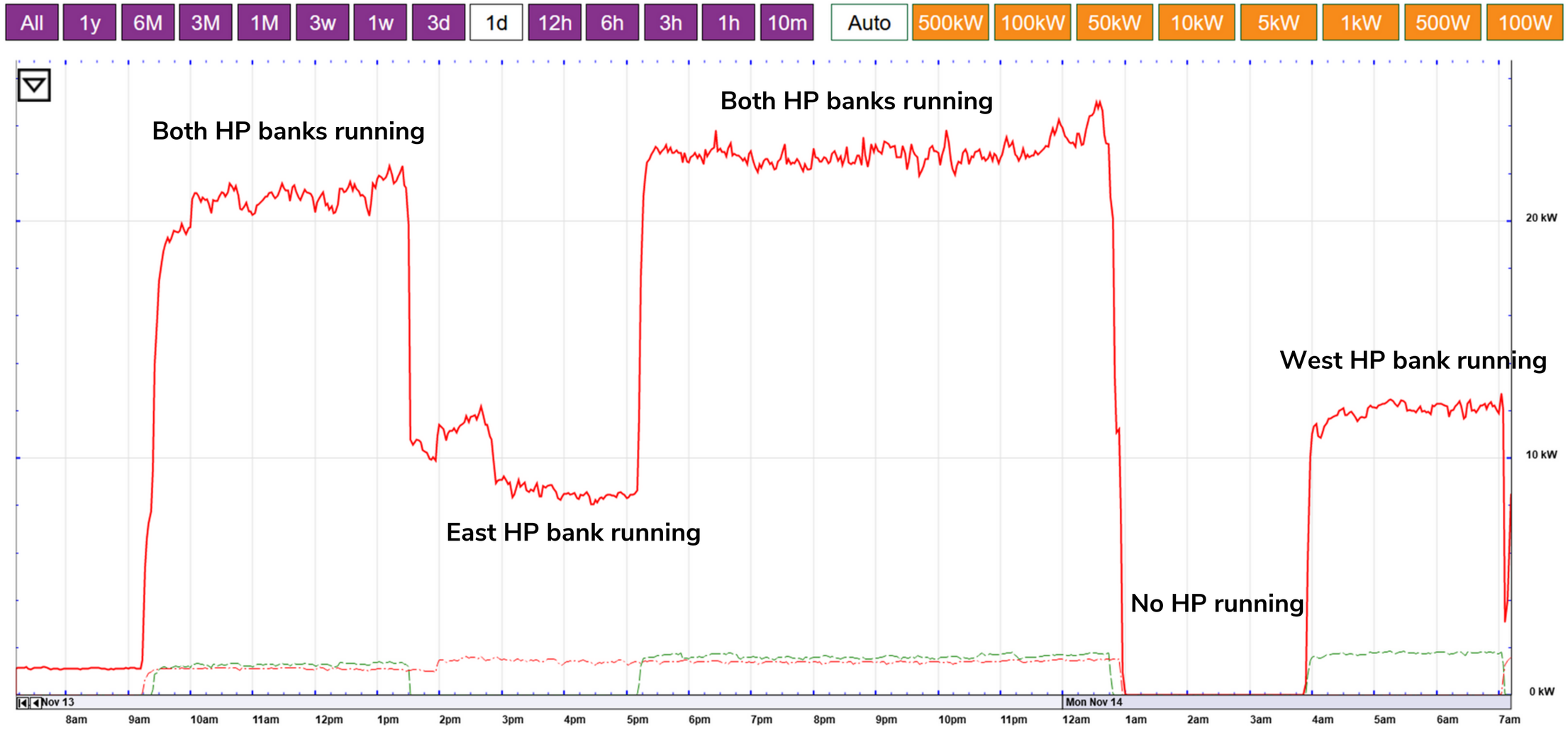
Ithaca Arthaus

measurement verification



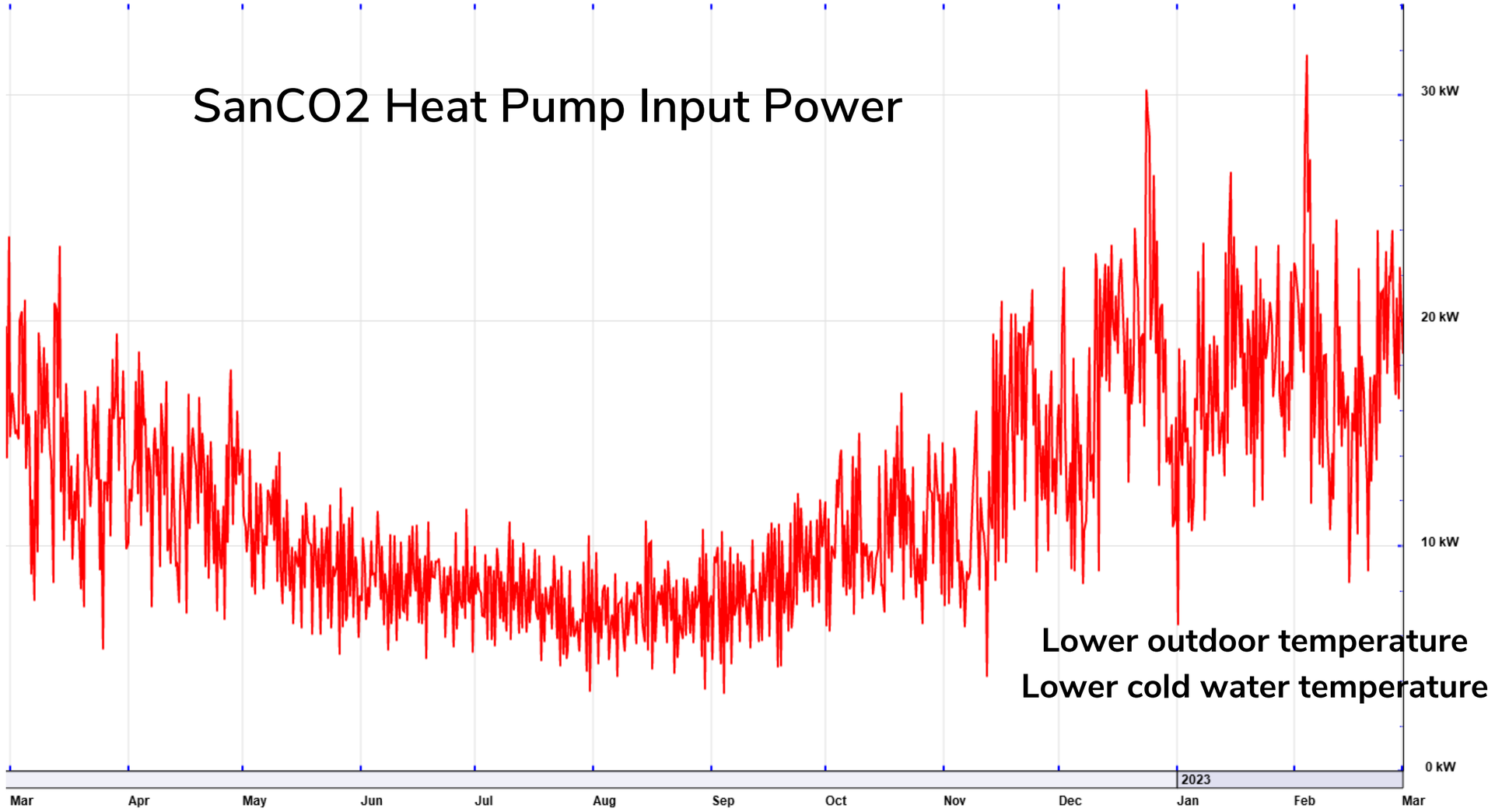
results

measurement verification



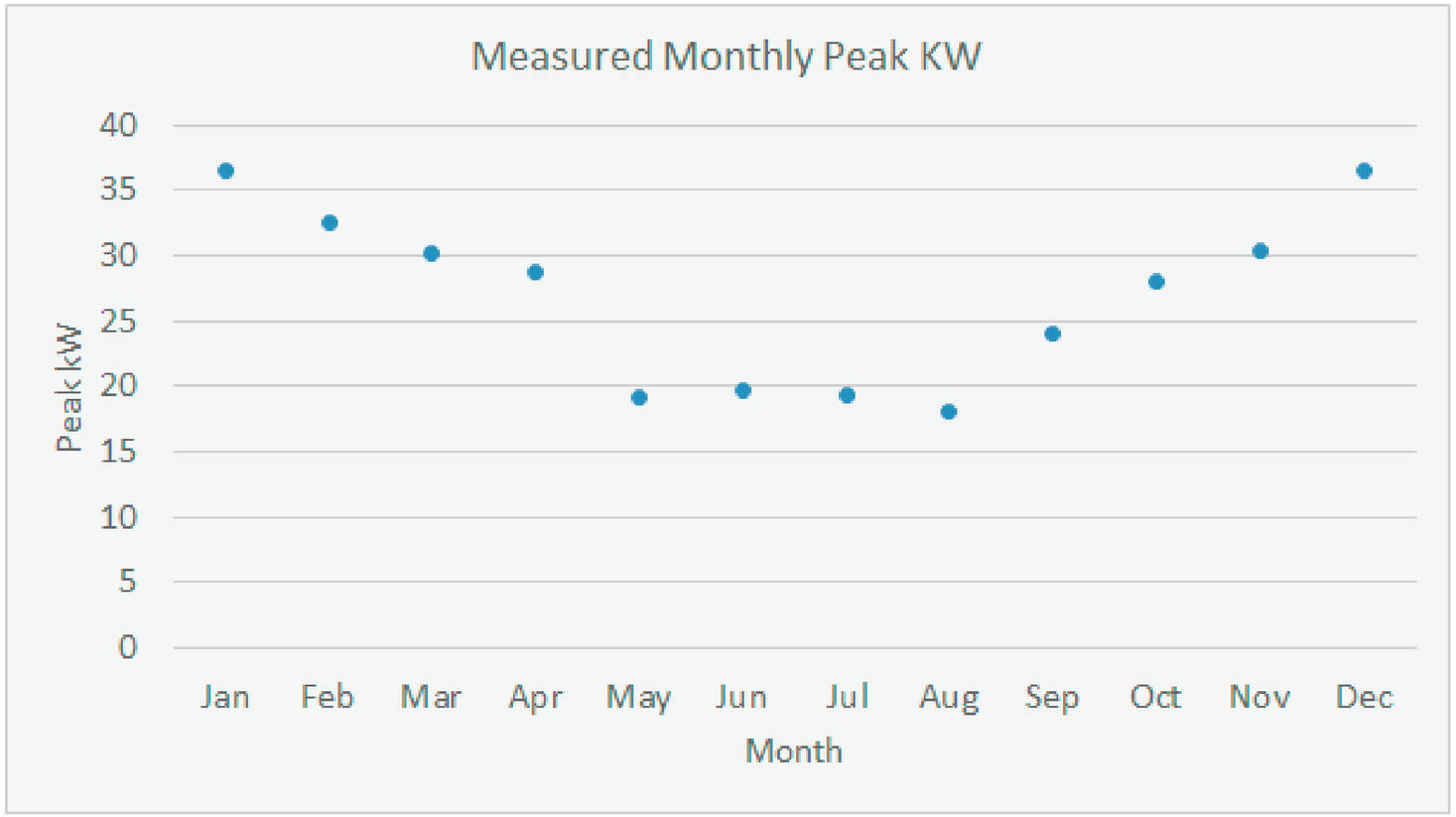
results

measurement verification



results

measurement verification



Central Heat Pump System

Peak Input Power: 37 kW

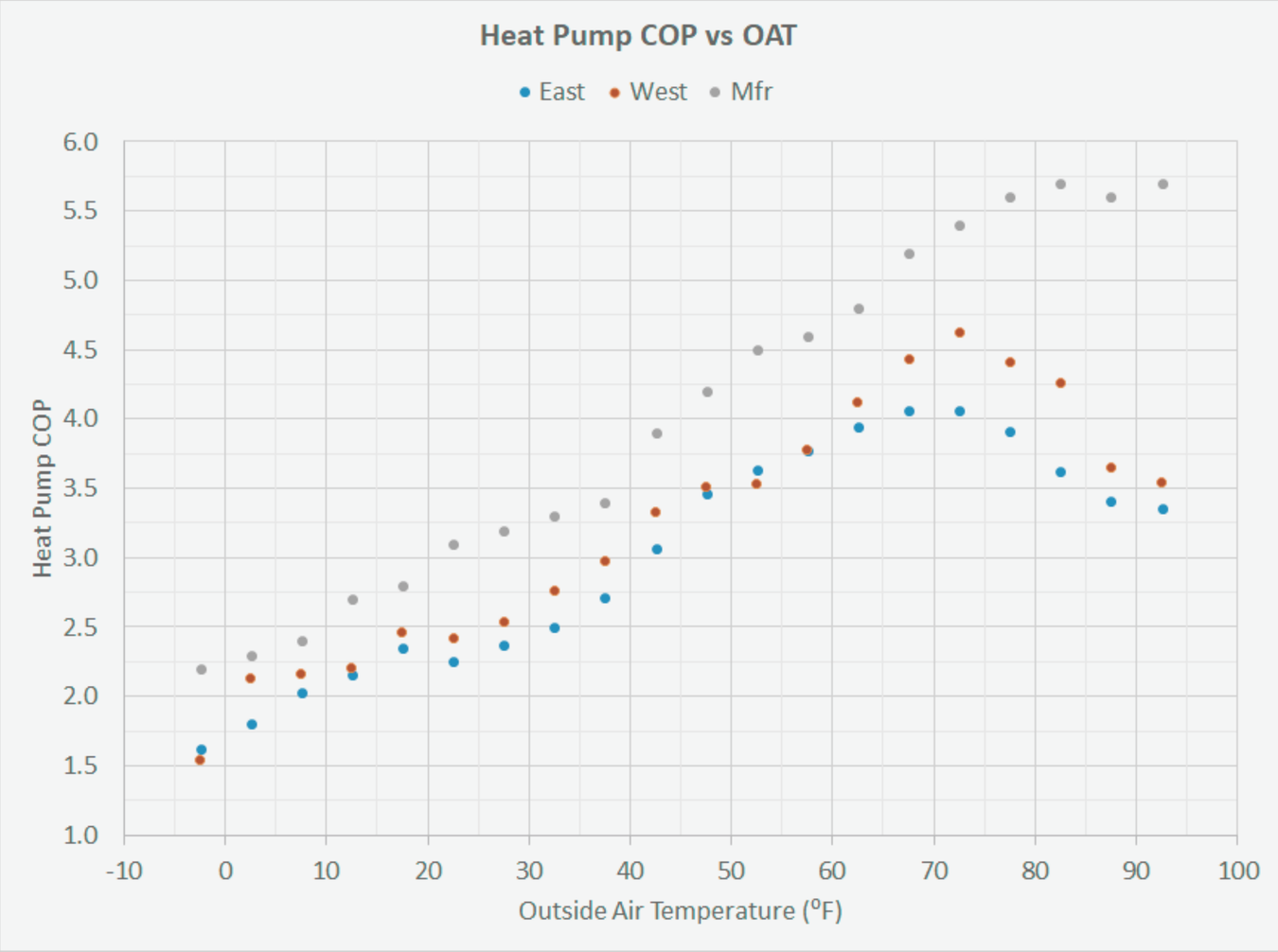
~0.3 kW/apartment

Individual Electric Resistance Tanks

4.5 kW * 124 = 558 kW * NEC 220.84 demand factor 23% = 128.3 kW or ~1.0 kW/apt

results

measurement verification



June 4, 2022 - February 27, 2023

East HP Bank COP: 3.17

West HP Bank COP: 3.62

Measured Heat Pump COP: 3.41

- System COP: 2.01
- System Losses: 37%
  Includes Standby Losses + Recirc Losses

results efficiency

measurement verification

Total DHW Energy Usage and Costs February 15, 2022 - February 14, 2023

105,403 kWh/yr
850 kWh/yr/apartment
$15,969/yr
$129/yr/apartment

Based on Current Commercial Utility Rates
$12.38/kW and $0.114/kWh

measurement verification

Assuming Electric Resistance In-Unit Water Heaters

~227,625 kWh/yr

1,836 kWh/yr/apartment

$30,502/yr

$246/yr/apartment

- Based on Current Residential Utility Rates $0.134/kWh
- **~$14,533 yearly energy cost savings from going with central heat pump DHW**

construction costs

System	Equipment Costs	Equipment Install Costs	Central Distribution System Costs	Total Cost[1]	Total Cost/SF	Cost Premium[2]
Central SanCO2	$86,000	$107,000	$45,000	$238,000	$2.33	$125,800
Central LG Hydro Kit	$91,000	$77,000	$45,000	$213,000	$2.09	$100,800
Central Electric Resistance	$25,000	$42,200	$45,000	$112,200	$1.10	-
Individual Electric Resistance	$60,000	$192,200	$0	$252,200	$2.47	-

Pricing Assumptions

- Pricing based on 2021 costs
- Pricing based off the Ithaca Arthaus, 124 Unit Building, ~102,000sf in Ithaca, NY
- Costs exclude apartment distribution which would be the same in each scenario
- Cost premium is calculated off of central electric resistance system
- NYS Clean Heat Incentives of ~$50,000 NOT included in costs above (will futher reduce cost)

<10 year payback

measurement verification

Summary

- System is meeting load and temperature requirements
- No electric resistance needed!
- Delivered hot water issues were distribution related
- Balancing of systems very important
- Heat pumps operating efficiently
- System losses are high, needs more attention
- Cost effective solution over electric resistance

results

Ironworks Ithaca

ITHACA, NEW YORK

PROJECT SIZE

113,000 SF, 129 dwelling units, 5-story

SERVICES PROVIDED

MEPS+FP design services; energy consulting, energy modeling, commissioning; testing & verification

PROJECT HIGHLIGHTS

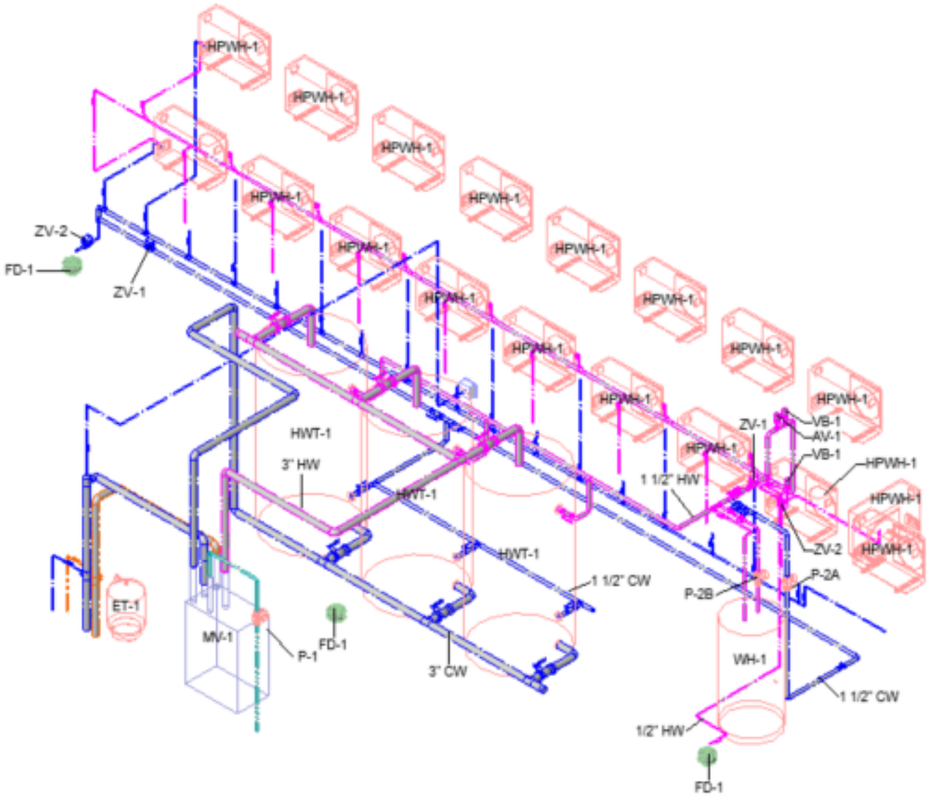
- All-electric building, utilizing heat pumps for space heating/cooling and domestic hot water
- Envelope system with significantly better-than-code R-values
- Projected to achieve over 50% site energy savings over a code baseline building
- Energy Star Multifamily High Rise Program
- Incentives through NYSERDA's Multifamily New Construction Program and NYS Clean Heat, over $500,000 of incentives secured for project

Final System Selection

Storage: (3) 505 gallon hot water storage tanks stored at 140 F

Primary heating system: (18) SanCO2 GS4-45HPA-US heat pump water heaters.

Secondary/ back up heating system: (1) 72 KW Electric resistance boilers.




Ironworks Ithaca

Challenges

Design challenges specific to this buildings needs

1

System recovery rate

The building required a recovery rate larger then the heat pump array was able to produce in de-rated conditions.

2

Automatic electric resistance

To address system recovery rate we decided to include automatic supplemental electric resistance and back up electric resistance when required in emergencies.

3

Pipe length

The total pipe length of the heat pump array exceeded the manufacturers allowable pipe length per heat pump.

Asteri Ithaca

ITHACA, NEW YORK

PROJECT SIZE

200,000 SF
181 affordable dwelling units
12-story

SERVICES PROVIDED

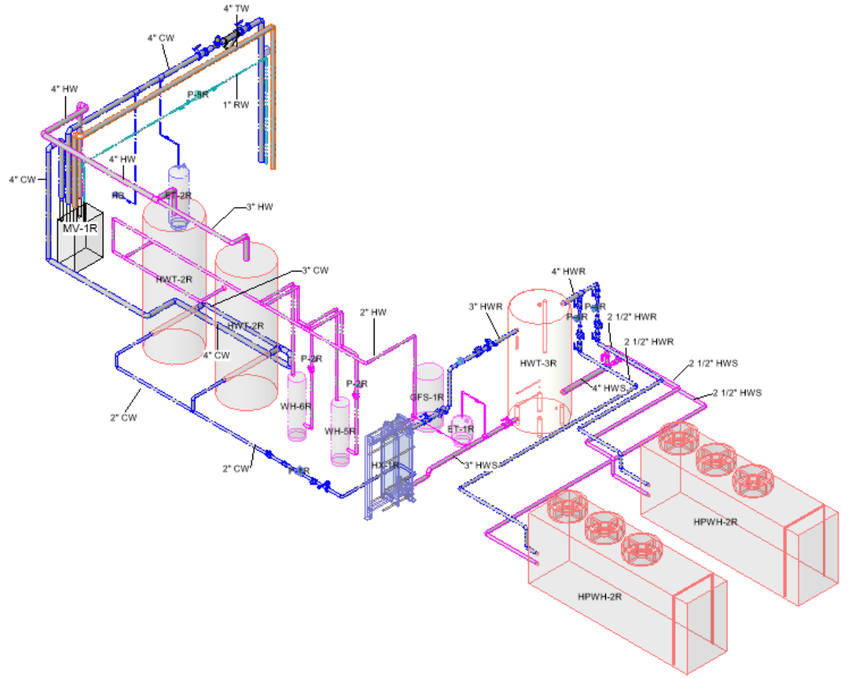
DHW design, ventilation design, electrical service sizing, energy consulting, energy modeling, Energy Star, testing & verification

PROJECT HIGHLIGHTS

- All-electric building, utilizing heat pumps for space heating/cooling and domestic hot water (both residential and conference center)
- All electric commercial kitchen serving 800+ person banquet all
- Energy Star Multifamily High Rise Program
- Incentives through NYSERDA's Multifamily New Construction Program and NYS Clean Heat, over $800,000 of incentives secured for project

Final System Selection Residential

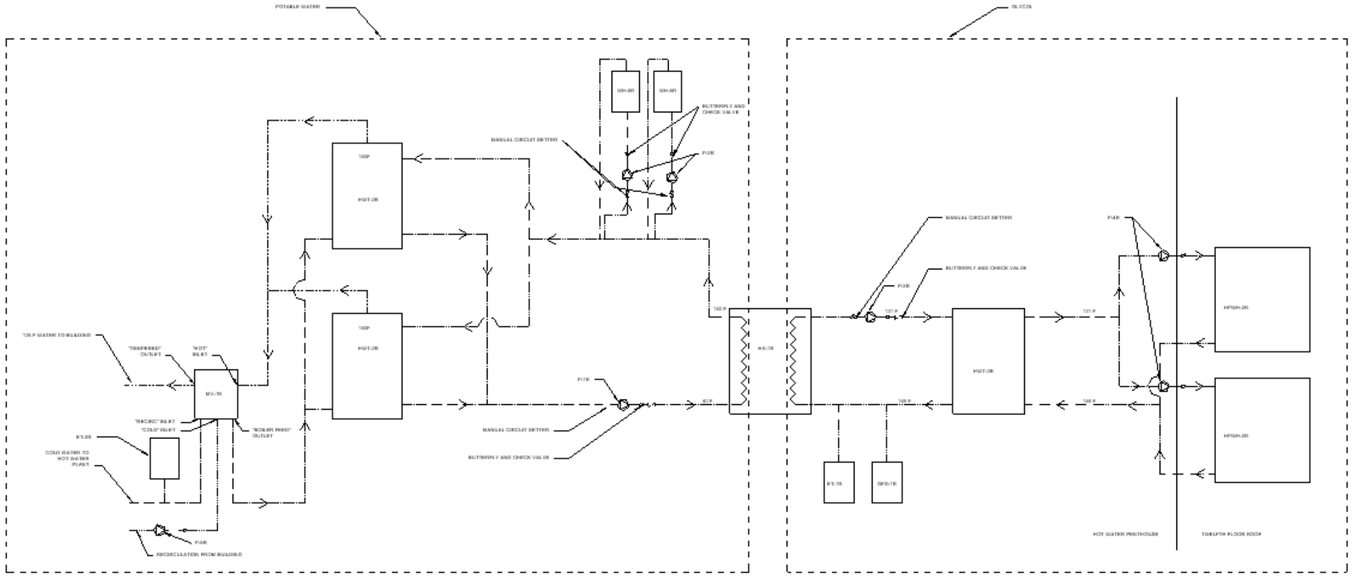
CENTRAL ASHP WITH SUPPLEMENTAL ELECTRIC RESISTANCE



- **Primary** (2) 540,000 BTU/hr heat pumps with glycol working fluid, separated by a double wall heat exchanger. (1) electric resistance boiler in series after heat exchanger

- **Secondary** When heat pumps not operable (1) 90 KW and (1) 108 KW electric resistance boiler

Estimated annual COP = ~2.0



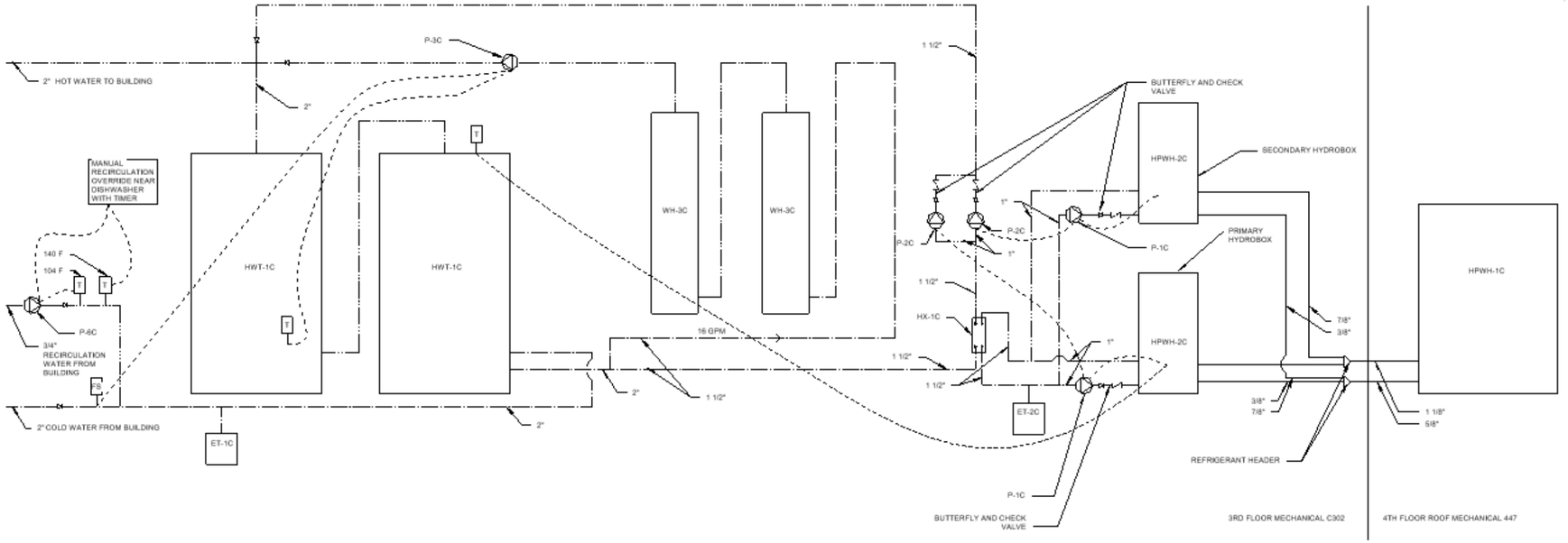
Final System Selection Conference Center

Central ASHP

- **Commercial Kitchen** LG VRF with K3 HydroKit composed of (2) 86,000 BTU/h hydrobox's (1) 14 ton condensing unit and back-up/supplemental electric resistance (2) 120 KW 119 gallon electric boilers and (2) 430 storage tanks.

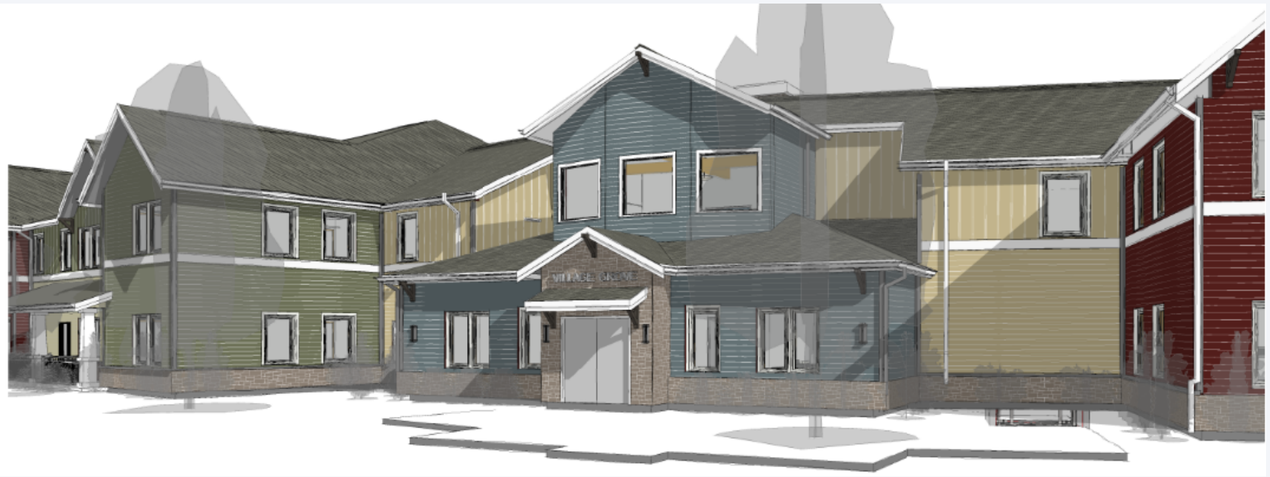
- **Bathrooms** Hybrid HPWH

- **Isolated Sinks** Instantaneous under sink water heaters

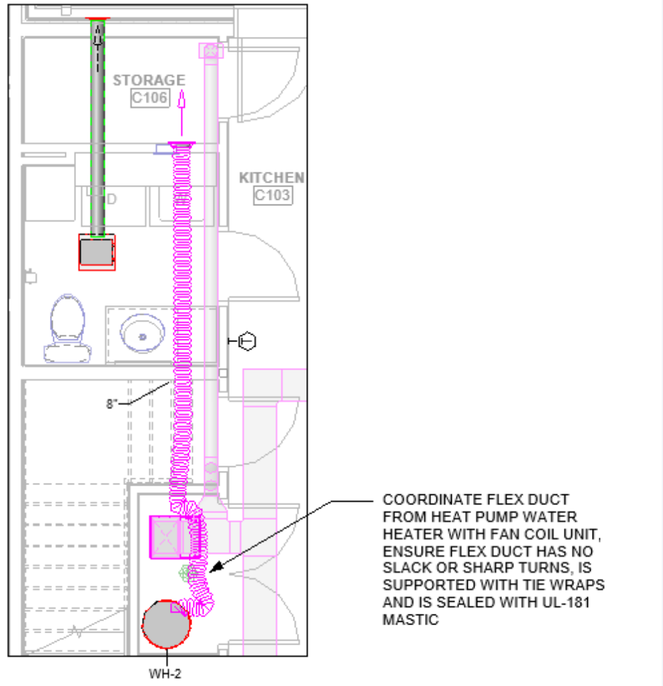


INHS Trumansburg Village Grove

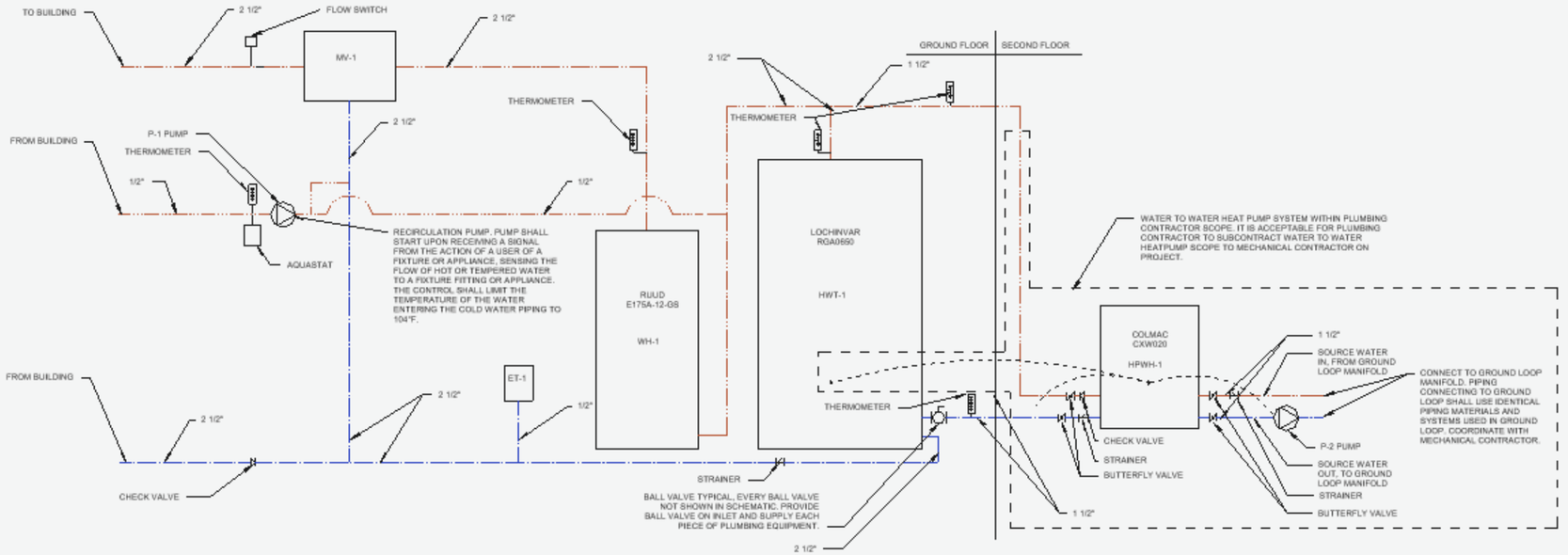
TRUMANSBURG, NEW YORK



TOWNHOUSE



MULTIFAMILY



Takeaways

CHALLENGES

Fully-engineered design

Commissioning/M&V

IDEAL EQUIPMENT

We'd like to see come on the market - bigger Sanden, etc.

WE HAVE OPTIONS

There are options for fossil-fuel-free DHW

DISCUSSION

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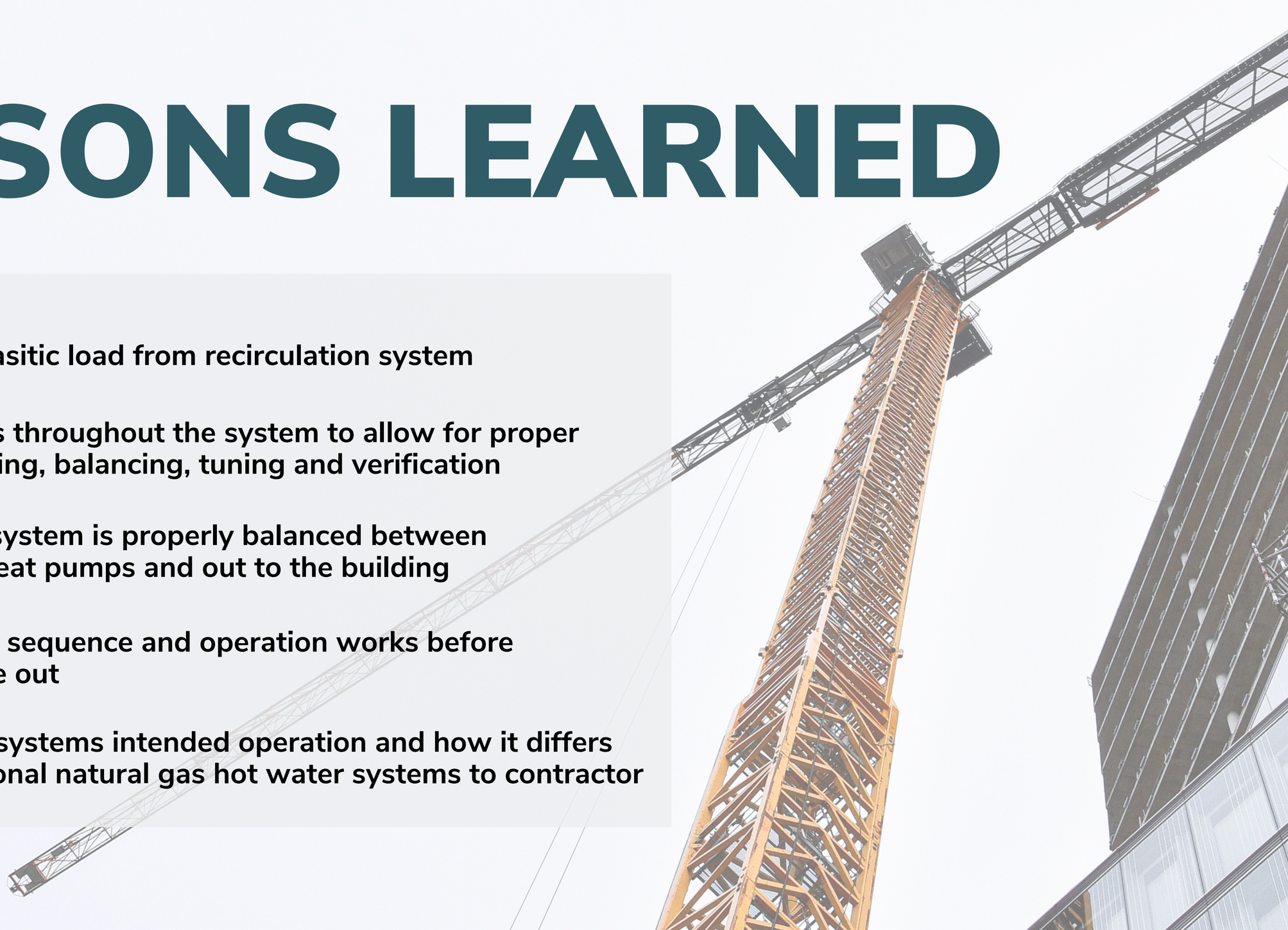
LESSONS LEARNED

1. Reduce parasitic load from recirculation system
2. Add sensors throughout the system to allow for proper commissioning, balancing, tuning and verification
3. Ensure the system is properly balanced between tanks and heat pumps and out to the building
4. Verify every sequence and operation works before project close out
5. Explain the systems intended operation and how it differs from traditional natural gas hot water systems to contractor



System install and operation
TROUBLESHOOTING

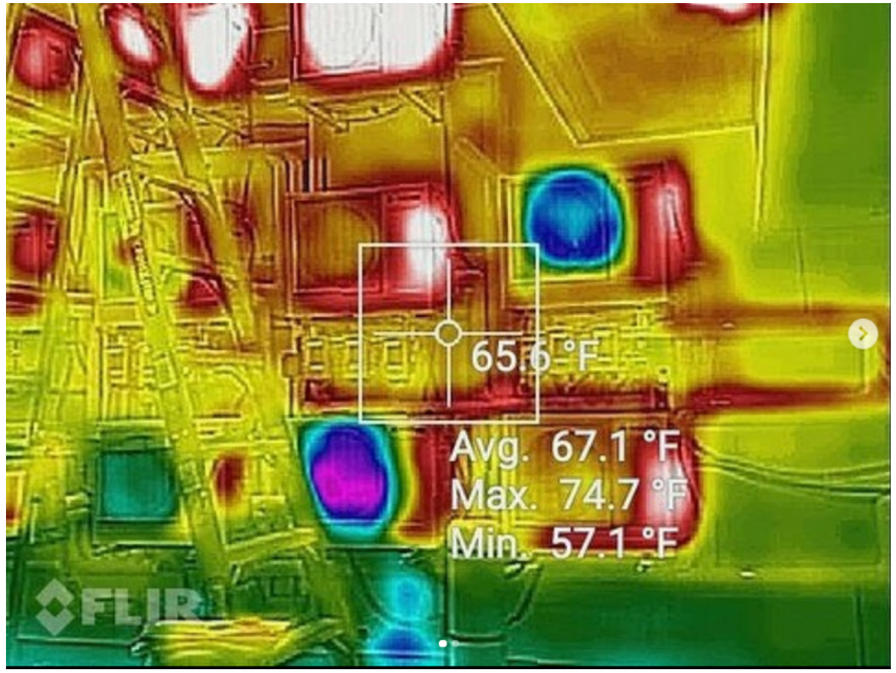
TAITEM ENGINEERING

Automatic drainback
TROUBLESHOOTING

- Automatic drain back system (triggered by a power outage) was trapping air in the heatpumps on refill causing an airlock at several unit, resulting in an error code requiring a manual air purge and restart of the affected heat pumps.

- 1st image shows that even though most of these units had their fans running, only two (the ones with the blue and purple) were actually transferring heat correctly.

- 2nd image shows all units operations correctly. With some minor adjustments to the timing of the startup of the system, we confirmed that the system could be fully purged of air, allowing all the units to operate as intended.



Condensate drip and freezing
TROUBLESHOOTING

CONCERN
Condensate from drain pan can drip on units below and freeze during the winter

Operation during construction

TROUBLESHOOTING

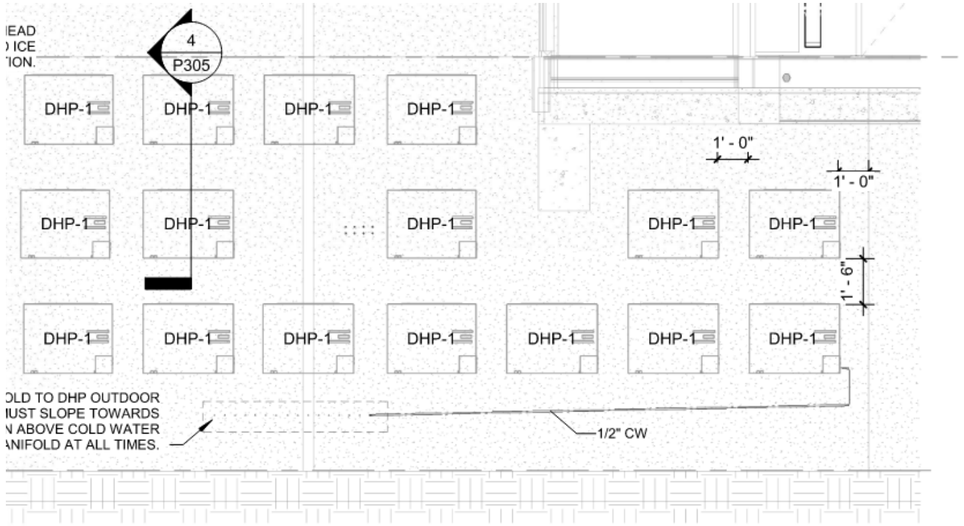
Contractor turned on the heat pump system to provide tempered water to the building. Usage profile was low (<100 gallon/day) with recirculation system operable and set to 104F

RESULT

- No new cold water introduced to the system and the tanks being mixed.
- Observed that tanks were not able to rise 120F and heat pumps would shut down due to high pressure (Low heat transfer at heat exchanger)
- Contractor temporarily switched to back up electric resistance for the rest of construction which addressed the issue.

Pipe length and layout
TROUBLESHOOTING

With the insulation requirements and amount of pipe penetrations clustered together, the contractor struggled to run piping through the wall as designed

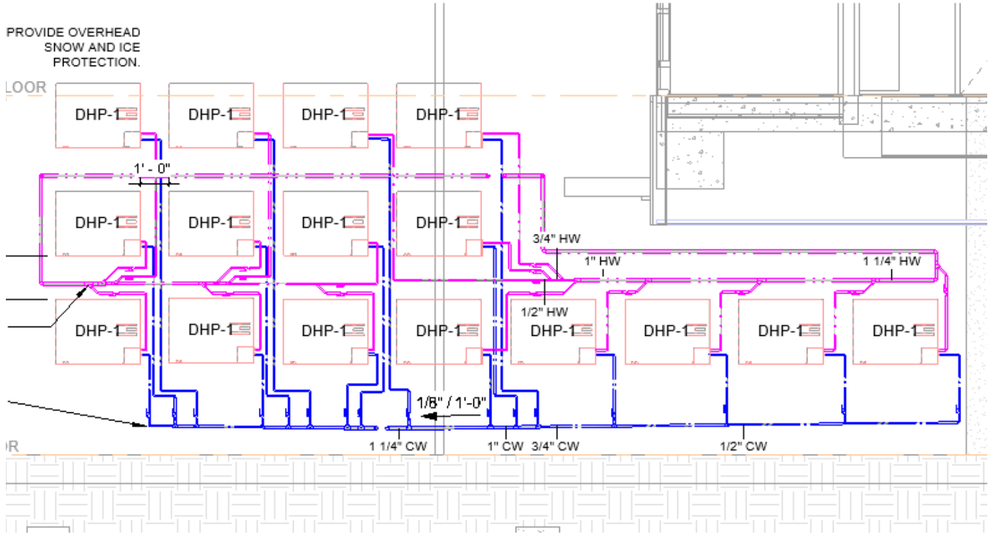


TOP IMAGE

- Original system design with pipe manifold within building envelope

BOTTOM IMAGE

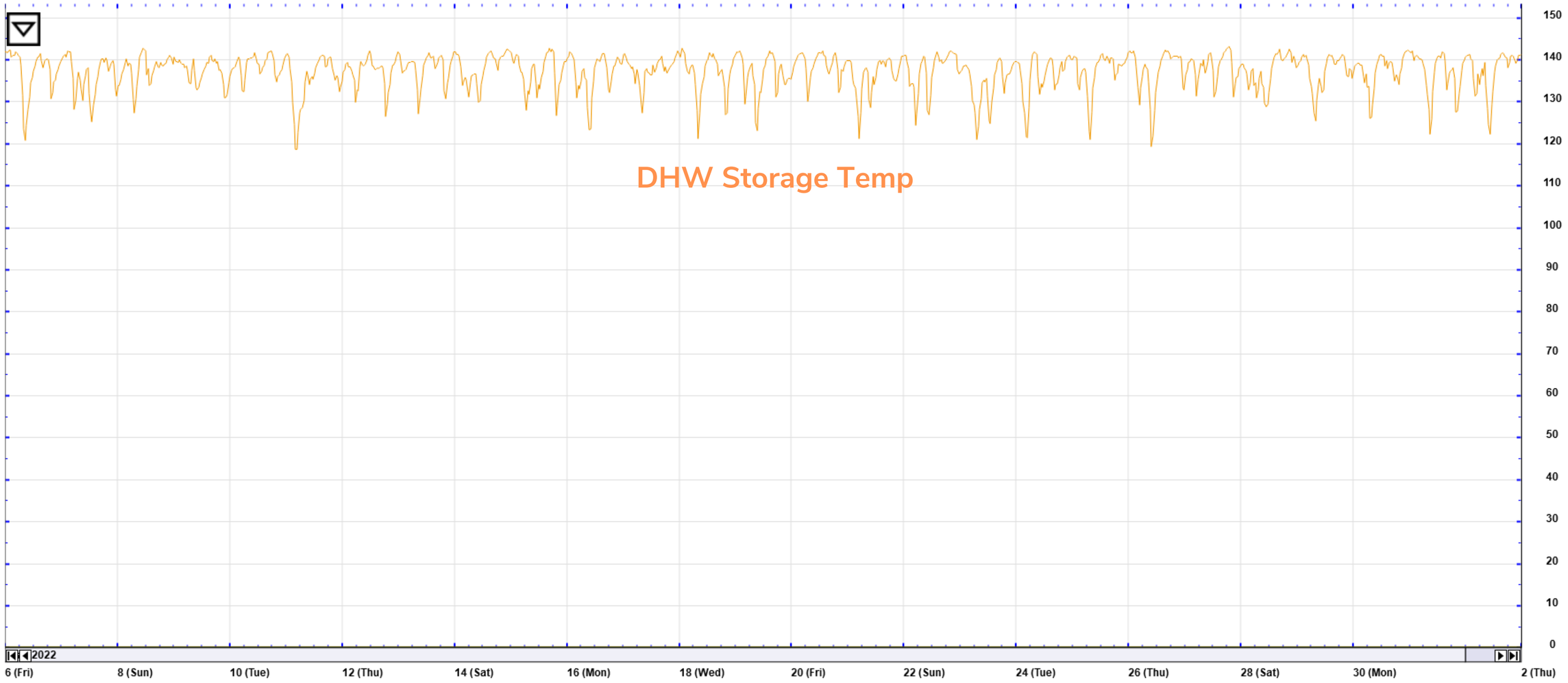
- Final design with pipe headers outside building envelope



NEW DESIGN ISSUES

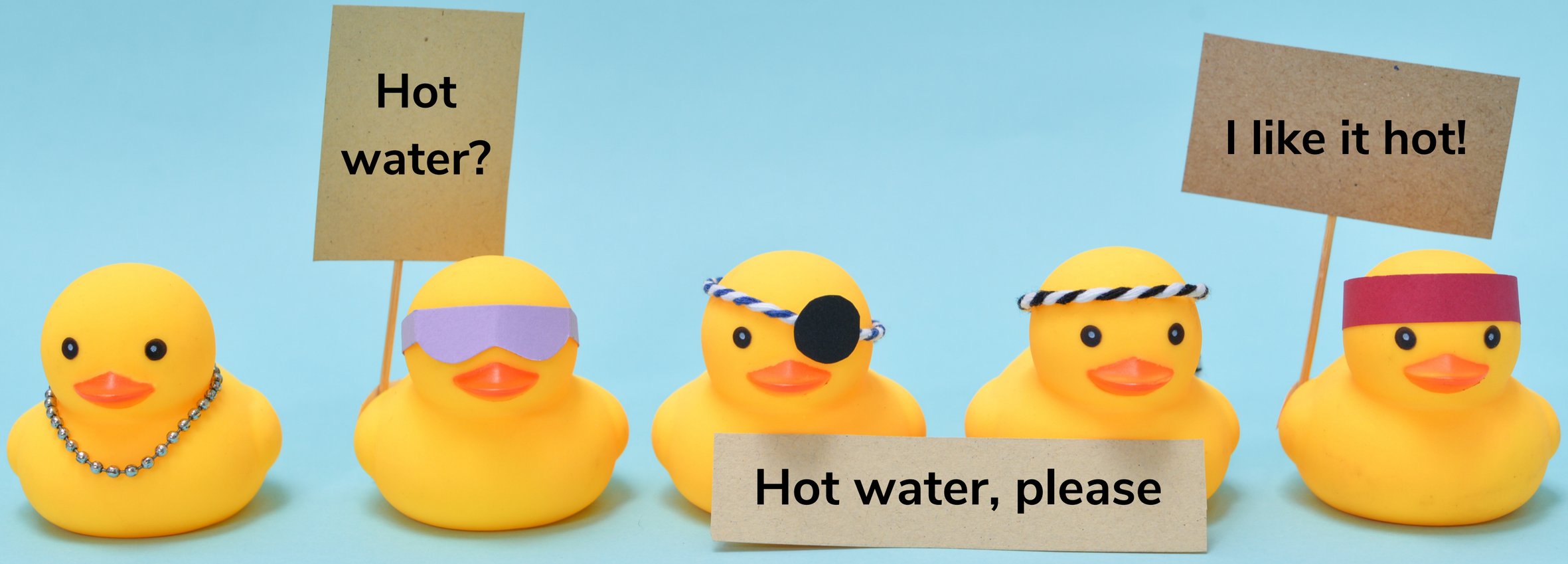
- Pipe length now got close to the total ~70' allowed per SanCO2 requirements

measurement verification

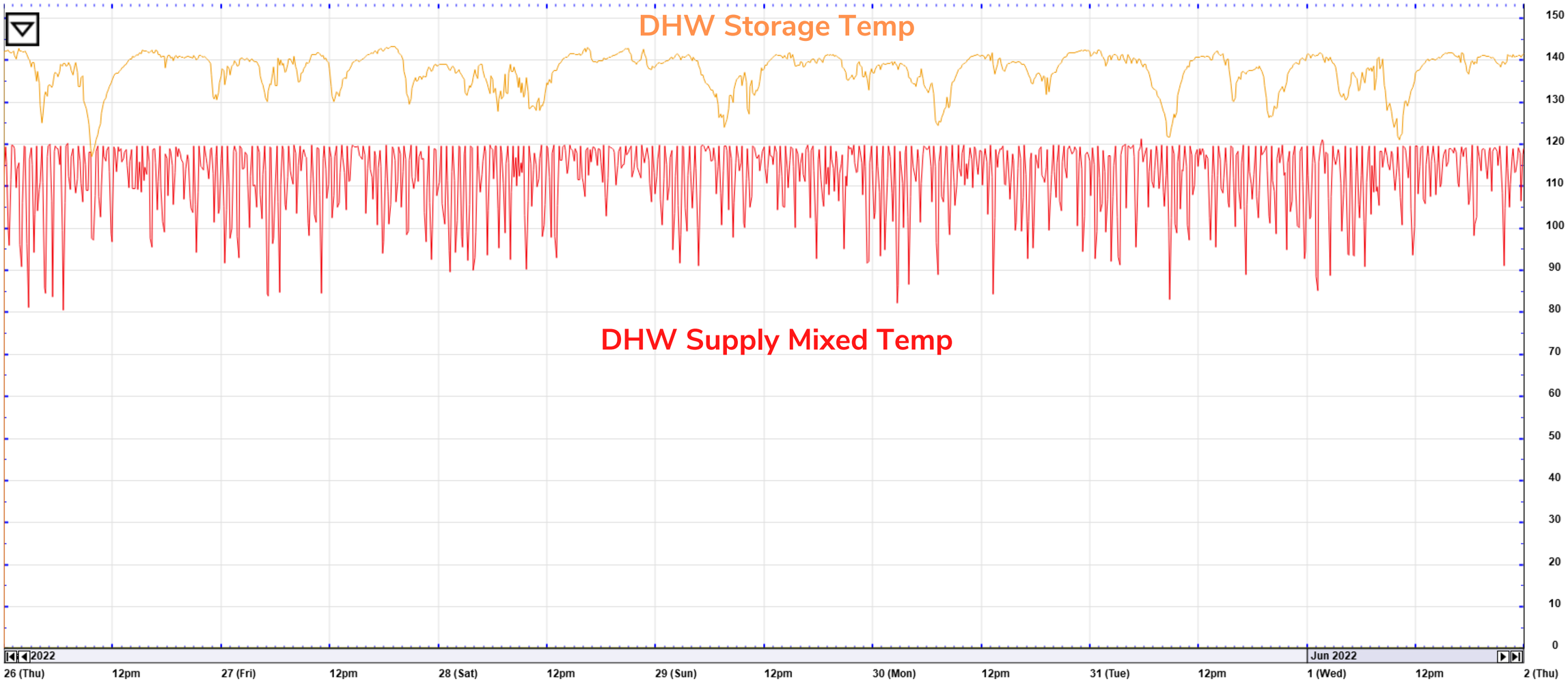


results

Hot water complaints...

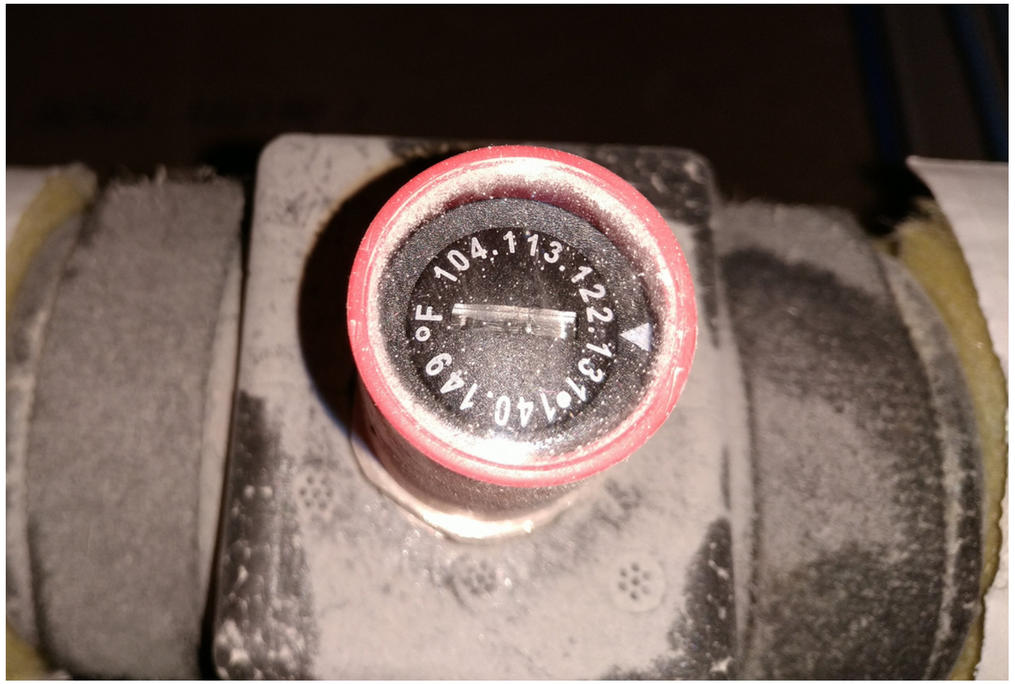


measurement verification

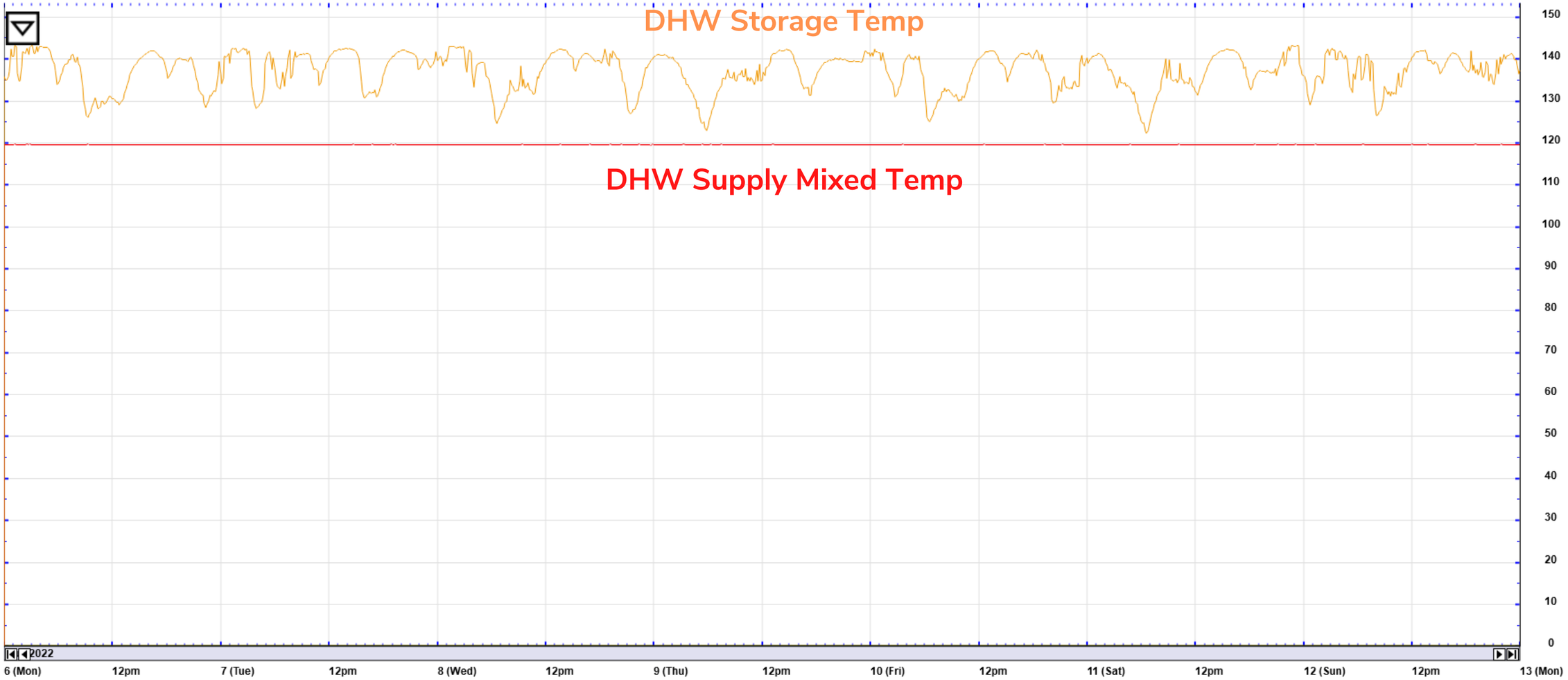


results

More Commissioning...



measurement verification



results