Hot Water Forum - 2019

Central Heat Pump Water Heating with 3 Case Studies

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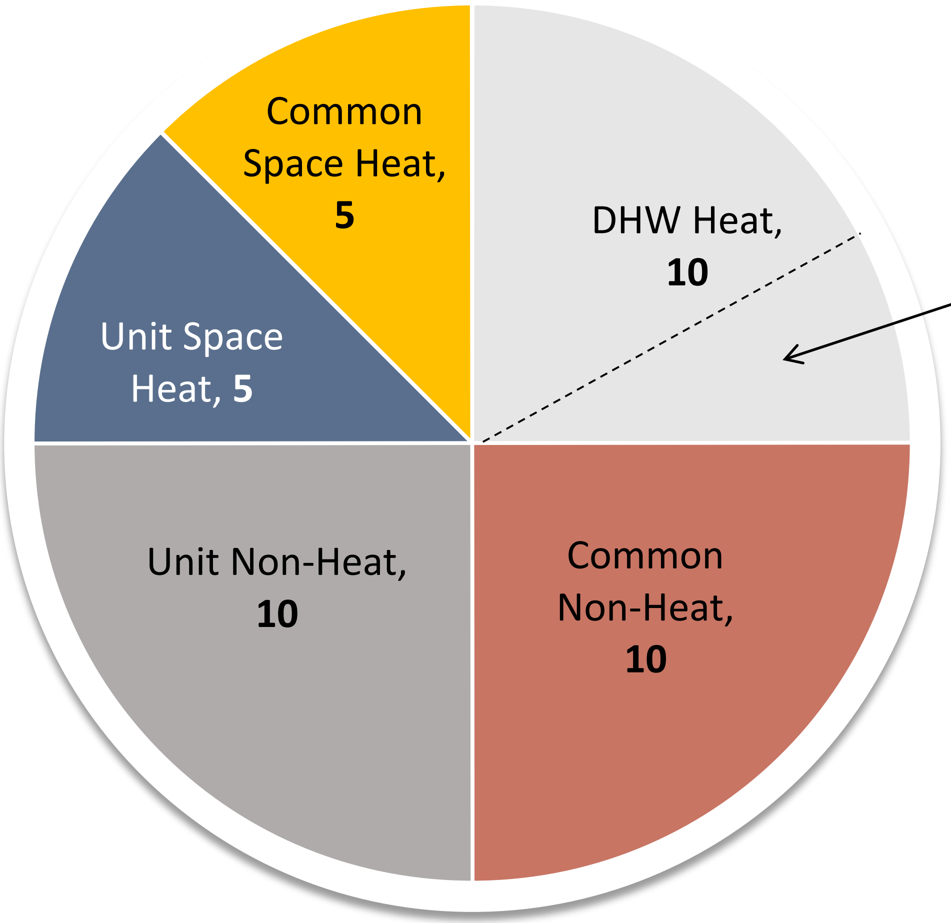
ECOTOPE

Multifamily EUI
~(40 kBtu/ft^2/yr)



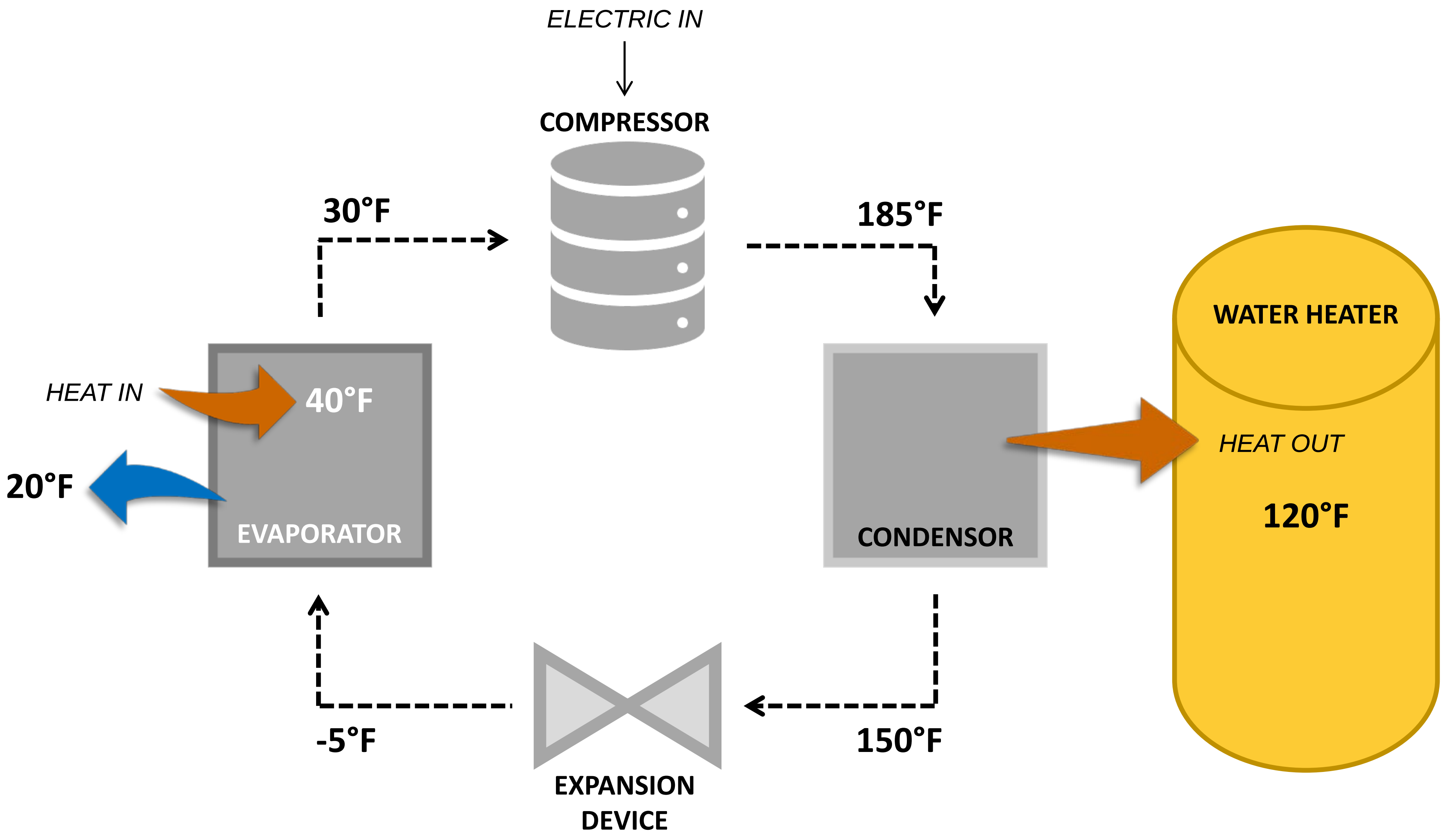
1/3 to 1/2 of the DHW load is temperature maintenance

Half the Load is Thermal
Half is Process and Lights

Goals:

- Reduce DHW EUI from 10 to 3 kBtu/sf/yr.
- Use Renewable Clean Grid Power to Heat DHW from 8 am to 4pm, coast through the rest of the day and night

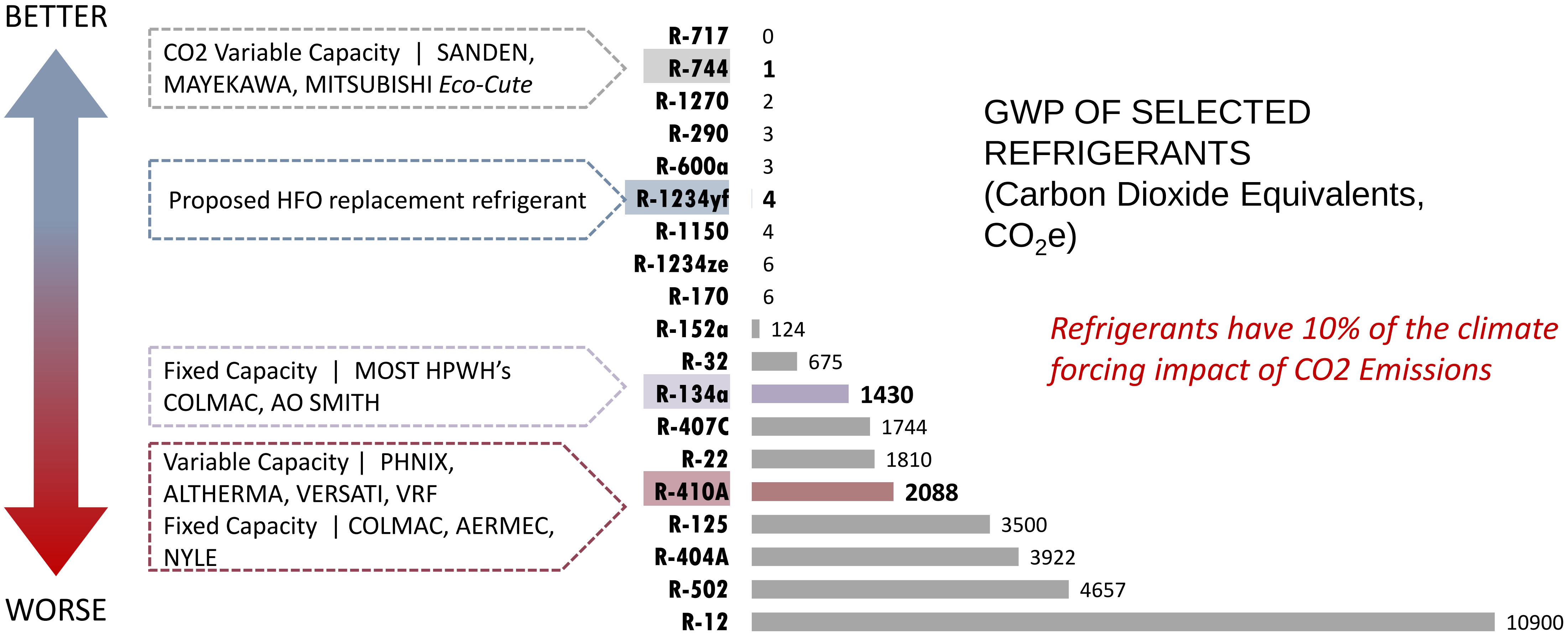
Multifamily Energy End Uses – Seattle Climate



Heat Pumps **MOVE** Heat

Central Heat Pump Water Heater Overview

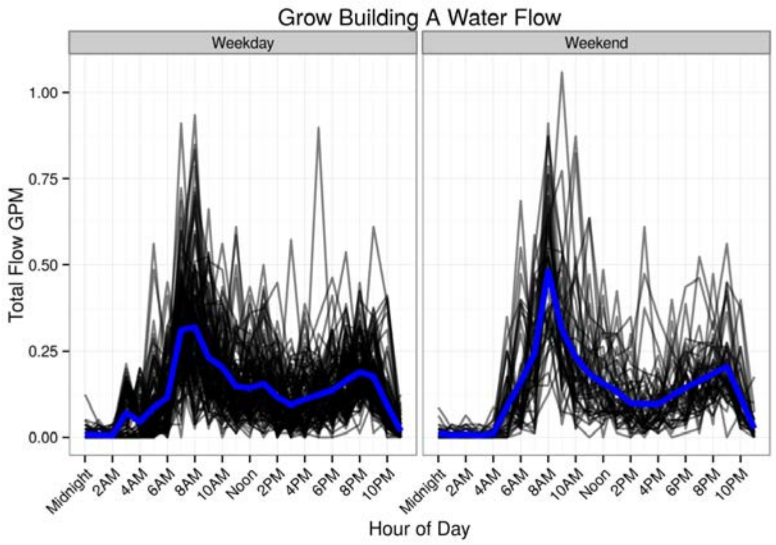
Refrigerant Types

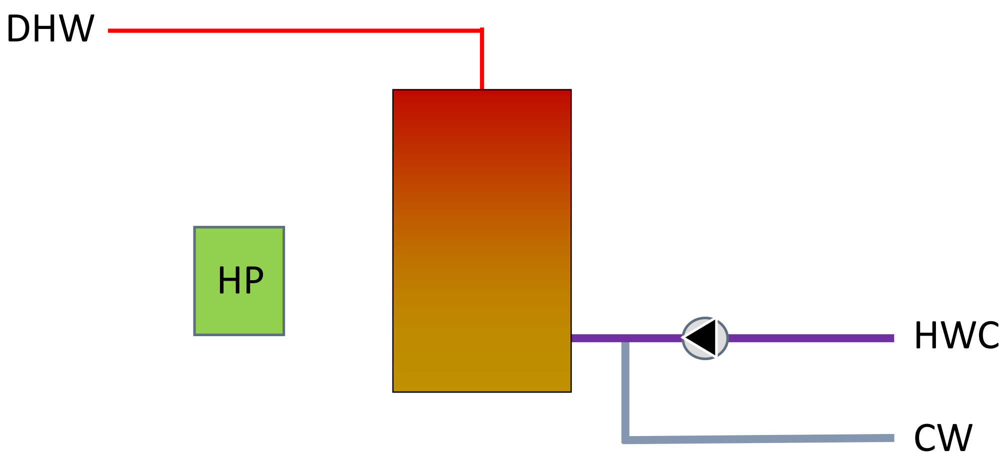


GWP OF SELECTED REFRIGERANTS
(Carbon Dioxide Equivalents, CO_2e)

Refrigerants have 10% of the climate forcing impact of CO2 Emissions

Two Different Loads in a Building,



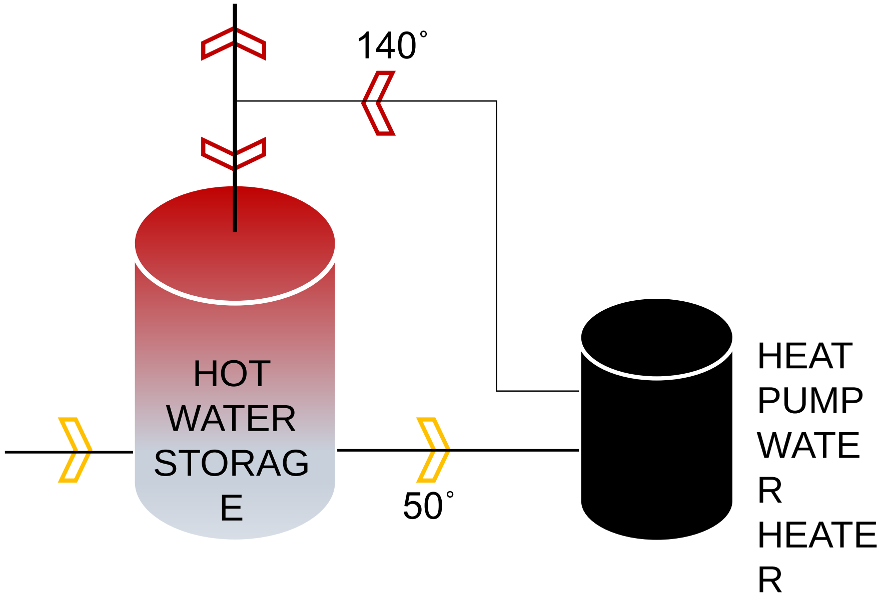


Hot Water Load

- Hot water load, sized for morning and evening peak draws
- Typical design is small heat pumps and large storage
- Heat pump sized to make all the water needed in the determined amount of production time

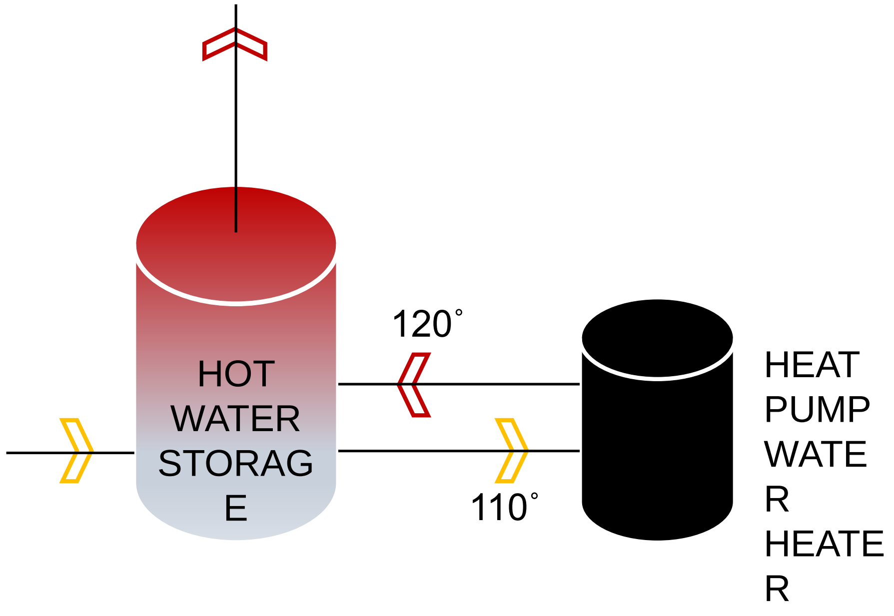
Temperature Maintenance

- 24/7, 365 day load keeping lines hot
- Ranges from 50-400 Watts/apartment
- Recirculation load is hard to calculate accurately
- Dependent almost entirely on piping and plant UA and flow
- Since the load is continuous, the heat pumps need to be able to match the load, oversizing can be problematic



Single Pass

Heats up Water to working temp in single pass



Multi-Pass

Heats up water to working temp in multiple pass

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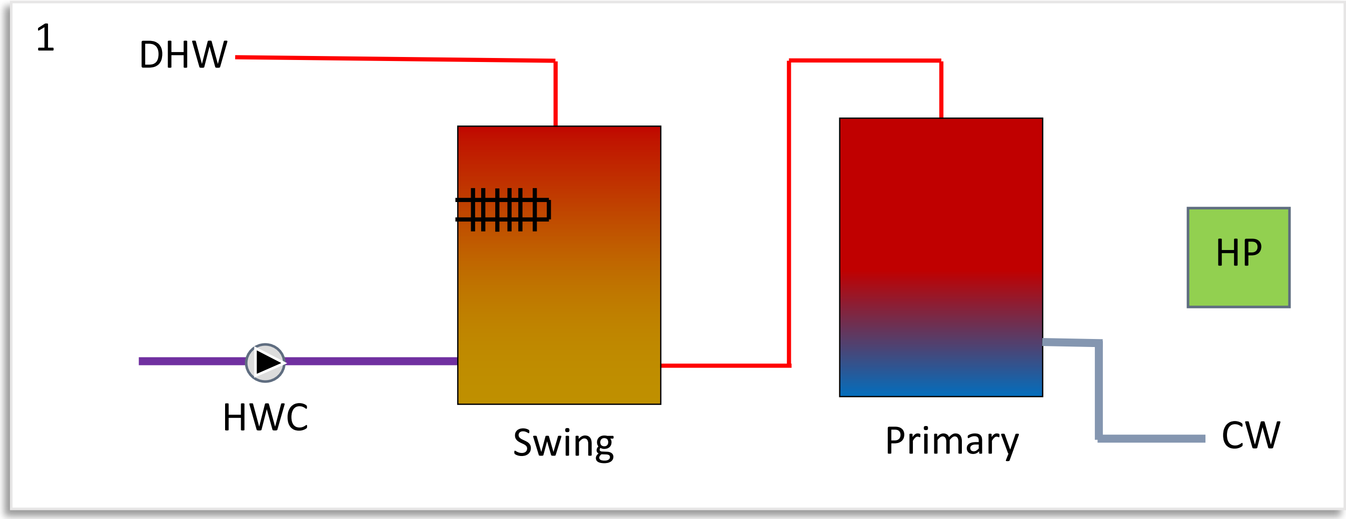
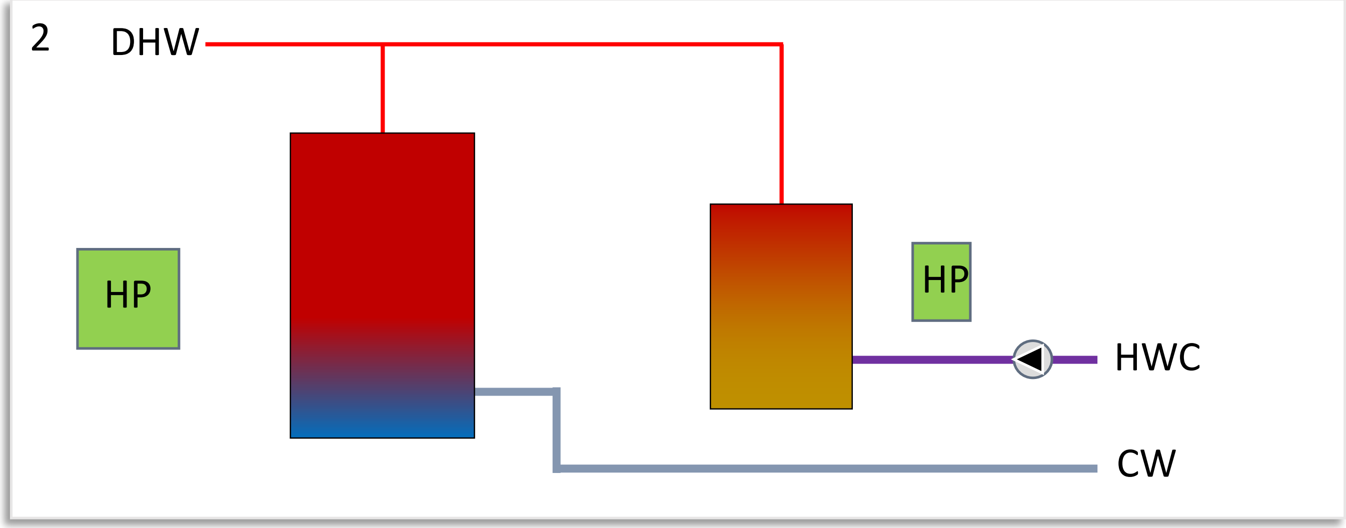
Single Pass or Multi-Pass





Problem

Recirculation return temps are too high and flowing too fast for single pass heat pumps and storage.

- Degrades system COP significantly
- Can destroy stratification
- Makes Load Shift Difficult

Solutions

Option 1. Primary Storage feeding Swing Storage

- Make 150F water, Main storage feeds into swing tank.
- Add resistance coil to swing tank
- Single pass heat pump never sees recirc flow

Option 2. Dedicated TM Heat Pump Plant

- Primary plant is single-pass
- Secondary HWC plant is multi-pass

Temperature Maintenance and Single Pass

Central Heat Pump Water Heating Products

Variable Capacity (4) | PHNIX, ALTHERMA, VERSATI, VRF (Mitsu and LG)

Fixed Capacity (4) | COLMAC, NYLE, TRANE, CARRIER, MULTISTACK

R-410a Refrigerant Heat Pumps

- Colder Temperature range
- Designed for space heating, we use for DHW
- Inverter: -5F to 110F entering air
- Defrost Starts around 38F
- Water Temp – 120F possible
- Vapor injection technology can make 140F, COP hit.
- Requires additional double wall heat exchanger
- COP 2.5 in Seattle for DHW production
- Can do temp maintenance and water heating
- VRF Hydronic – COP 1.8-2.0 in Seattle for DHW

Refrigerant Types | **Currently Available**

R-410a

Mostly Fixed Capacity | Most Integrated HPWH (“hipwa”), COLMAC, AO SMITH, NYLE

R-134a Refrigerant Heat Pumps

- Warmer Air Temperature range
- Designed for DHW
- Constant Volume: 40F to 110F entering air
- Defrost Starts around 45F EA
- Water Temp – 130-160F possible
- Includes Double Wall Heat Exchanger
- Single Pass Water Heating in BG Garage- COP 2.7 Seattle
- Temperature Maintenance in BG Garage – COP 2.5 Seattle
- Available as Single or Multi-pass
- Temperature maintenance with single
- Available with communicating controls

Refrigerant Types | **Currently Available**

R-134a

CO_2 Variable Capacity
SANDEN (1.25 Ton)

R-744 (CO2) Refrigerant Heat Pumps

- Entering Air Range -25 to 110 F
- Inverter Driven Compressors
- Available as Single Pass only
- Designed for DHW
- Water Temp – 150F and 190F possible
- Technically does NOT require double wall (CO2)
- Water Heating COP 3.2
- Temperature Maintenance Challenging

Refrigerant Types | **Currently Available**

R-744 (CO_2)

CO_2 Variable Capacity (Available Internationally)
Mayekawa (22T), Mitsubishi (11T), MHI (8T), Itomic (3, 7, 22T), Sanden (larger 4.2T)

R-744 (CO2) Refrigerant Heat Pumps

- Entering Air Range -14F to 110 F
- Inverter Driven Custom Compressors
- 1400+ PSI rated components
- Single Pass
- Designed for DHW
- Water Temp – 150F and 190F possible
- Technically does NOT require double wall (CO2)
- Water Heating COP 3.2
- Temperature Maintenance Challenging
- No UL on any of these products yet (field test possible)

Refrigerant Types | **Currently Unavailable**

R-744 (CO_2)

Outdoor Unit (Heat Pump) Model No. GS3-45HPA-US		
Performance	**43-gal. system**	**83-gal. system**
Energy Factor	3.09	3.84
First Hour Rating	71 gallons	101 gallons
Specifications		
Water Temperature Setting	130°F to 175°F	
Ambient Air Operating Temperature	-20°F to +110°F	
Heat Pump Capacity	15,400 Btu/h	
Heat Pump Capacity	4.5 kW	
Heat Pump COP	5.0	
Refrigerant Type	R744 (CO_2)	
Compressor Type	Inverter	
Power Voltage	208/230v –1Ph – 60Hz	
Breaker Size	15 Amps	
MCA	13 Amps	
Outdoor Operating Noise Level	37 dB	
Weight	106 lbs	
Pipe Size (Tank to Heat Pump)	½" (Hot & Cold)	
Max Length Inc Vertical	50 ft	
Max Vertical Separation	16 ft	
Max Water Pressure	95 Psig	

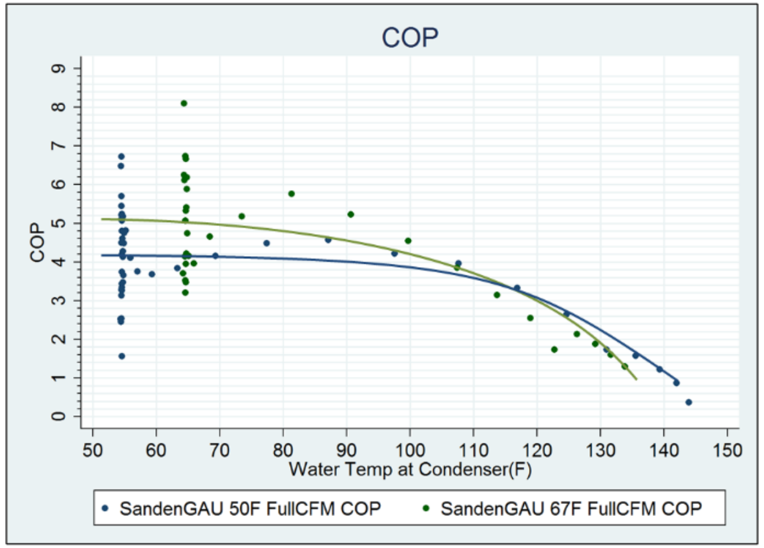
Table 3. Efficiency, Output, & Input vs. Outside Temperature

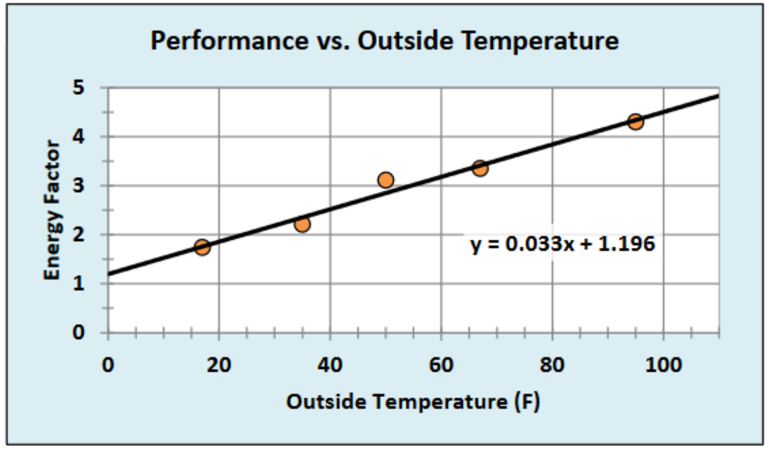
Outside Air Temperature (F)	Energy Factor (EF)	COP	Output Capacity (kW)	Input Power (kW)
17	1.74	2.1	4.0	1.9
35	2.21	2.75	3.6	1.3
50	3.11	3.7	4.0	1.1
67	3.35	4.2	4.1	0.97
95	4.3	5.0	4.6	0.93

Table 4. Annual Performance Estimates for 10 Climates

Climate	Annual EF	Climate	Annual EF
Boise	2.9	Minneapolis	2.7
Kalispell	2.6	Raleigh	3.2
Portland	3.0	Boston	2.9
Seattle	2.9	Chicago	2.9
Spokane	2.8	Houston	3.5

COP 5.0 in literature, Actual COP is closer to 3.0





AHR Performance Ratings Issue – Lab Tests Required

Sanden Lab Test – (Larson-Ecotope 2012)

Ecotope Central HPWH Design Portfolio

<u>Low Rise | 10-65 dwelling units</u>

- Elizabeth James - 65 units - (4) Sanden CO2 Heat Pumps
- Grow Communities - 3 bldgs. 12 units each - Daikin Althermas
- Puyallup Tribal - 20 units - VRF Plant, GSHP Plant

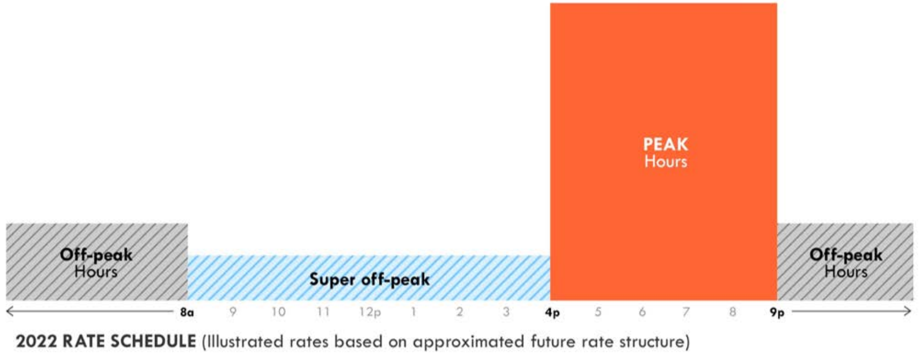
<u>Mid Rise | 50-400 dwelling units</u>

- Stream - 134 units - (2) 10T Colmac Air-Source HP in below-grade parking
- Sunset Electric - 92 units - Colmac in below-grade parking
- Stackhouse - 120 units - Colmac in underground parking deck
- Augusta Apartments - 224 units - Colmac in below-grade parking
- Batik Apartments - 195 units - Colmac in underground parking deck
- Yesler 3 - 227 - Colmac in underground parking deck
- Jackson Apartments - 526 units - Colmac in underground parking deck
- Colina Apartments – 131 units, Sanden - Decentralized
- The Vale Apartments - 134 units - Versati 2, Multi-Pass
- Waterfront Place - 137/135 units - Versati 2, Multi-Pass
- Hopeworks – 67 units , Sanden CO2 Stacks

<u>High Rise | 200-450 dwelling units</u>

- 4700 Brooklyn - 284 units - Colmac with VRF Temp Maintenance
- Cascade - 430 units - Colmac with VRF Temp Maintenance
- 1200 45th -245 units - In Design

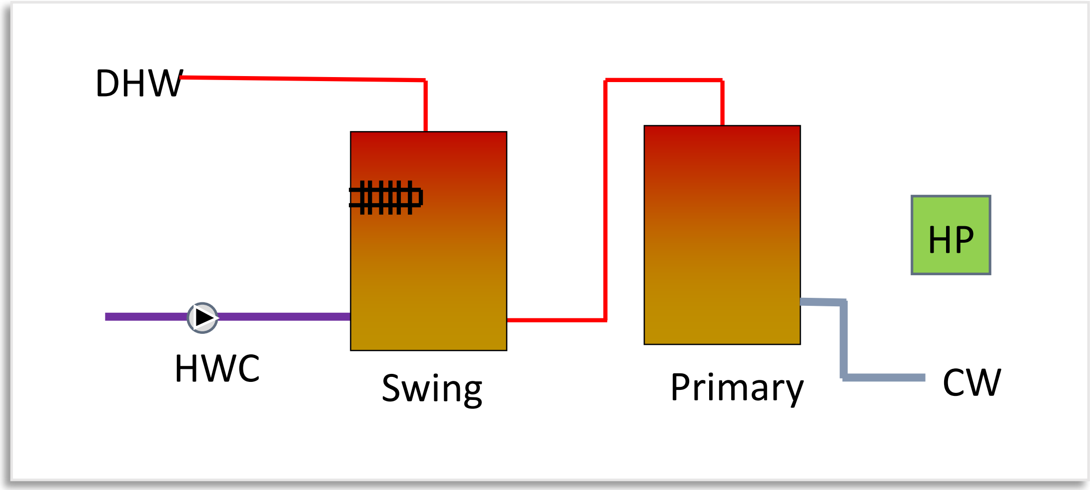
Smart Grid Capable Central DHW Heat Pump Product Performance Specification

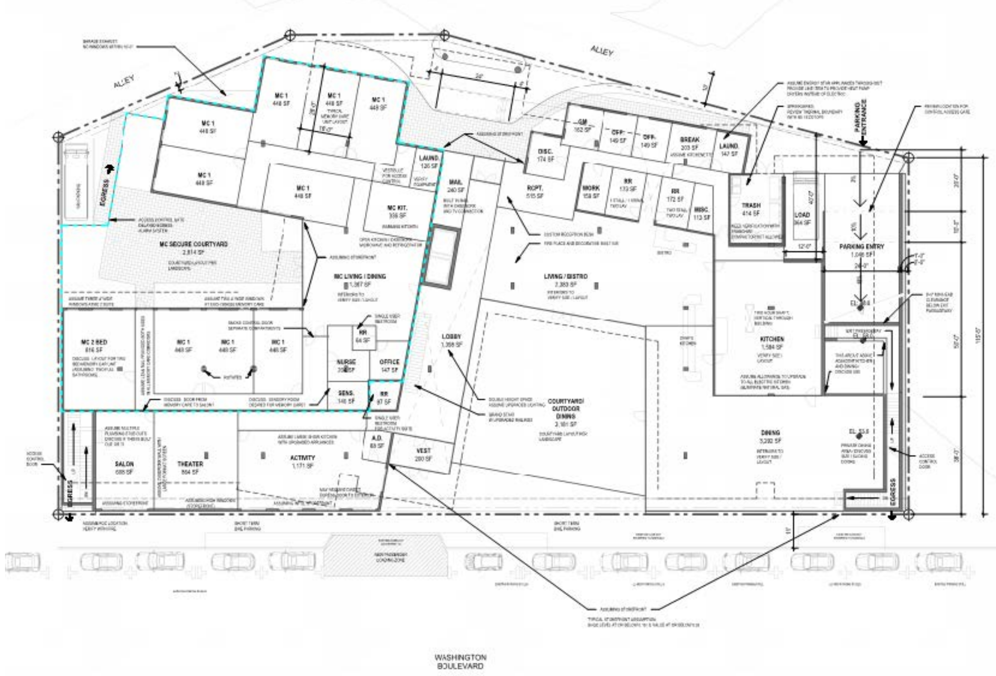


- Low GWP Refrigerant – Single Digits
- Single Pass Design to enable stratification
- Capable of making 150 F water.
- Operational from -13F to 110 F EAT
- Min COP Rating – 3.5 at 47F AHRI
- 208VAC, 3 Phase, 240 VAC Single Phase
- 5 to 10-Ton Air Source Heat Pumps
- Potable water rated everything
- Fully packaged controls with heat pump; no on-site programming, Demand response controls
- Fully optimized defrost controls
- Digital Thermostatic Mixing Stations
- Integrated M&V, diagnotics, alerts, alarms, app.
- Sizing support from manufacturer and rep.

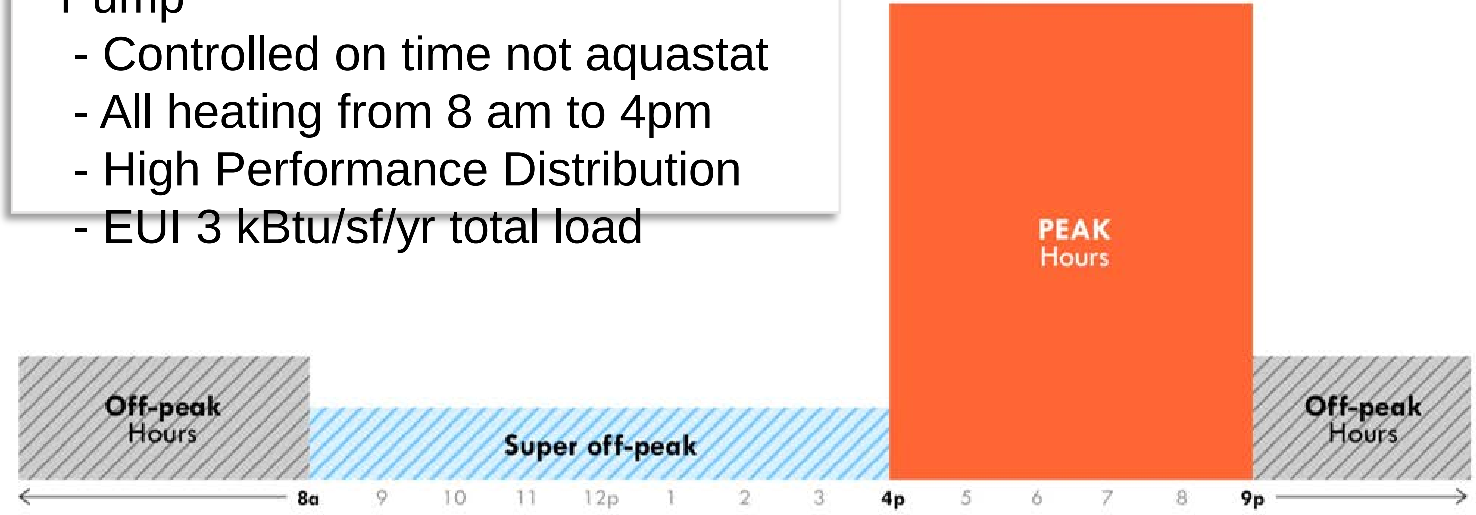
Culver City Grid Harmonize Pilot

- Demonstrate Demand Response, CO_2 Central DHW
- All Heating from 8am-4pm
- High Performance Distribution System
- DHW EUI to 3 kBtu/sf/yr





2000 Gallon Primary (150F)
1000 Gallon Swing (150F)
20 Tons of Single Pass CO_2 Heat Pump
- Controlled on time not aquastat
- All heating from 8 am to 4pm
- High Performance Distribution
- EUI 3 kBtu/sf/yr total load



2022 RATE SCHEDULE (Illustrated rates based on approximated future rate structure)

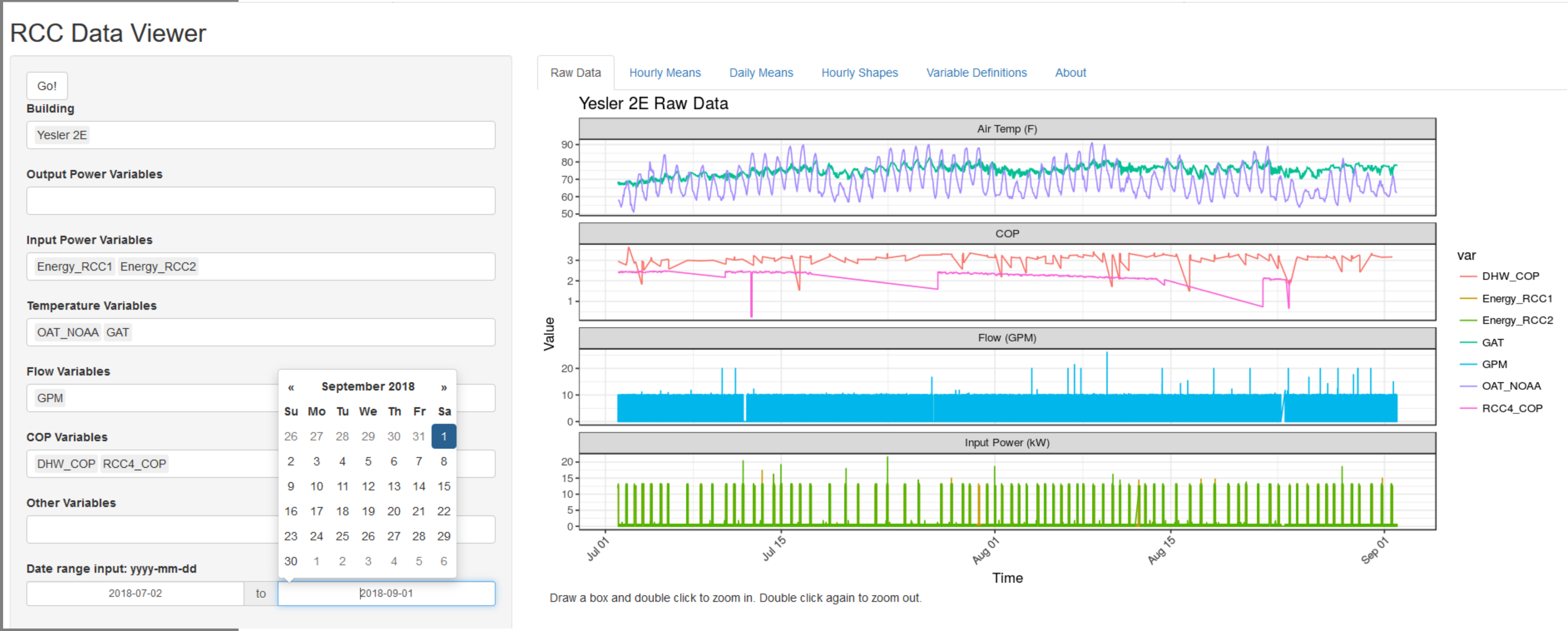
Case Study: Batik Apartments\ 195 units

Buffered Garage Located Air Source Heat Pumps

Batik Stats

Batik		
Apartments	195	units
Primary Water Heating	134a Colmac air source	Single-pass
HW temperature maintenance	134a Colmac air source	Multi-pass
HW storage	3000	gallons
HW equipment capacity	29	tons
HWC losses per apt	68	watts/apt
Primary system performance	2.7	COP
Temperature maintenance performance	2.5	COP

Batik M&V Data




COLMAC
WATERHEAT
COLMAC
WATERHEAT


COLMAC
WATERHEAT


GRUNDFOS


BACK
POWERS
A WATTS Brand
Mixed Outlet Temp
120 °F
Mixed Outlet Temp
120 °F
PRGM Recirc Pump OFF
IntelliStation
Domestic Hot Water Regulation
BACK


BACK
POWERS
A WATTS Brand
Recirc Flow
6.1 gpm
Recirc Flow
6.1 gpm
PRGM Recirc Pump OFF
IntelliStation
Domestic Hot Water Regulation
BACK


BACK
POWERS
A WATTS Brand
Mixed Outlet Flow
14.0 gpm
Mixed Outlet Flow
14.0 gpm
PRGM Recirc Pump OFF
IntelliStation
Domestic Hot Water Regulation
BACK

Balik Lessons learned

1. With any large central heat pump system, full DDC control system is highly recommended.

2. 134a heat pumps start frosting of coils when the entering air drops below 45F. In parking garages this happens when outside air is around 25F or lower.

3. Keep the controls simple, KISS. We had to reprogram the heat pumps during a cold spell to optimize the backup systems. Primary RCC's had trouble melting ice.

4. Focus on the backup systems and the sequence for these backup systems. Big buldings cannot have any downtime on hot water systems.

5. Use the derated equipment capacity for design, 15 tons is really 9 tons at entering air of 50F is an example at design

Case Study – Sitka Apartments 384 unit

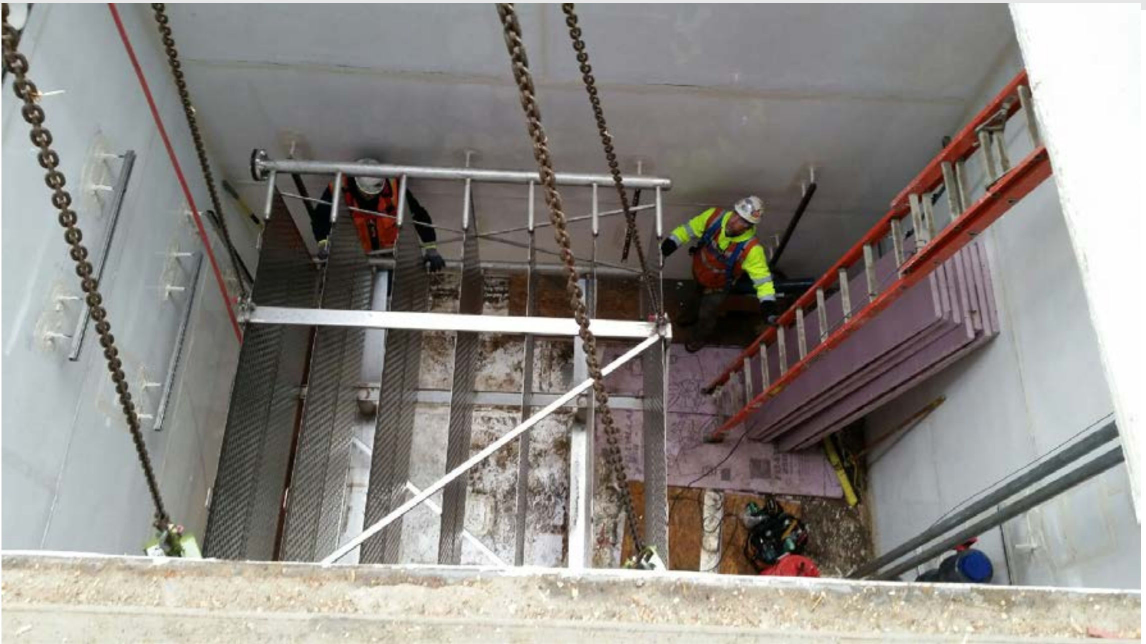
Wastewater Source Central Heat Pump Water Heater

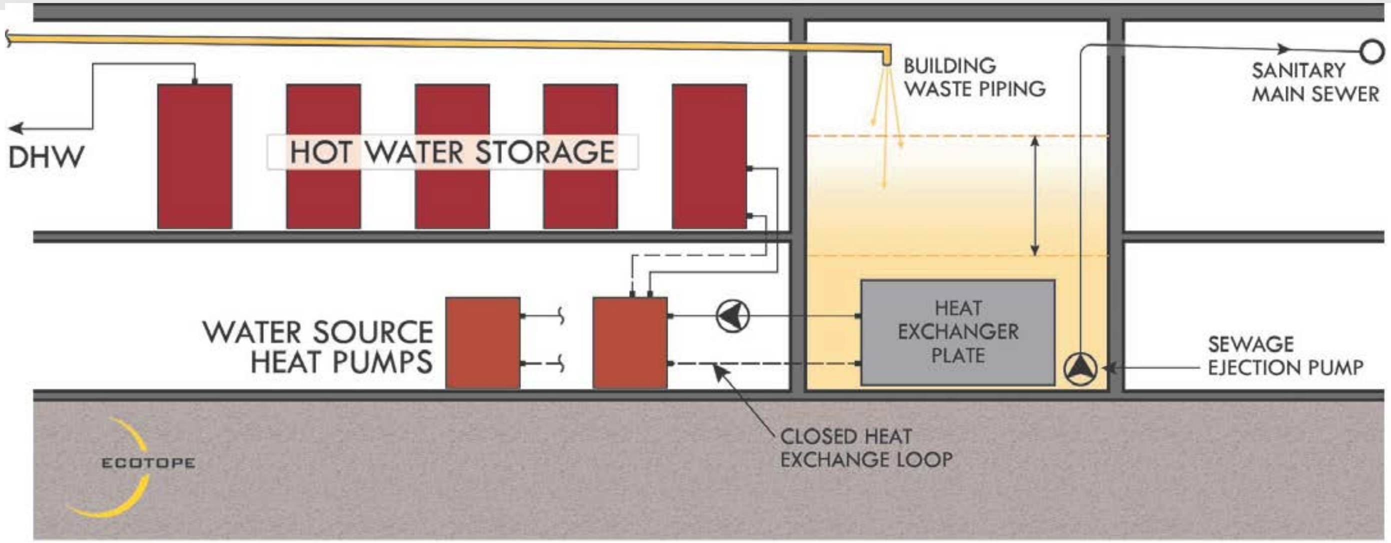
Sitka- WWHP Stats

Sitka		
Apartments	384	units
Primary Water Heating	134a Colmac water source	
HW temperature maintenance	134a Colmac air source	
HW storage	5375	gallons
HW equipment capacity	37	tons
HWC losses per apt	74	watts/apt
Primary system performance	4	COP
Temperature maintenance performance	2.5	COP


COLMAC
WATERHEAT
WWHP-1
WWHP-2
DANGER
GWH-1
GWH-2

| Wastewater Source Heat Pump – Seattle - 384 Units





Sitka- WWHP Lessons Learned

1. Get your local plumbing AHJ involved early in the design, make sure it is not a surprise.

2. There is not enough energy in the wastewater to heat both primary hot water and temperature maintenance. Use a separate heat pump system for temperature maintenance

3. Assume concrete vaults always crack, install a liner in all concrete wastewater vaults

4. This type of system has never been done before, the contractors have to be brought along during design, construction, plan for a lot more CA time.

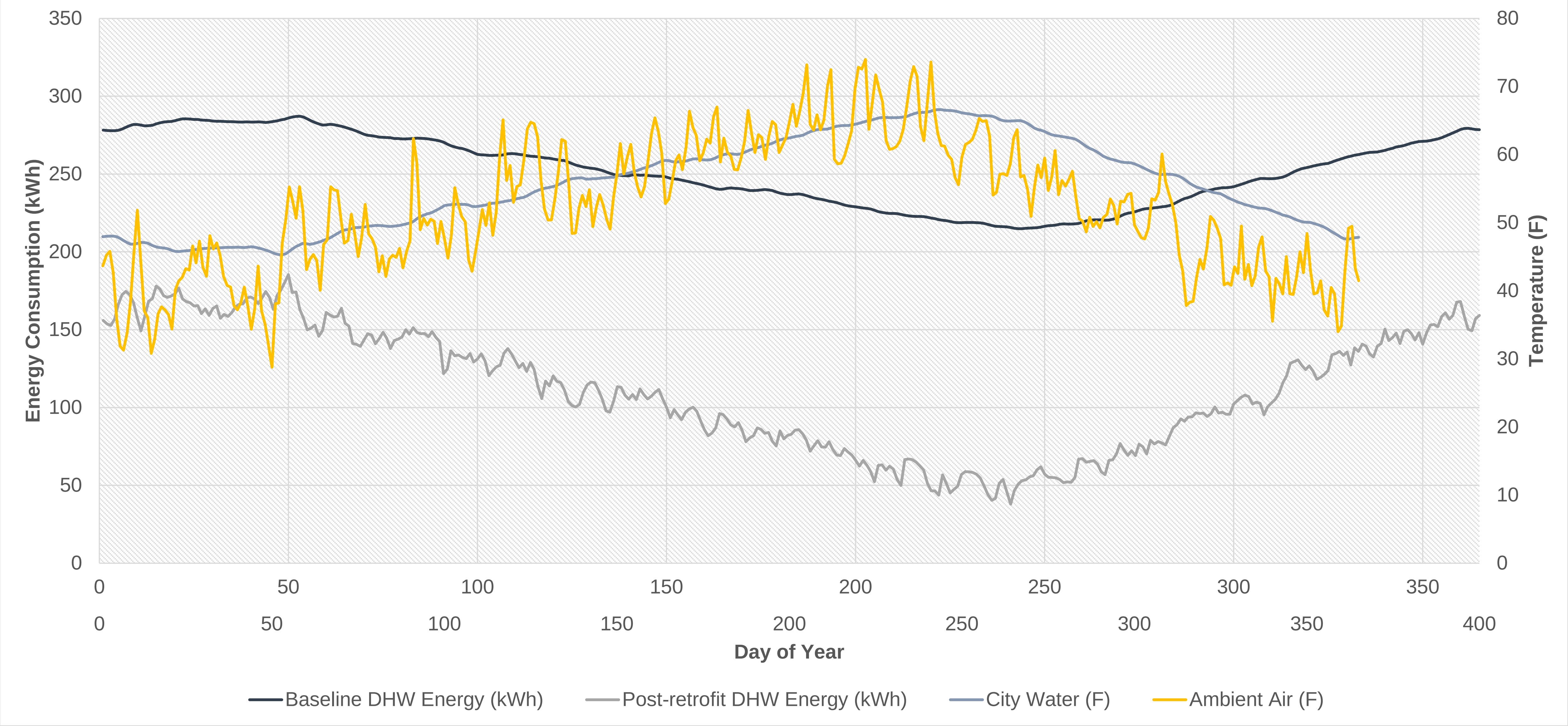
5. With any all electric building, the grid will go down, make sure you consider power outage scenarios, we had a power outage and installed a battery backup UPS on the controls and internet modem to ensure someone is notified of any problems.

6. Recommend 100% redundancy and backup systems

Case Study – Elizabeth James Central Hot Water Retrofit

60 Unit low income apartment

Elizabeth James- Monitoring – COP 2.7 Seasonal



Elizabeth James

Elizabeth James		
Apartments	60	units
Primary Water Heating	744 Sanden air source	
HW temperature maintenance	Swing tank (backup electric)	
HW storage	520	gallons
HW equipment capacity	5	tons
Primary system performance	2.7	COP
Temperature maintenance performance	0.9	COP *Existing electric boilers
Temperature maintenance performance	2.7	COP *Normal operating conditions

Elizabeth James Lessons Learned

1. Existing buildings have real space constraints, fitting the new hot water storage tanks through the door was a real constraint, 32” tanks were the largest we could fit

2. Consider the downtime to install this system. Since the existing systems was a working system ina live building, we installed a bypass valve and after the system was installed and commissioned, we flipped the valve over.

3. First installation of the swing tank in practice, our sizing was too liberal, we should have added 50% more storage (175 gallon installed, should have been 300 gallon electric trim tank)

4. We had an issue with one of the four heat pumps, then we had a giant snow storm…..

Elizabeth James – Snowstorm took care of finicky heat pump.