BUILDINGENERGY BOSTON

Take Charge and Electrify That Building!

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Northeast Sustainable Energy Association (NESEA)
March 1, 2022

Learning Objectives

- Electrification can be the cost-effective higher performance alternative to replacement in kind.
- Understand that operational heartaches cost more than energy.

Project 1: Heating & Cooling Retrofit

48 Unit Luxury Condo

3

Project 1: 140,000 sq.ft with 48 units

- Central Heating (oil)
- 60% of distribution failing
- WSHPs end of life
- Lack of control

- Indoor cooling towers

Project 1: What was wrong

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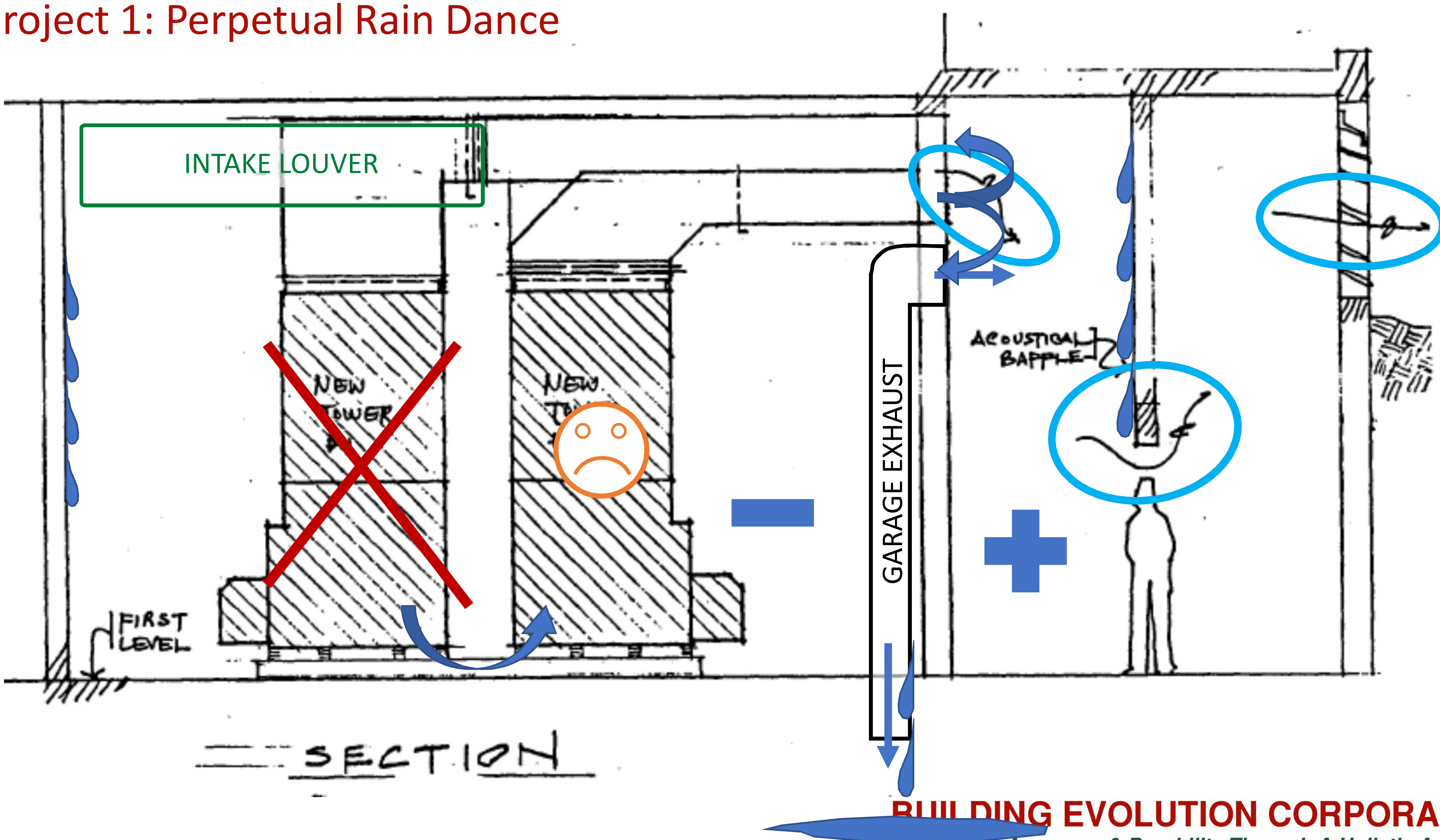
Project 1: Perpetual Rain Dance



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Project 1: What was wrong

Project 1: Logistical snags (they happen), they can be managed

Nauset virtual mockup during pandemic.

2nd Temp. CT rental, pandemic project delays.

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Project 1: Finished Product

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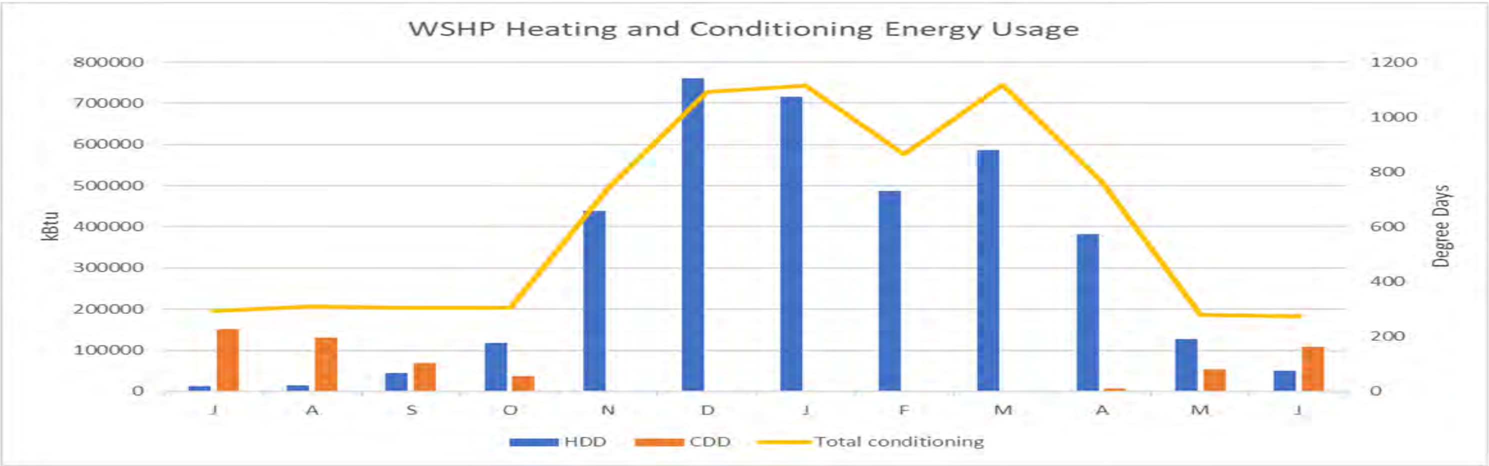
Project 1: Energy Usage

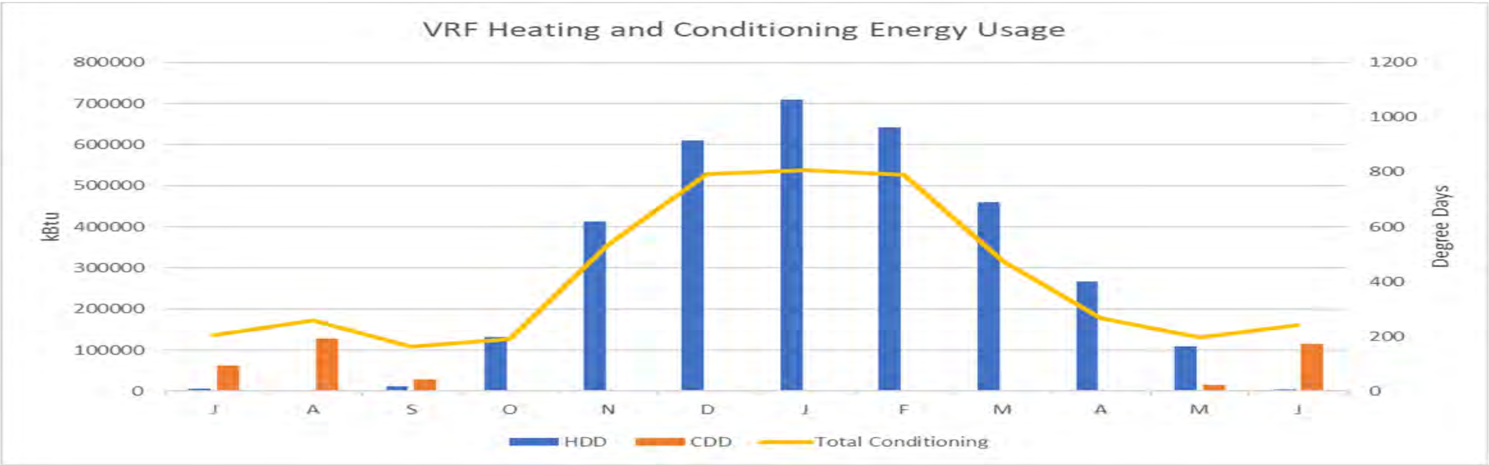
Metered Energy Usage			
	Electricity Usage* (kWh/year)	Oil Usage (gal/ year)	Total Site Energy Usage* (MMBtu / year)
WSHP / Cooling Tower	987,369	11,607	4,974
VRF	961,984	-	3,280

Metered usage shows 34% savings in site energy based on 1 year of data

*Does not include apartment baseload

Project 1: Metered Data





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Project 1: GHG & Emission Reduction

No More Oil!			
	Carbon Dioxide (CO_2) (kg)	Sulfur Oxide (SO_2) (kg)	Nitrogen Oxide (NO_x) (kg)
WSHP	534,353	1,358	2,834
VRF	396,054	433	2,639
% Reduction	26%	69%	7%

Significant reductions in emissions (nearly all of SO_2 reduction due to elimination of oil)

Project 1: Life Cycle Cost Analysis

Lets Talk Money!					
	Investment Cost	Average Building Operational Energy Cost**	Heating and Cooling Cost	Building Life Cycle Cost	Maintenance Cost
WSHP	$4,200,000*	$237,000	$175,000***	$8,070,000	Existing Deferred: High!
VRF	$3,300,000	$175,000	$130,000	$6,420,000	Preventative: Low

- Assumes 20-year life cycle and 3% escalation rate for capital costs
- *Investment Cost: Only accounts for piping and cooling tower upgrades on site; does not include replacement of original WSHP's
- **Same blended rate. Demand Rates!
- ***Compares electricity at same blended rates for simplicity.

NAUSET

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Project 2: Historical Rehab

Refrigerant Reduction. Like golf, less is more.

GTI: 86,000 sq.ft with 92 units

- Central Heating (Natural Gas)
- Distribution end of life
- FCUs
- Through wall AC to enclosed patios

GTI: Great maintenance, but FCUs not maintainable

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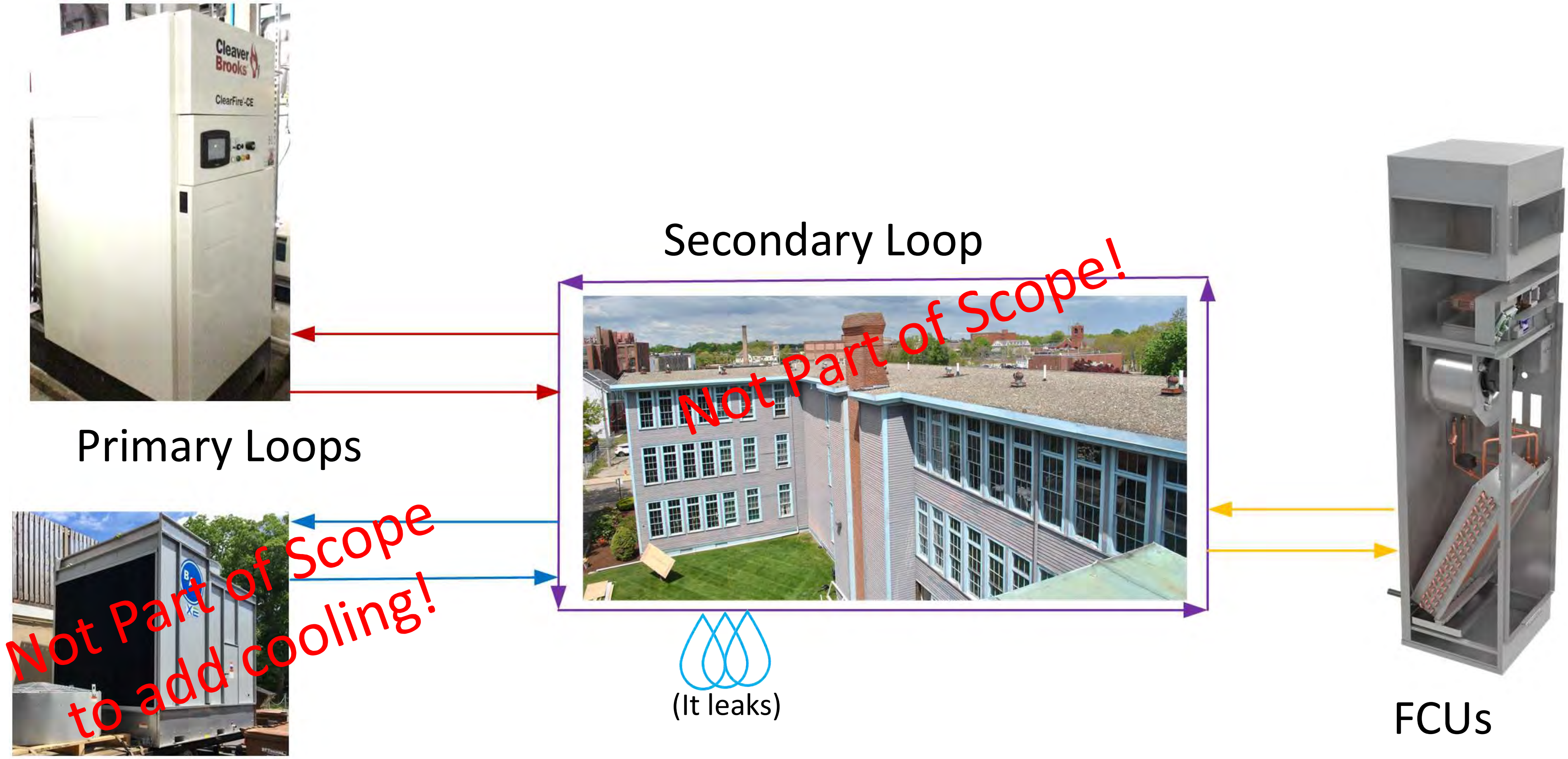
Business As Usual (BAU)

No – don't do that!!!

BAU

BAU – Terms and Conditions Apply!



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Variable Refrigerant Flow (VRF)

The Go-To Option for Electrification

VRF

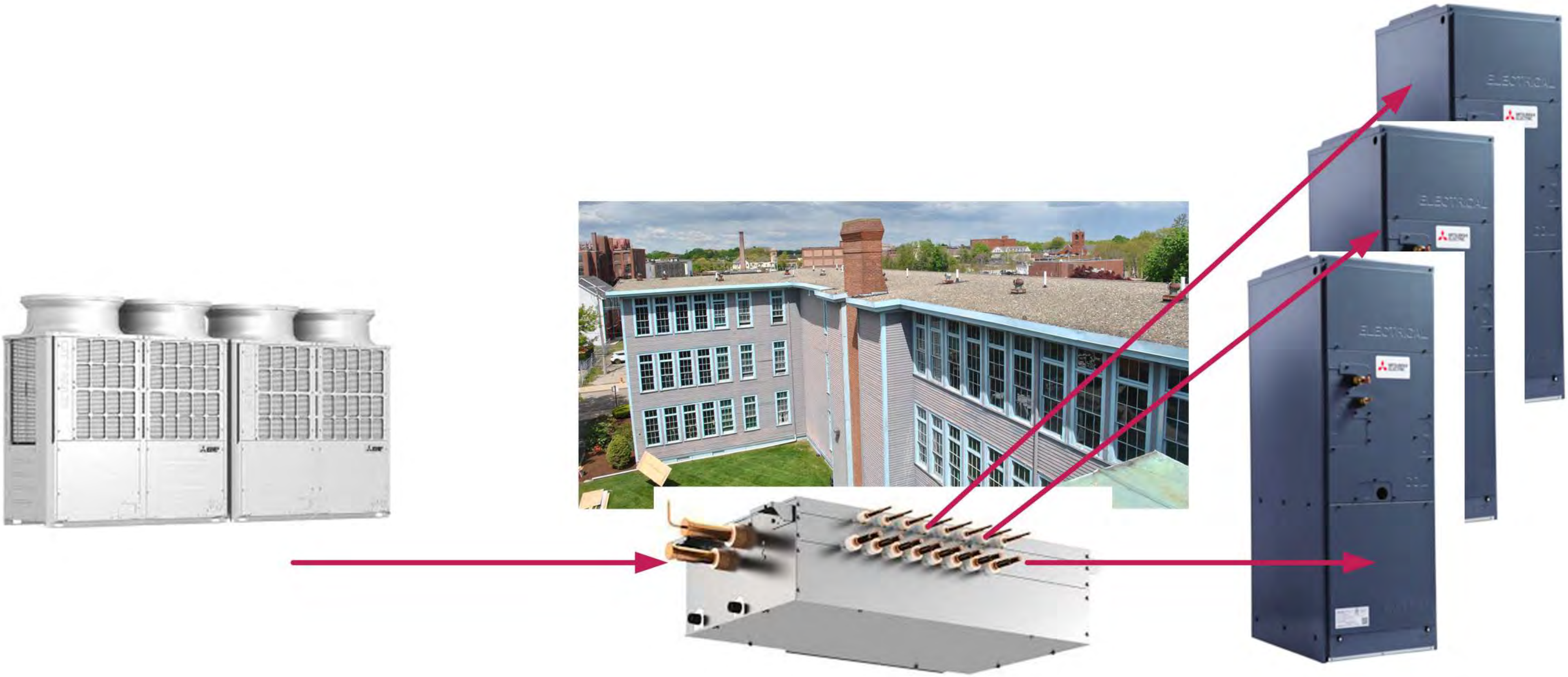
Refrigerant

Condensing Unit

Branch Controller

Fan Coil Unit

VRF – Typical Diagram



All new refrigerant distribution

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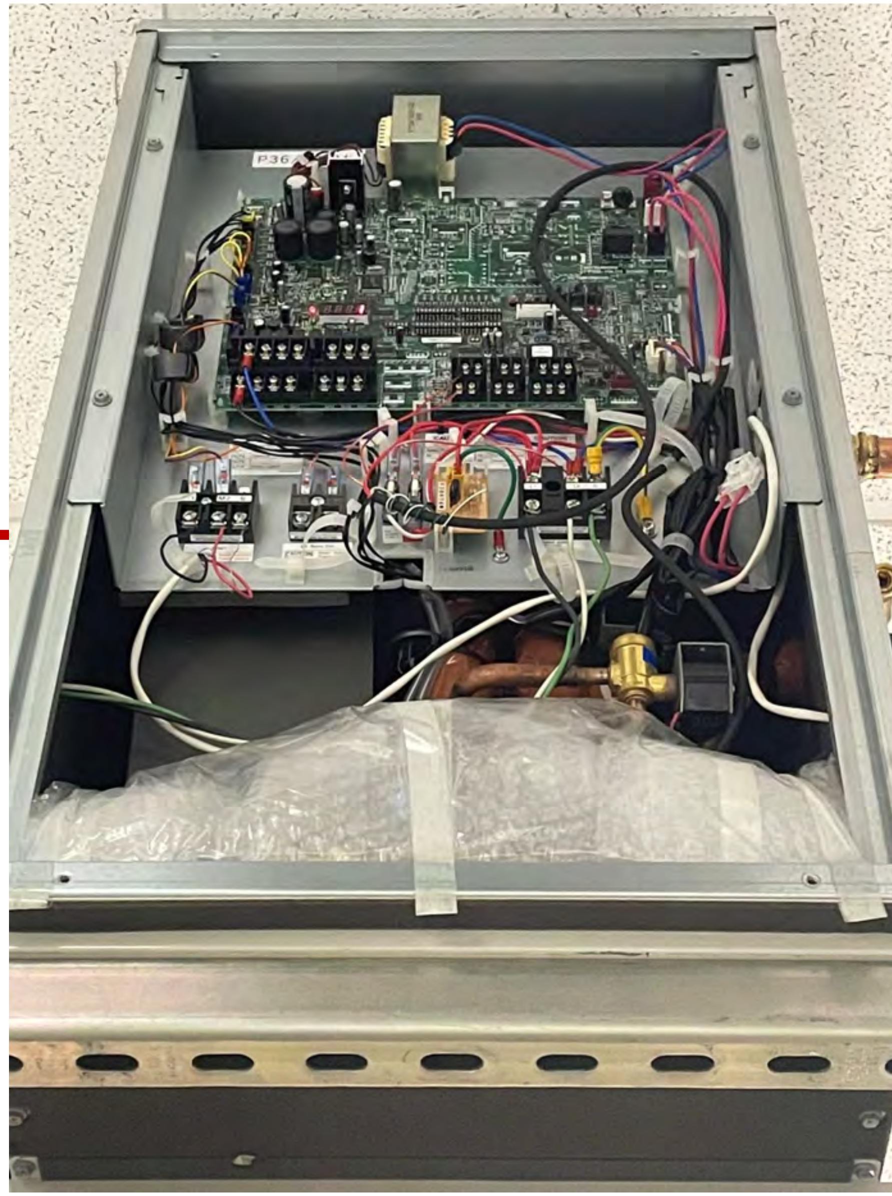
Heat Exchanger (HEX)

What the HEX is it?!
(An alternative to VRF and Hybrid VRF)

HEX System

Refrigerant



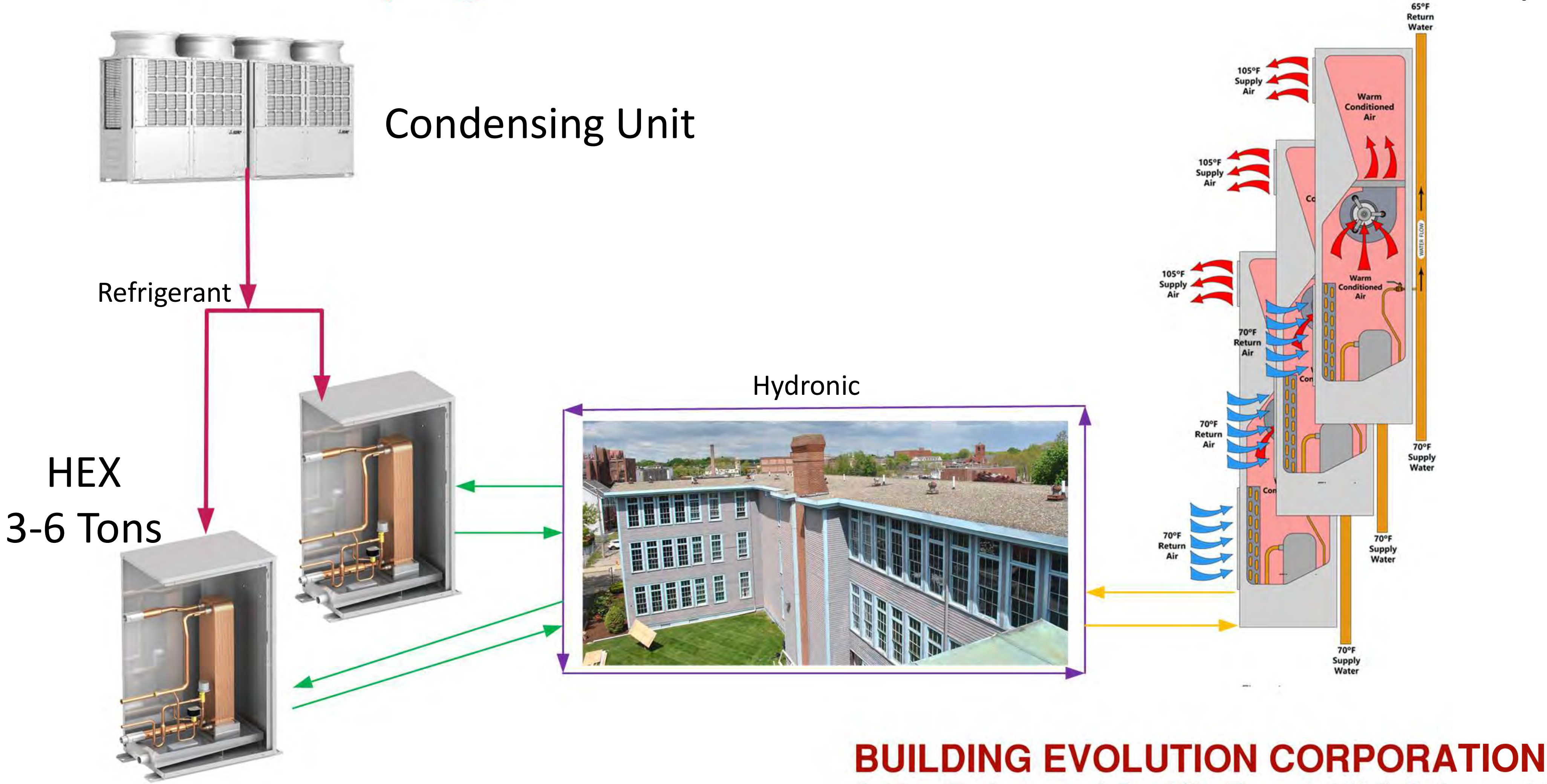
Hydronic

Hot or Cold Water

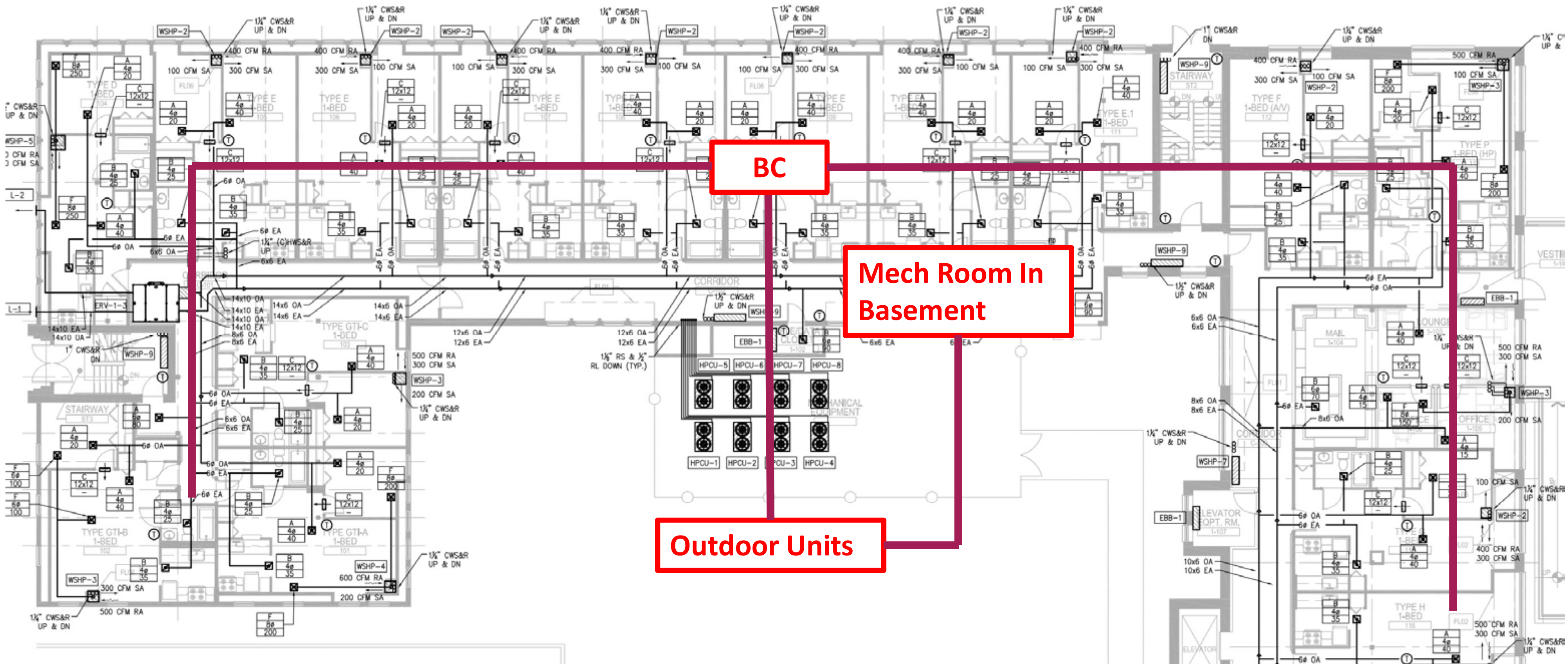
HEX Install Example

HEX Units – As it progressed: WSHP

Water Source Heat Pump



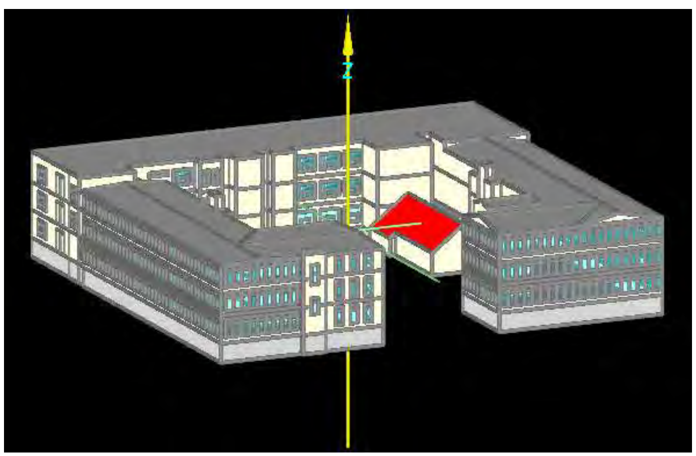
VRF vs. HEX: Refrigerant



- No refrigerant in occupied spaces.
- About 20% less refrigerant.

HEX vs. VRF: Energy Modelling

	Site Energy (kBtu/year)	Source Energy (kBtu/year)
HEX / WSHP	2,602,001	6,487,986
VRF	2,418,049	5,965,489
Boiler & Chiller	3,898,009	6,941,583



- All building components except mechanical systems are identical
- Site: Source ratios based on WUFI Standard USA (not updated for PHIUS 2021 electric ratio which is more favorable for electric)

- “Its only a model”

Project 2: GHG & Emission Reduction

No More Gas!			
	Carbon Dioxide (CO_2) (kg)	Sulfur Oxide (SO_2) (kg)	Nitrogen Oxide (NO_x) (kg)
HEX/ WSHP	147,820	162	985
VRF	125,083	137	834
Boiler / Chiller	223,921	960	840

*Assumes 20-year life cycle

Project 2: Energy & Cost Comparison

	Investment Cost	Annual Energy Cost	Life Cycle Cost	Maintenance Cost
HEX / WSHP	$3,370,000	$57,450	$4,301,409	
VRF (Estimated)	$3,010,000	$48,600	$3,798,148	
Boiler / Chiller	$2,820,000	$65,100	$4,536,784	

SOUTH COAST
Improvement Company
Construction • Renovation

- Assumes 20-year life cycle and 3% escalation rate for capital costs
- Southcoast did not price VRF, not feasible. Simple $/sq.ft. used for LCC
- Boiler/Chiller

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Thank You.

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SUSTAINABLE COMFORT

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Taitem
Technology As If The Earth Mattered

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.

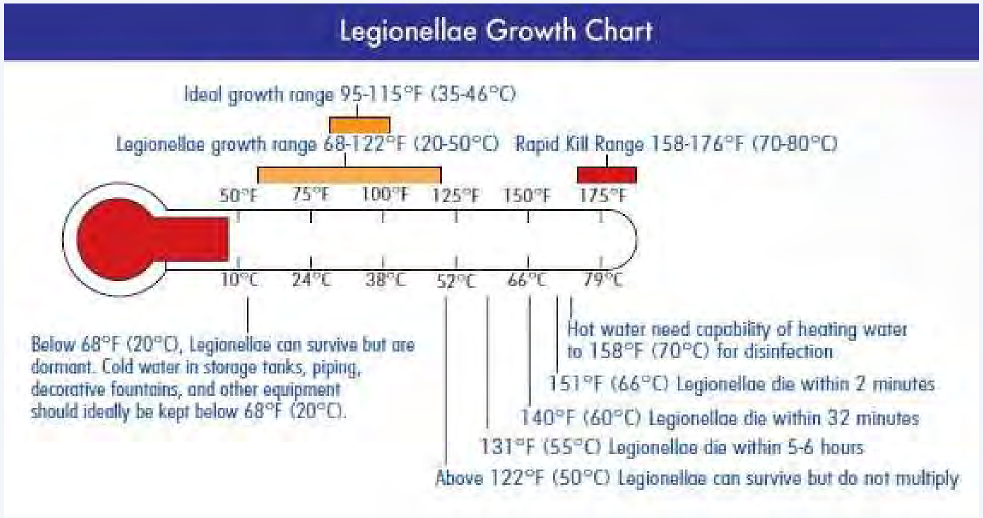


*Image courtesy of Powers

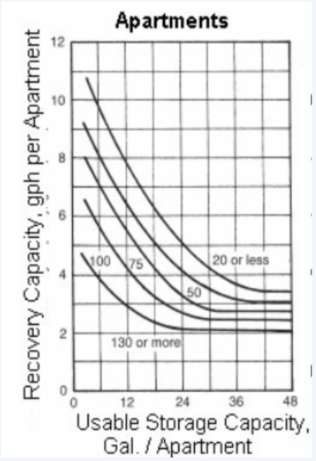


*Image courtesy of 2015 ASHRAE HVAC APPLICATIONS HANDBOOK

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	1GWP*

*May not require double wall heat exchanger

MULTIFAMILY

LOCATION

Ithaca, New York

PROJECT STATS - Arthaus Ithaca

PROJECT TEAM

Owner: Vecino Group
Architect: BW Architecture and Engineering
Engineers: Taitem Engineering

PROJECT SIZE

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

ENERGY PROGRAMS

NYSERDA's Multifamily New Construction Program, Tier 2
Energy Star MFHR

STATUS: COMPLETE

DHW SYSTEM DESIGN
MULTIFAMILY

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 washers

Peak hourly usage
1248 GPH

Max daily usage
4740 Gallons

DHW SYSTEM OPTIONS

MULTIFAMILY

1

Central GSHP

2

Central R-410A ASHP

3

Central CO2 ASHP

4

Semi-Central Hybrid Water Heater

selected system

SIZING

Total storage:
Peak usage @ 125F

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

Or

Capacity to recover peak usage in 4 hours normal capacity or 6 hours de rated capacity

Peak usage
1248 GPH

Max daily usage
4740 Gallons

Design challenges

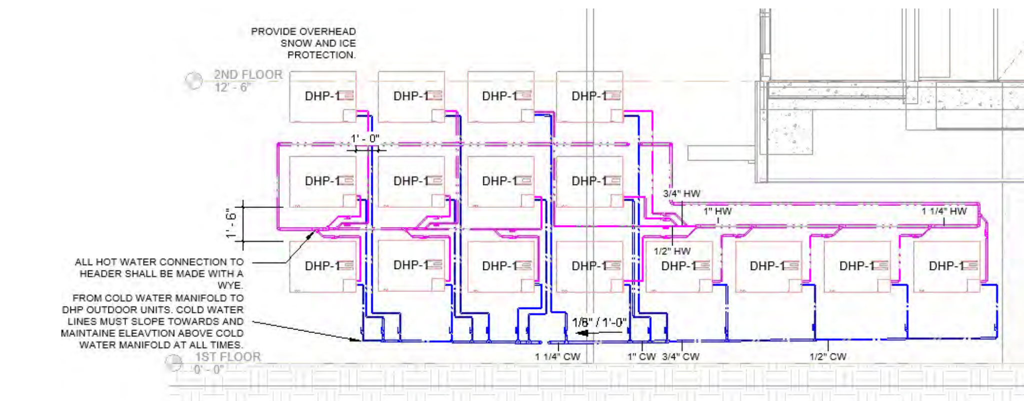
DOMESTIC HOT WATER DESIGN

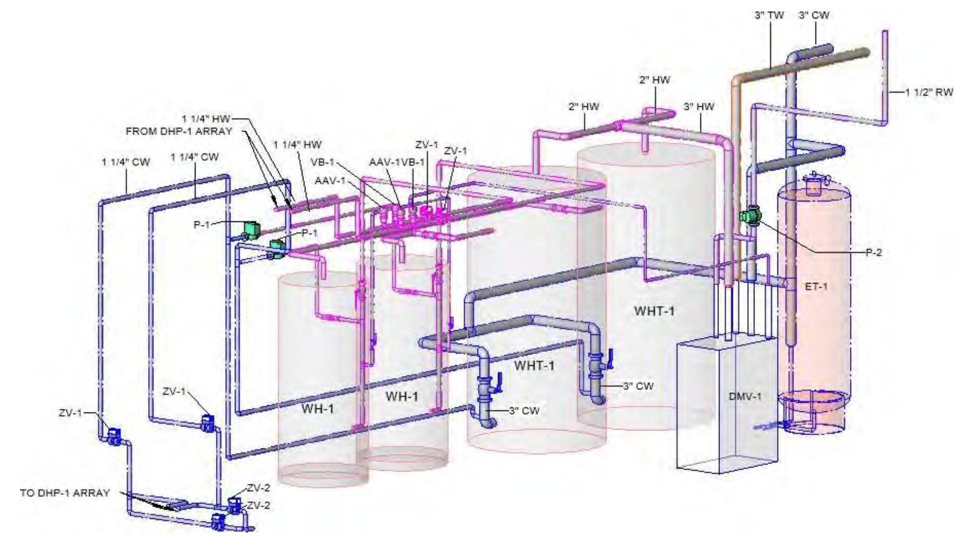
- Freeze protection of water
- 100% back up system
- Space limitation, large hot water storage requirement

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

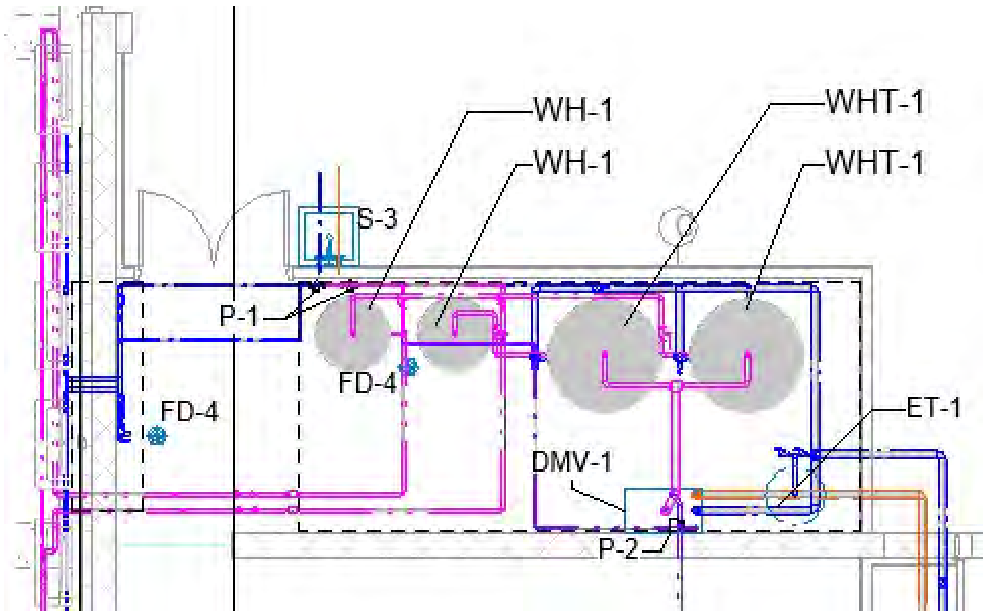




Space limitation

DOMESTIC HOT WATER DESIGN

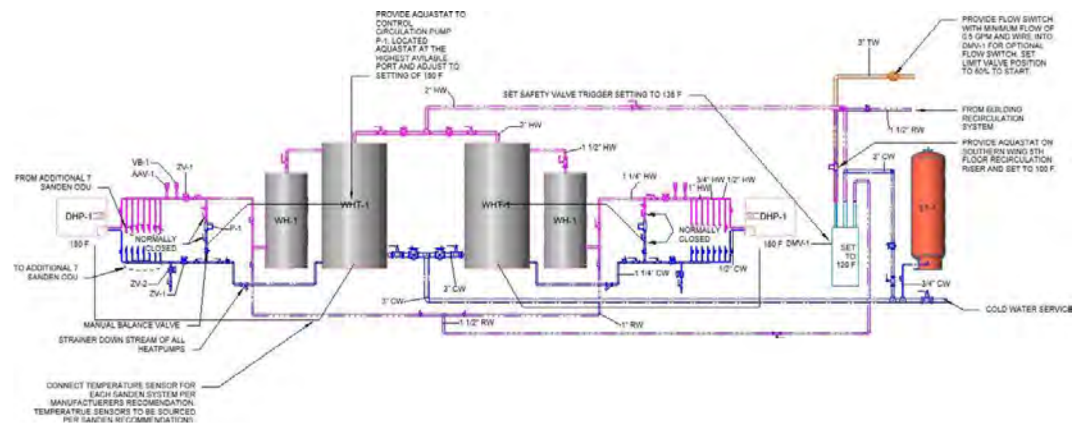
- Limited space in hot water room
- 1248 gallons of 125F water required
- Combined extra storage of 120 Gallon electric resistance tanks
- "Charge" tanks to 150F to allow for 30% more capacity



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



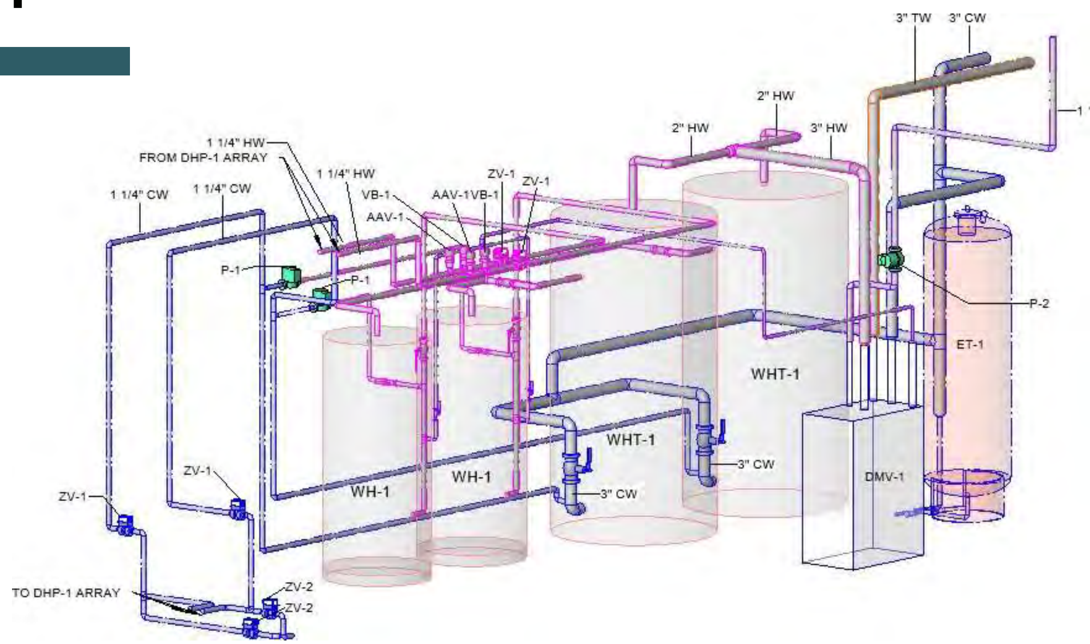
Final System Selection

Central CO2 ASHP
with 100% electric resistance backup

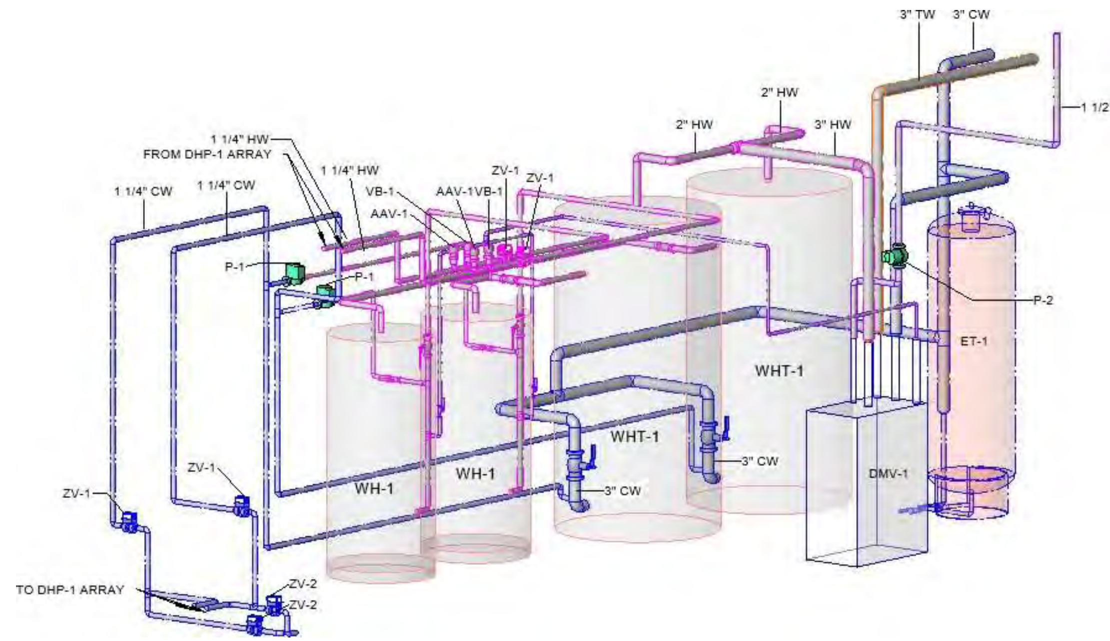
- **Primary** Two parallel systems made up of (8)HP WHs in parallel (piped reverse return) (1) electric resistance water heater and (1) 500 gallon storage tank with target temp 150F
  - Total of (16) 15,400 BTU/ hr HP WHs; auto drain back; 1248 gallons of storage

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

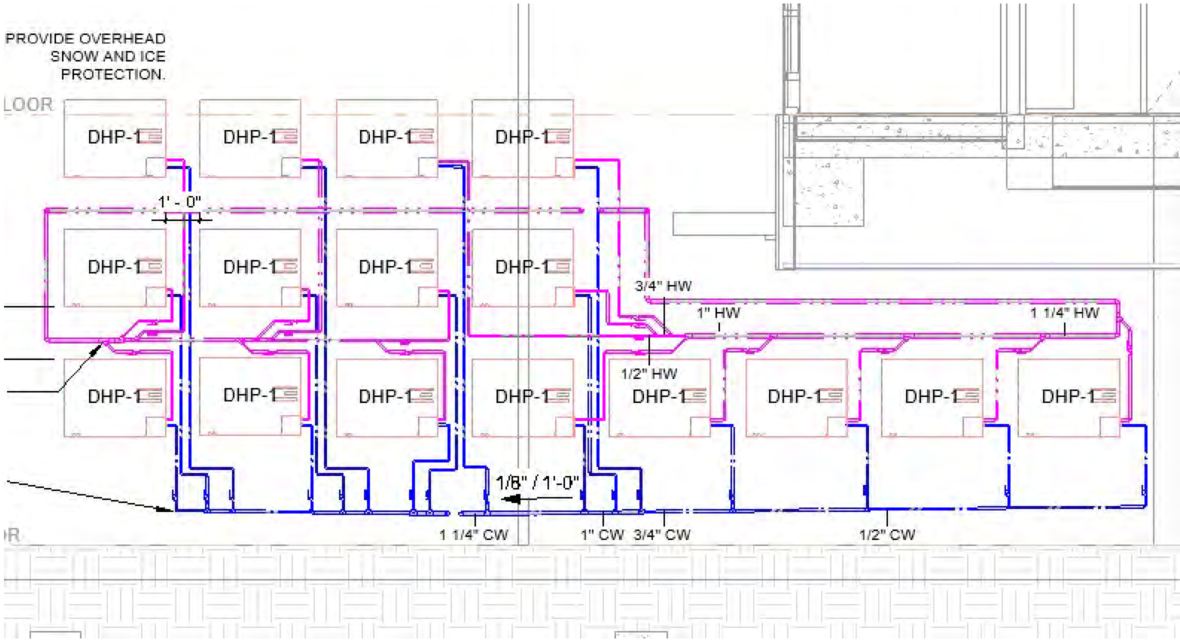
Estimated annual COP =~4.2



Final System Selection



Final System Selection



System install and operation
TROUBLESHOOTING

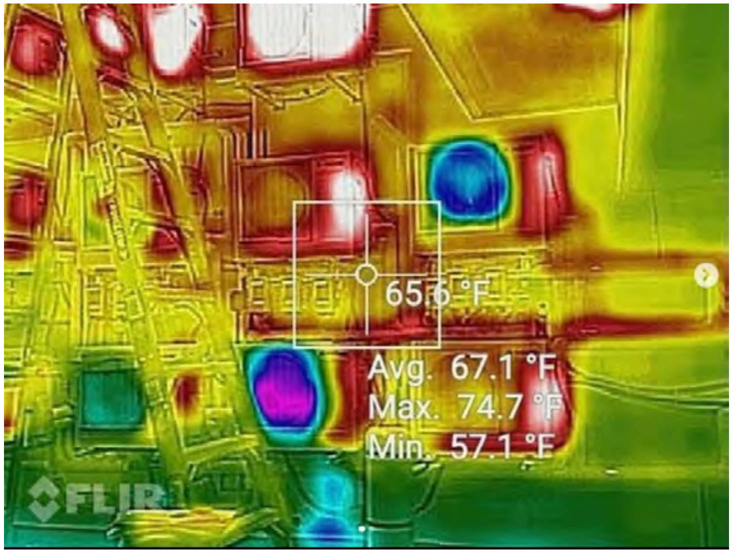
Automatic drainback

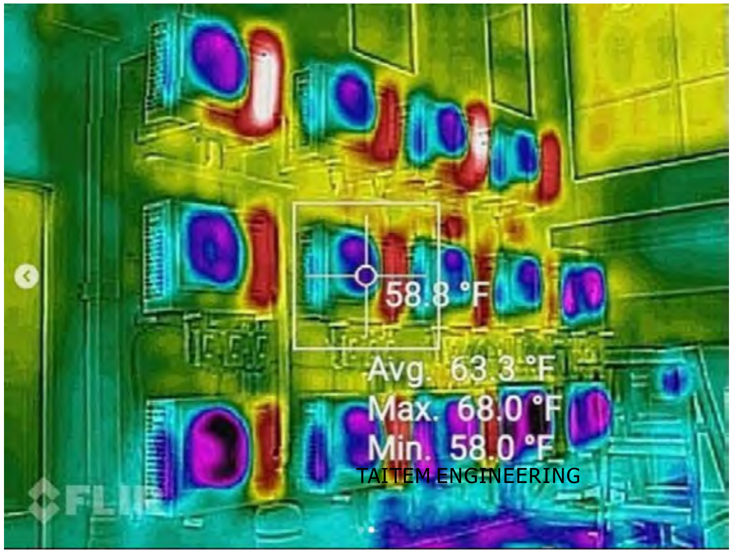
TROUBLESHOOTING

- 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

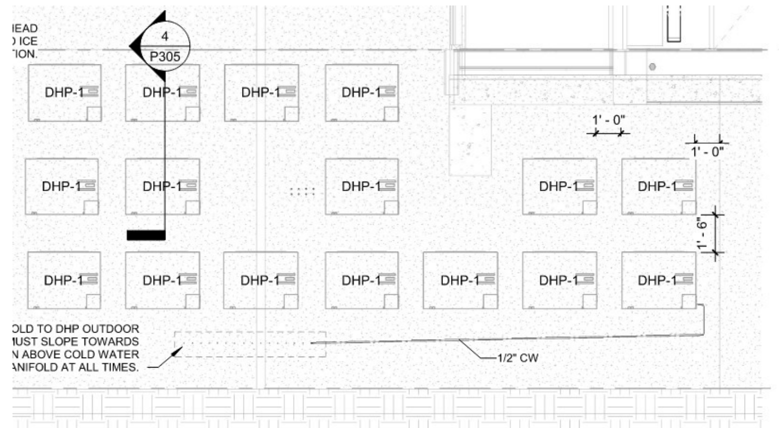
- Original system design with pipe manifold within building envelope

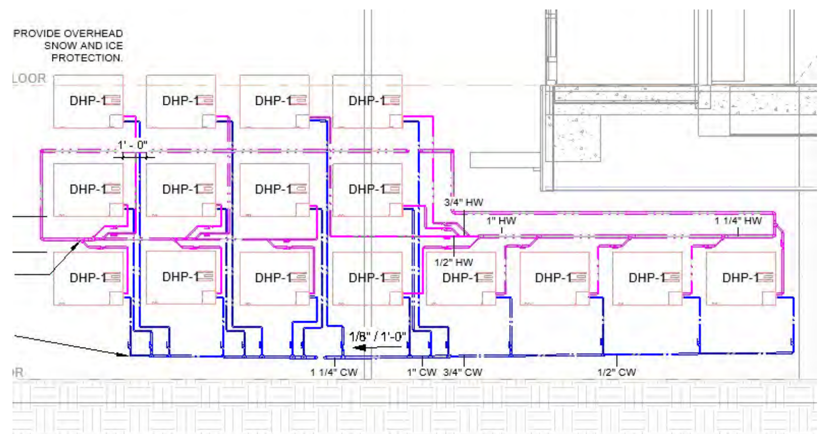
BOTTOM IMAGE

- Final design with pipe headers outside building envelope

NEW DESIGN ISSUES

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

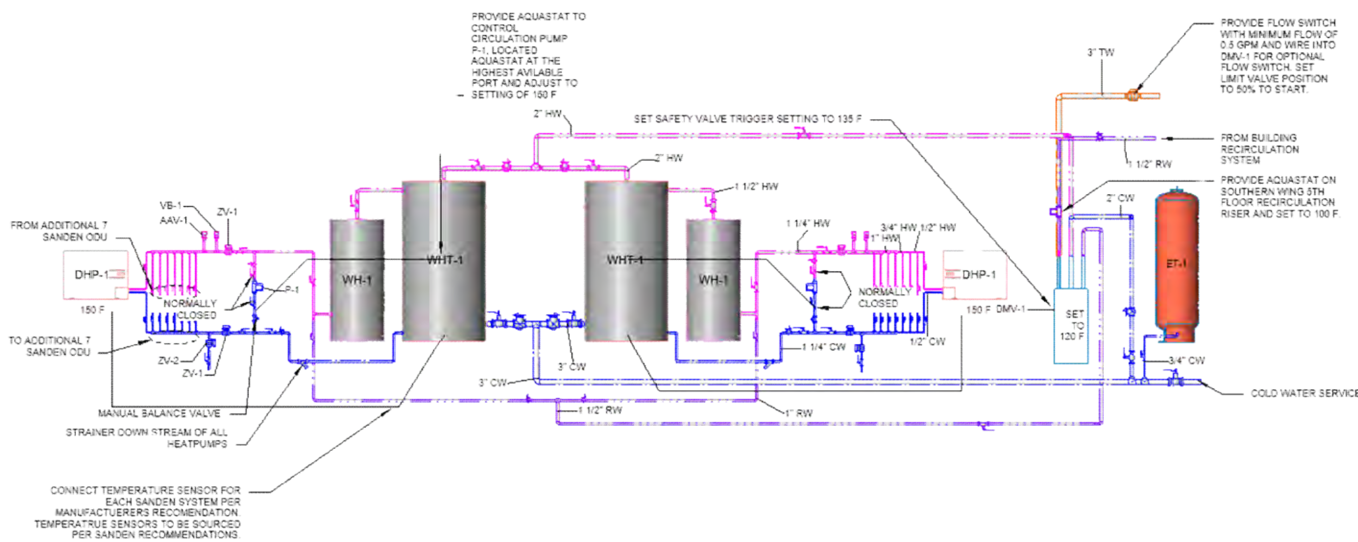




Measurement &Verification

CURRENT POINTS OF MEASUREMENT

- POWER: Heat trace tape, recirculation pump, all (16) heat pumps individually
- TEMPERATURE: Cold water inlet to system, cold water to each heat pump array and hot water from each heat pump array, Hot water out of each tank, hot water to mixing valve and tempered water to building.
- FLOW RATE: Cold water to DHW plant, cold water to one heat pump array.

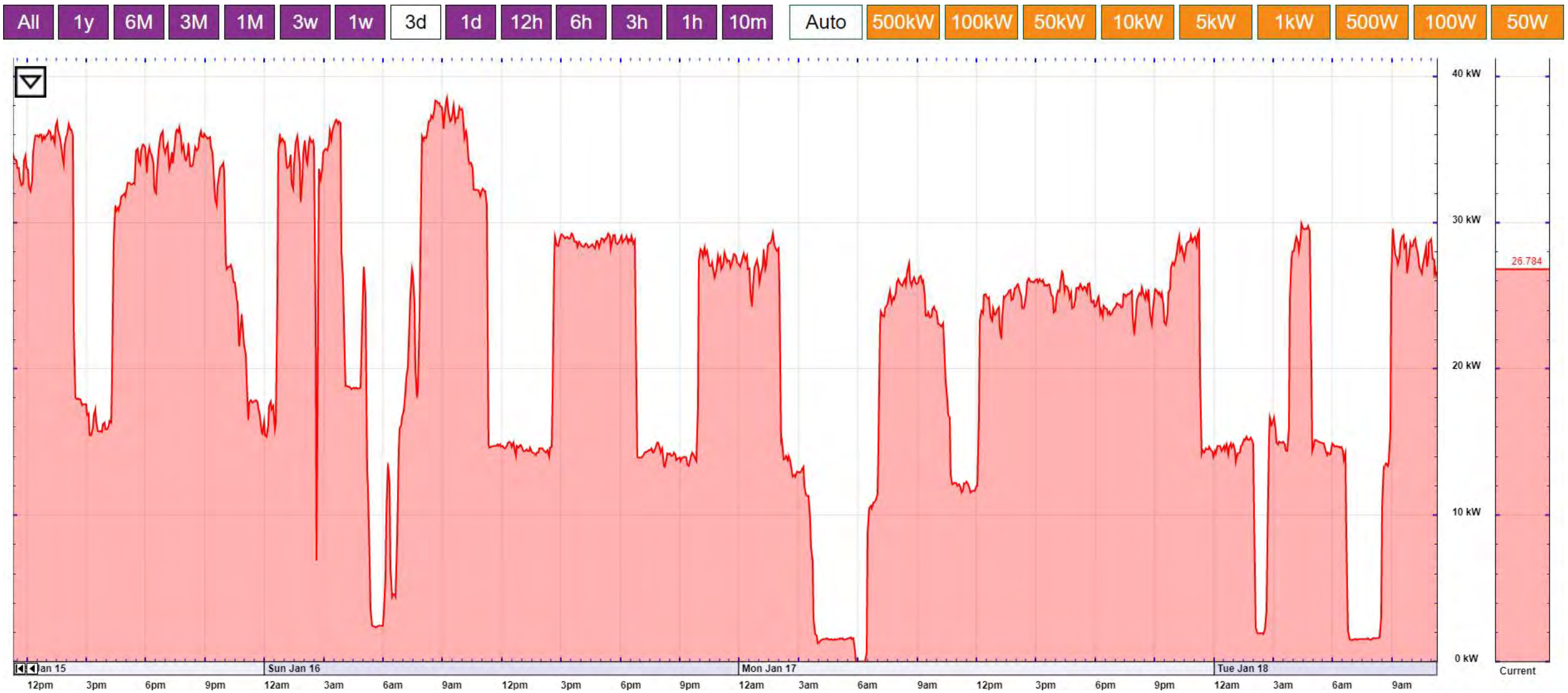


Measurement & Verification: Heat pump water outlet temp

-5 F minimum, 32 F maximum ambient temperature.

Measurement & Verification: Total power

-5 F minimum, 32 F maximum ambient temperature.



Hot Water Heating Systems – Alternative Central Options

Central CO2 System

LG VRF System

Shared Integrated DHW

Hot Water Heating Systems – Electric Central Plant

Central CO2 Based System (Ex. Sanden SanCO2, Mitsubishi QAHV, Aegis A)

Runs hot water outside of the building to exterior condensers.
CO2 refrigerant means hot water system needs to go outside.
May need many outdoor condensers, Sanden smaller capacity units.
Indoor storage tank capacity large
Central distribution system with associated piping and pumps needed
Freeze protection needed if water running outside, or if allowed using glycol to outdoor units
(Currently Mitsubishi unit does not have freeze protection option available)
COP: 3-3.75

Sanden SanCO2

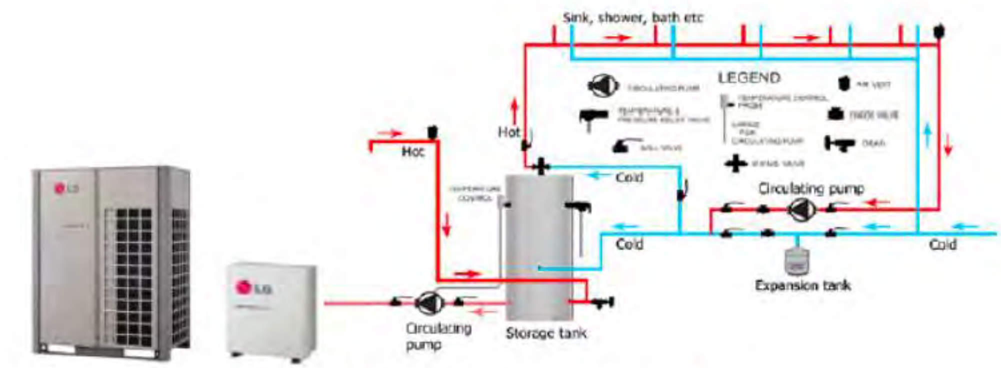
Mitsubishi QAHV

Lync by Watts Aegis A 350

Hot Water Heating Systems – Electric Central Plant

LG VRF Central System

- Standard outdoor condensing unit – LG VRF Systems
- Indoor unit with additional heat pump – Hydrokit K3 to boost temp from outdoor condenser loop
- Additional heat exchanger to large indoor storage tank
- Central distribution system with associated piping and pumps needed
- Simulated COP of 3.18 for Rochester, NY climate



Proposed : LG Multi V 5 system + Hydro Kit

Hot Water Heating Systems – Electric Central Plant

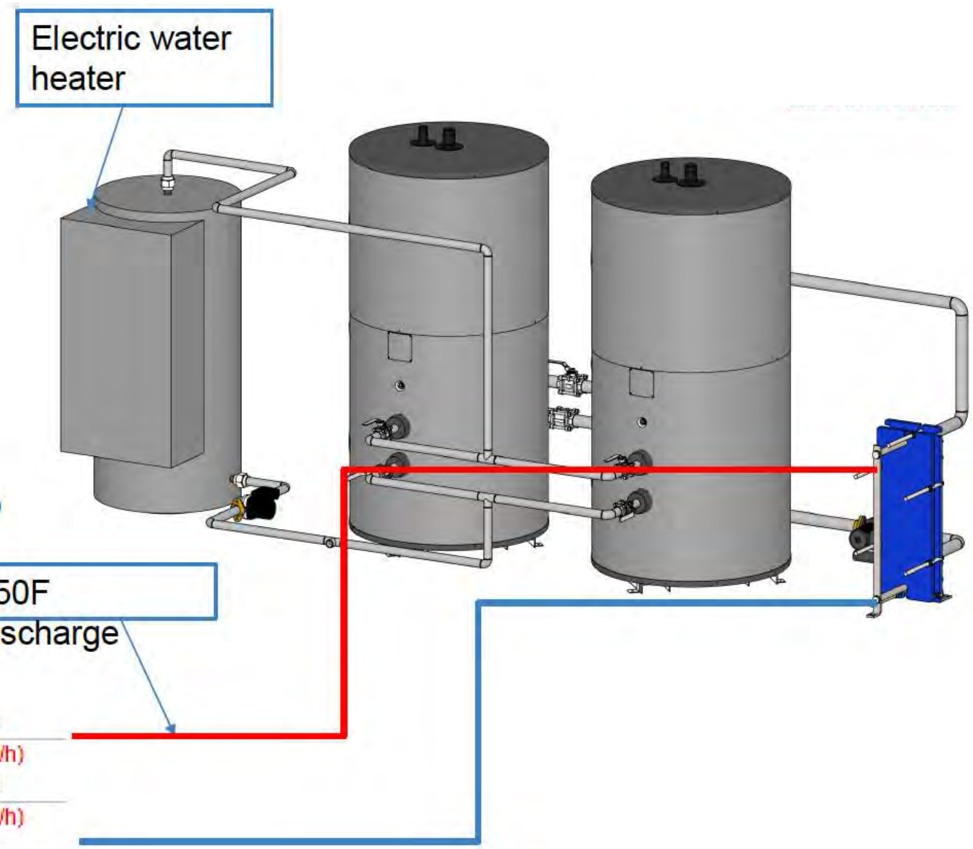
LG VRF Central System

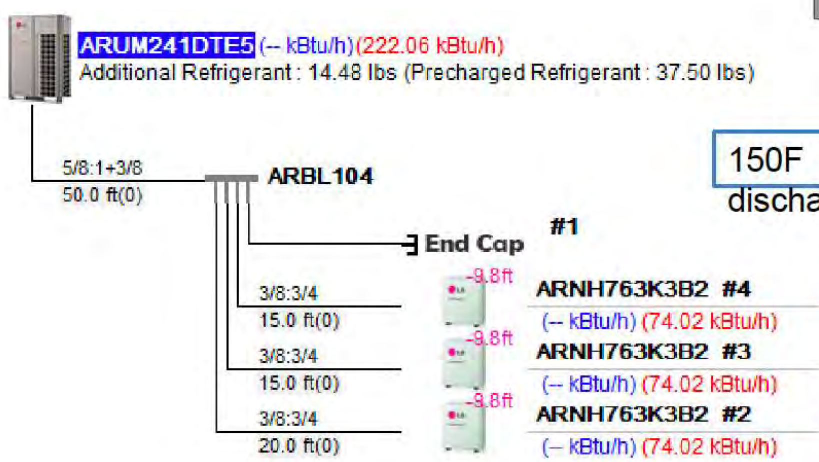
Pros

- No additional freeze protection needed due to using refrigerant systems
- Less outdoor units, 1 outdoor unit with 2 compressors capable of handing whole building.

Cons:

- Higher global warming potential refrigerants
- Controls, startup and operation may be more complex





Hot Water Heating Systems – Electric C

LG VRF Central Systems

R-410A refrigerant to outdoor unit, separate R-134A cycle within K3 hydrokit to boost temperature.

Storage tank able to achieve 150F

K3 Hydro Kit

Engineering Information

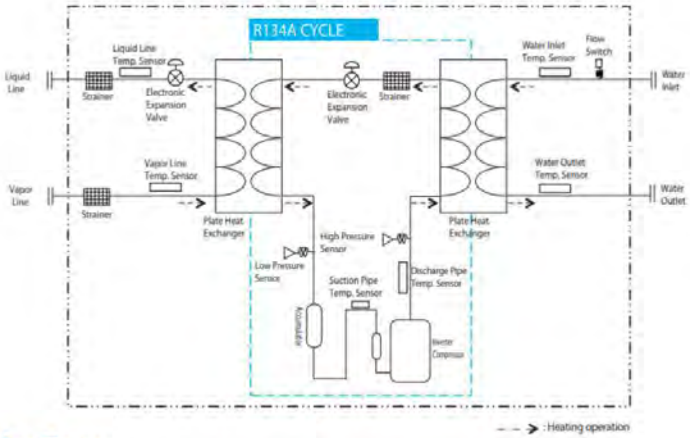


Table 2: Hydro Kit General Data

	Hydro Kit	
	ARNH963K2A2	ARNH763K3A2
Cooling Mode Performance		
Rated Capacity[1] (Btu/h)	95,900	-
Entering Water Temp Range (°F)	50-95	-
Leaving Water Temp Range (°F)	42-77	-
Indoor Air Temp Setpoint Range (°F)	64-86	-
Heating Mode Performance		
Rated Capacity[1] (Btu/h)	107,500	86,000
Entering Water Temp Range (°F)	41-113	53-167
Leaving Water Temp Range (°F)	68-122	86-176
Indoor Air Temp Setpoint Range (°F)	60-86	60-86
Hot Water Tank Setpoint Range (°F)	86-122	86-176
Unit Data		
Refrigerant Type (Primary/Secondary)	R410A/—	R410A/R134A
Refrigerant Control	EEV	EEV
Factory Charge[2](lbs)	—	6.51
Sound Pressure[3] dB(A) Cooling/Heating	26	43
Net Unit Weight (lbs)	77	207
Shipping Weight (lbs)	89	219
Heat Rejected to Equipment Room (Btu/h)	Negligible	512
Oil Type	—	PVE (FVC68D)
Heat Exchanger		
Material/Type	316 Stainless/Brazed Plate	316 Stainless/Brazed Plate
Rated Water Flow (GPM)	24.3	9.5
Rated Pressure Drop[4] (ft-wg)	23.1	6.7
Range of Flow (GPM)	8-24.3	5-19
Waterside Volume (US Gallons)	0.58	0.58
Water Side Design Pressure (psig)	640	640
Compressor		
Type	—	Twin Rotary
Operating Range (Hz)	—	20-95
Piping		
Liquid Line (in, OD)	3/8 Braze	3/8 Braze
Vapor Line (in, OD)	7/8 Braze	3/4 Braze
Condensate Line (in, ID)	1-MPT	Bottom Panel Hole Only
Water Inlet/Outlet (in, ID)	1-MPT	1-MPT

[1]All capacities are net with a Combination Ratio between 95–100%.
[2]Internal second stage refrigerant circuit.
[3]Sound pressure levels are tested in an anechoic chamber under ISO Standard 3745.
[4]Water only (no antifreeze).
The combination ratio range for mixed use (Hydro Kit units mixed with indoor units) is 50% - 100%. The combination ratio range for dedicated use (all Hydro Kit units) is 50 – 130%.

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Hot Water Heating Systems – System Cost Comparisons

Electric Central Plant Installation Cost Comparison

System	Equipment Cost	Piping + Install Cost	Total Cost	Total Cost/SF	Cost Premium	Premium/Unit
Sanden SanCO2	$86,000	$107,000	$193,000	$1.89	$104,000	$838
LG Hydrokit	$91,000	$77,000	$168,000	$1.64	$79,000	$637
Base: Gas Boiler	$46,400	$42,200	$89,000	$0.87	-	-

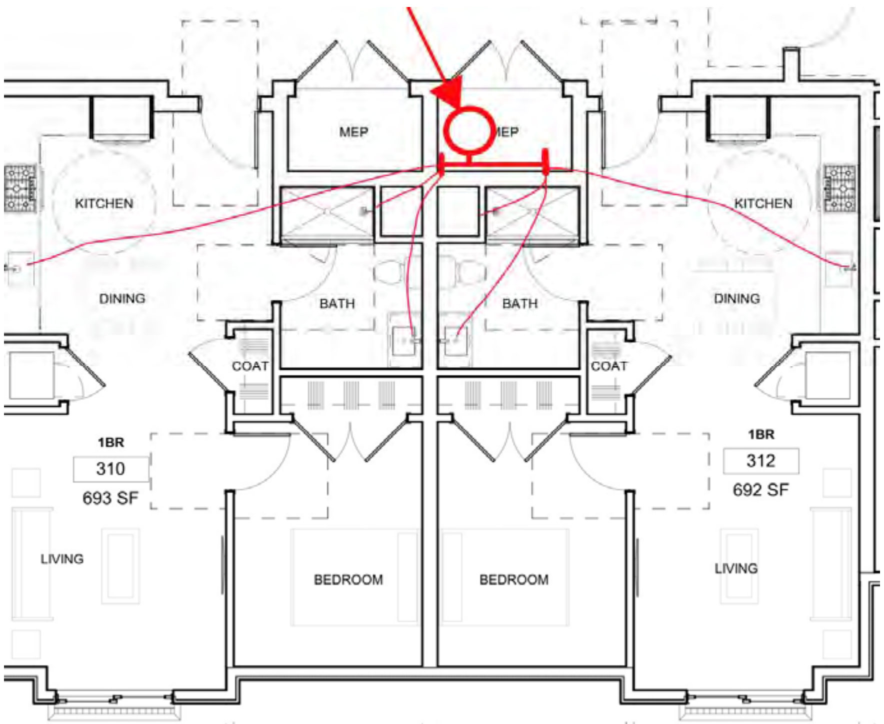
Pricing Assumptions

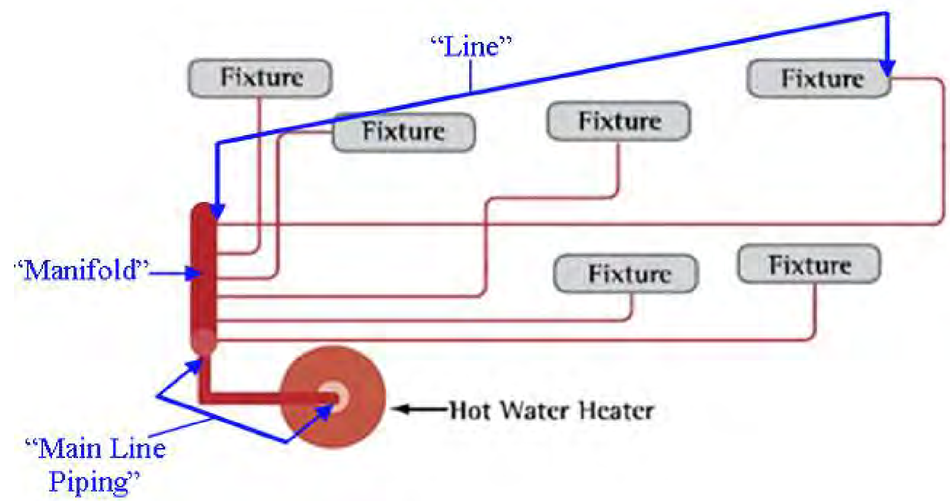
- Pricing based off the Ithaca Arthaus, 124 Unit Building, ~102,000sf in Ithaca, NY
- Costs include domestic water systems within the mechanical room to the storage tanks, excludes distribution which is expected to be the same in each scenario
- Pricing based on 2021 costs
- Pricing provided by installing contractor Woodcock and Armani, Syracuse, NY www.csusasyr.com Daniel.bruyere@comfortsystemsusa.com
- Additional LG Hydrokit and boiler pricing supported by Ben Curwin, VP Supply Corp, Rochester, NY www.vpsupply.com bcurwin@vpsupply.com

Alternative Hot Water Heating System – Shared Heat Pump Water Heaters

While individual heat pump water heaters per apartment are an option, results in higher space needs, installation and maintenance costs. To reduce the number of tanks, reduce noise to tenants, and keep apartment temperatures consistent, a heat pump water heater off the corridor can be shared among units.

Shared Heat Pump DHW Option





Alternative Hot Water Heating System – Shared Heat Pump Water Heaters

Since the system takes heat from the surrounding air, there needs to be adequate air distribution for small closets. It is recommended to provide ducting of air to avoid a cold closet, and ducting air to corridor allows additional cooling in the summer. Corridor heat pumps need to be sized for additional heating load in winter.

Closet Option 1 - Recommended

What about Individual Electric Resistance?

Individual Heat Pump Operating Cost Comparison

1 Bedroom	Electric Resistance		Heat Pump Water Heater	
Category	kWh / Year	Cost / Year	kWh / Year	Cost / Year
Heating	1,214	134	1,710	$ 188
Cooling	222	24	91	$ 10
Domestic Hot Water	2,432	268	924	$ 102
Lighting	277	30	277	$ 30
Miscellaneous Loads	2,188	241	2,188	$ 241
Service Charge	-	204	-	$ 204
Total	6,333	901	5,190	$ 775
		Savings	1,143	$ 126

2 Bedroom	Electric Resistance		Heat Pump Water Heater	
Category	kWh / Year	Cost / Year	kWh / Year	Cost / Year
Heating	1,600	176	2,271	$ 250
Cooling	307	34	133	$ 15
Domestic Hot Water	3,303	363	1,255	$ 138
Lighting	365	40	365	$ 40
Miscellaneous Loads	2,660	293	2,660	$ 293
Service Charge	-	204	-	$ 204
Total	8,235	1,110	6,684	$ 940
		Savings	1,552	$ 170

***Savings based on energy modeling only, including heat pump DHW results in an associated increase in heating usage, and reduction in cooling.**
***Assumptions: Rates: $0.11/kWh, $17/month meter fees, 1 Bed = 630sf, 2 Bed = 830sf, Location: Buffalo, NY**

Questions?

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