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2022 Partner Exchange

Electrification of Heat is More Than Just a Fuel Change

September 19, 2022

TRANE TECHNOLOGIES

Agenda

- Introductions and recognizing workshop advisors
- Heating sources
- Heating loads and coil selection implications
- Carbon emissions and example analysis
- Introduce newer applied heating products
- Overview two chiller heater system concepts
- Summary and final questions

Welcome questions and interaction during the workshop

Thank You to our Partner Advisory Team Members

- Bill Champion – Partner

- Mike Warmbold – Trane

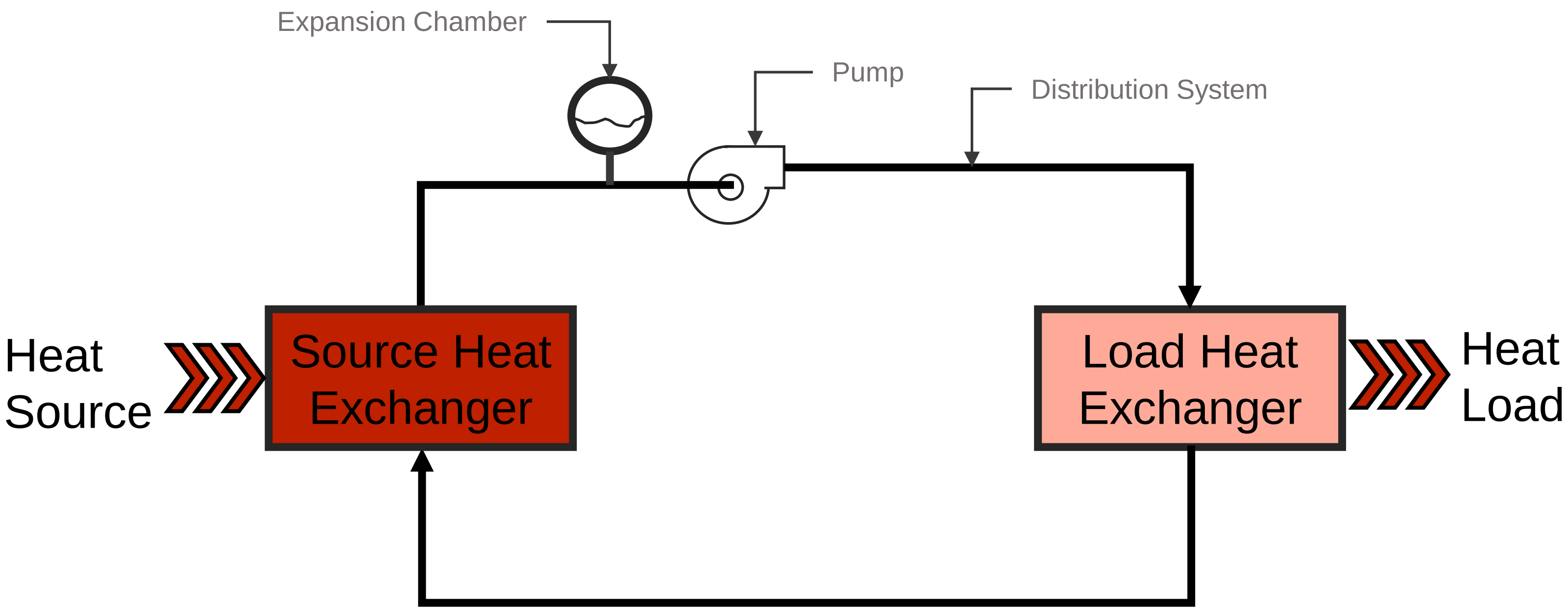
Hydronic Heating for HVAC: Closed Water System
Source and Load Requirements for Hot Water Supply and Return

What is the source of heat making the hot water?

➔Hot Water Temperature
+ Hot Water Flow Available

What is the load and equipment used?

➔Hot Water Temperature + Hot Water Flow Required



Hydronic Heating for HVAC: Closed Water System

Source and Load Requirements for Hot Water Supply and Return

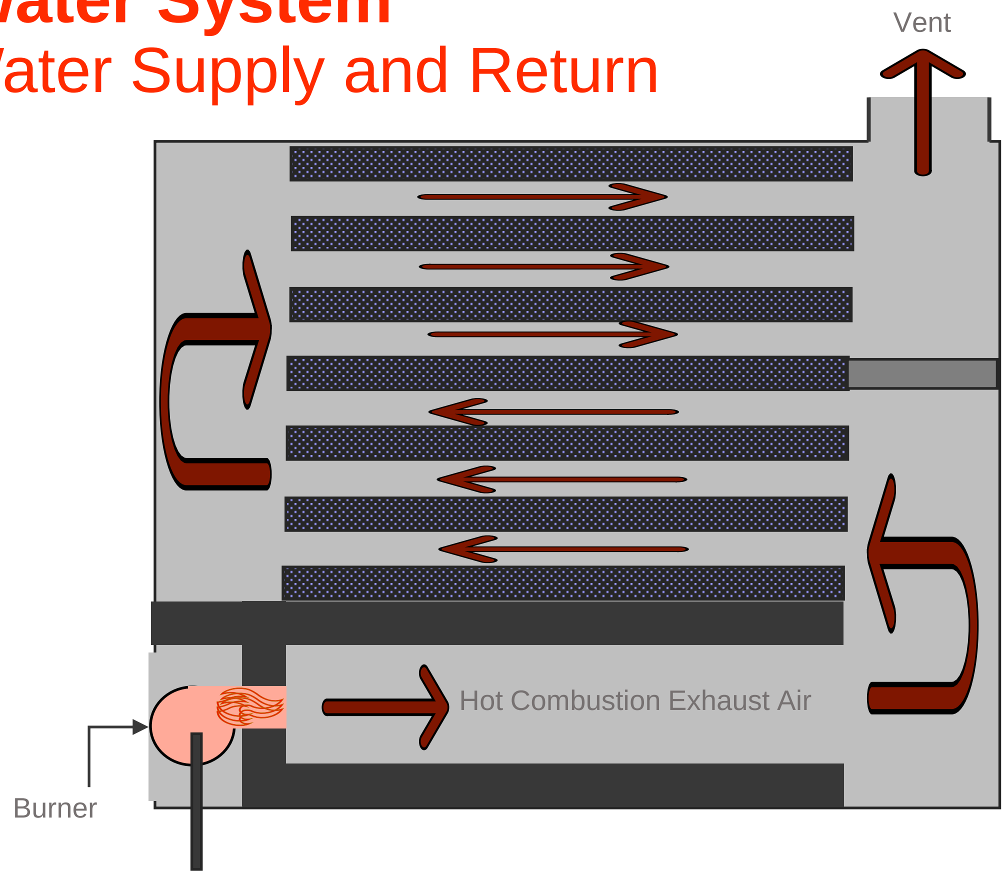
Traditional Boiler

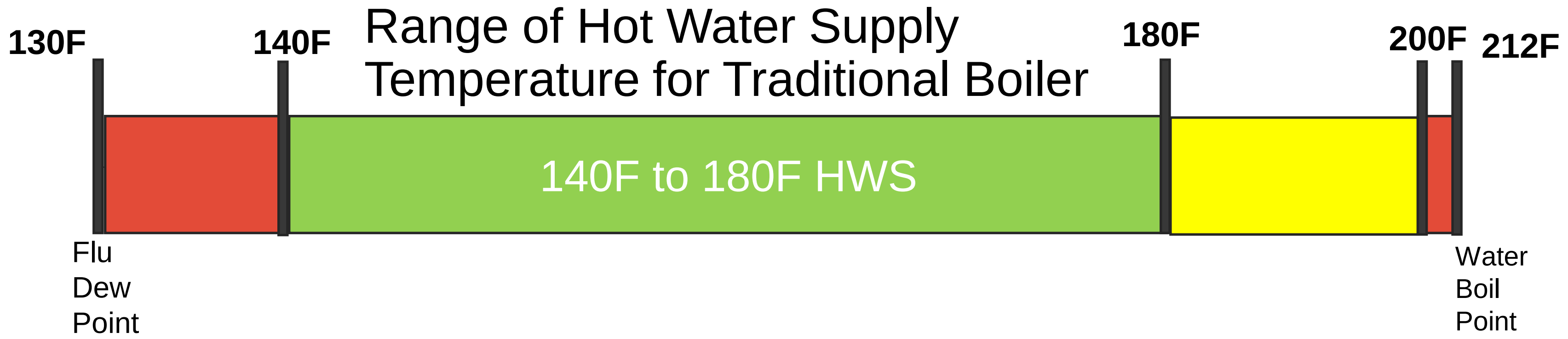
What is the source of heat making the hot water?

Combustion—Make Heat

Natural Gas ≈ 1030 btu/ft^3

Source Heat is combustion exhaust air (flu gas) ≈ 300-500F





Hydronic Heating for HVAC: Closed Water System

Source and Load Requirements for Hot Water Supply and Return

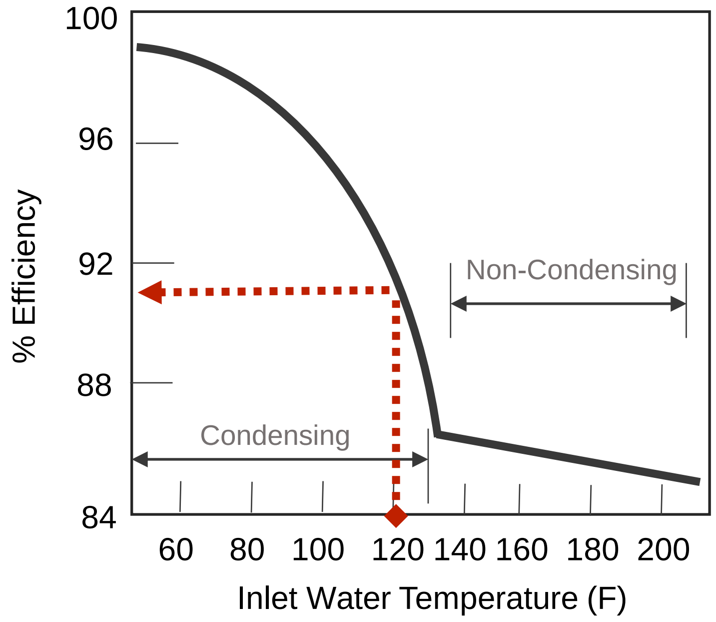
Condensing Boiler

What is the source of heat making the hot water?

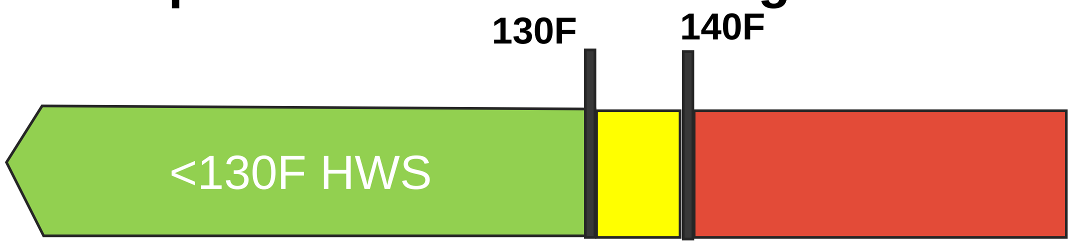
Combustion—Make Heat

Natural Gas ≈ 1030 btu/ft^3

Source Heat is combustion exhaust air (flu gas) ≈ 300-500F + condensation



Range of Hot Water Supply Temperature for Condensing Boiler



<120F Inlet Water to Boiler
to get benefit of condensation

ASHRAE® 90.1-2019 Section 6.5.4.8.2

a. Coils and other heat exchangers shall be selected so a that at design conditions the hot water return temperature entering boils is 120F or less

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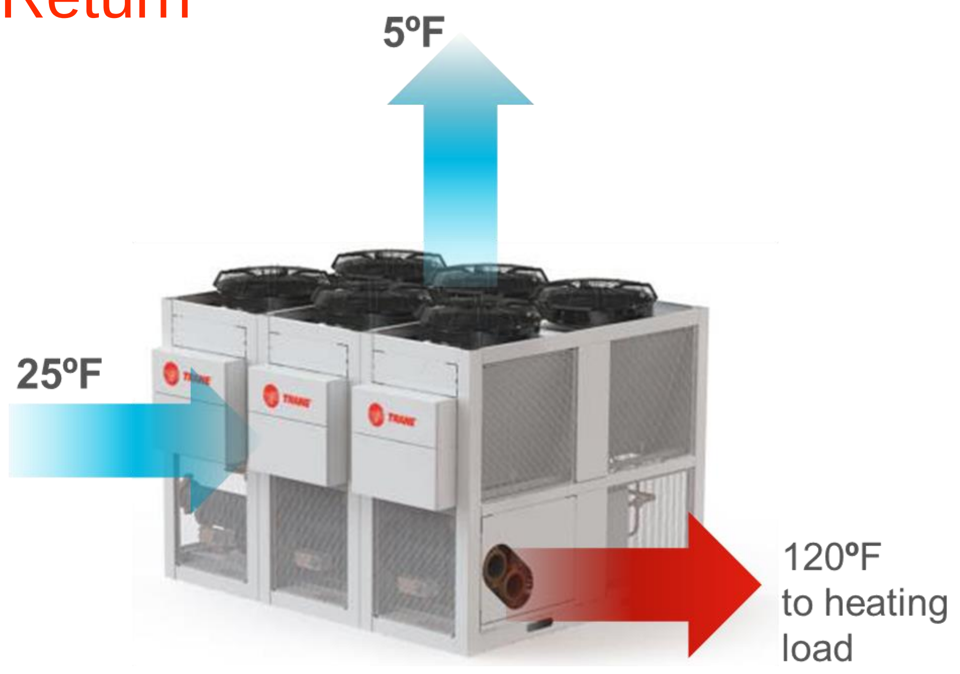
Hydronic Heating for HVAC: Closed Water System
Source Requirements for Hot Water Supply and Return
Heat Pumps

What is the source of heat making the hot water?

Heat Pumps- **MOVE** Heat

Source Heat

Air Source: Extract Heat from Outdoor Air



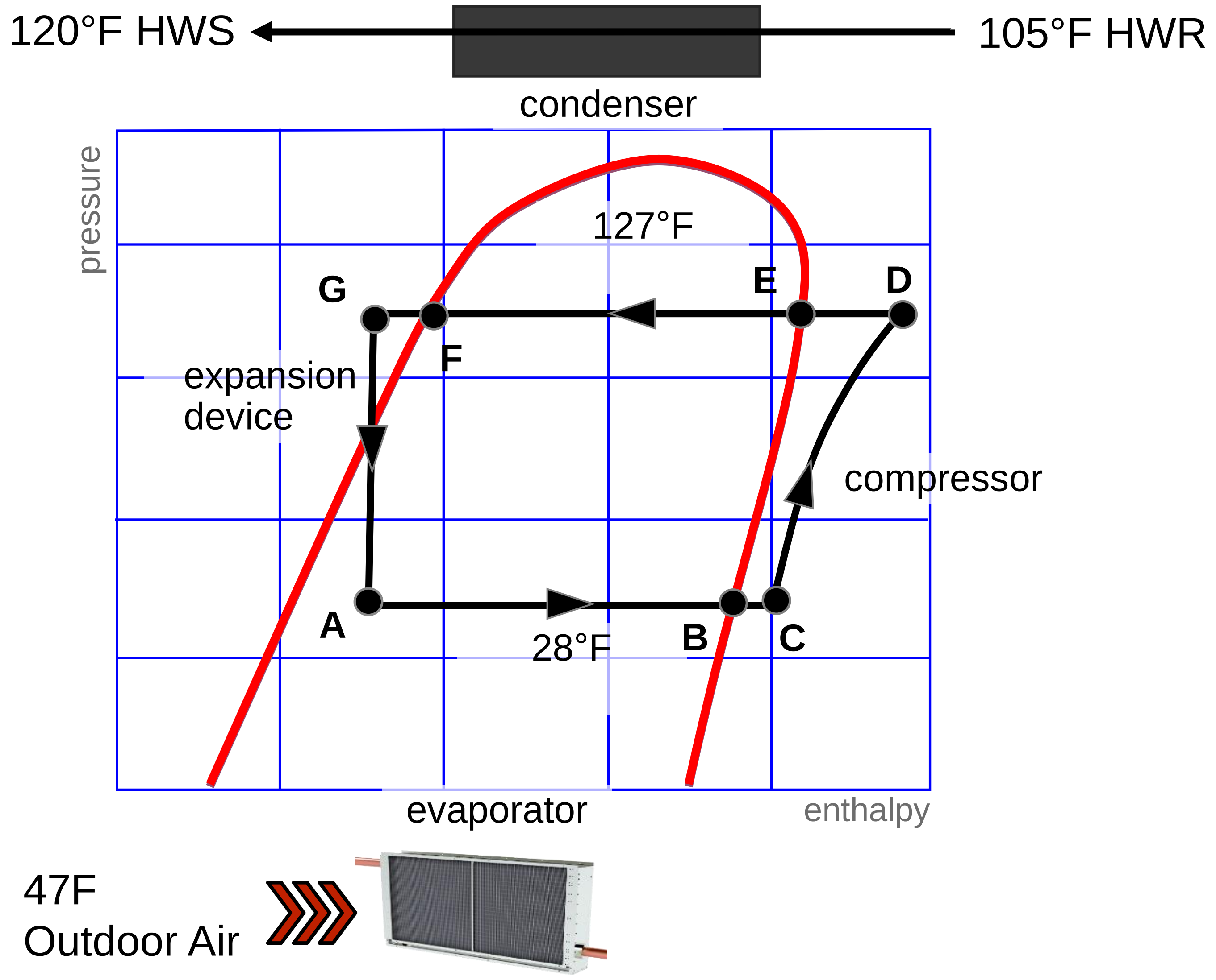
Hydronic Heating for HVAC: Closed Water System
Source Requirements for Hot Water Supply and Return
Air Source Heat Pumps

Heat source is outdoor air

Move heat from the outdoor air to the hot water loop for building.

Moving heat is more efficient than making heat   COP>>1.0

Example: 47F ambient conditions
This example, make 120F HW
COP=2.81… 281% efficient



Hydronic Heating for HVAC: Closed Water System

Source Requirements for Hot Water Supply and Return

Air Source Heat Pumps

Heat source is outdoor air

Example: 5F ambient conditions

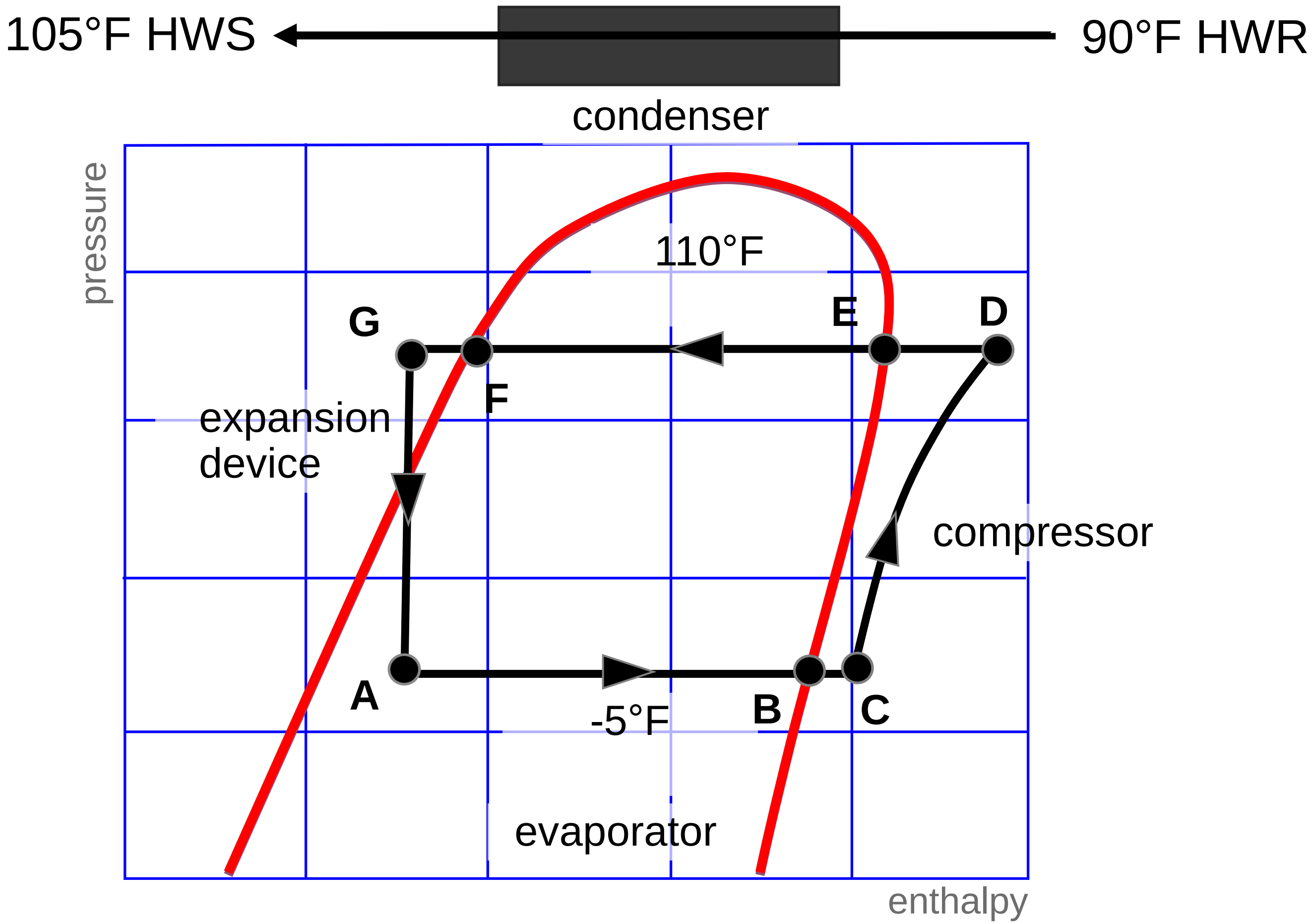
Colder Air

The maximum available temperature hot water is reduced

Available Heating Capacity is reduced

This example, make 105F HW

COP=1.8… 180% efficient



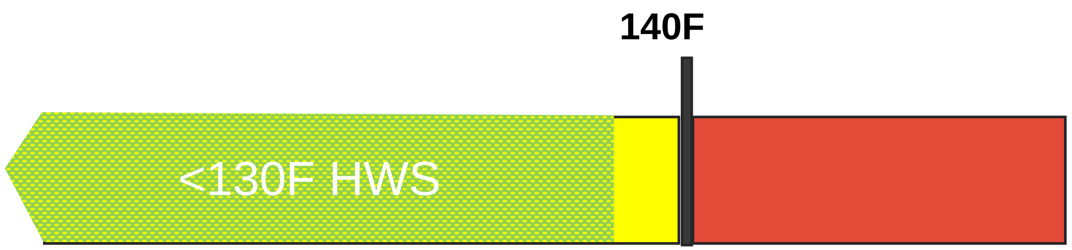
5F
Outdoor Air

Hydronic Heating for HVAC: Closed Water System
Source Requirements for Hot Water Supply and Return
Air Source Heat Pumps

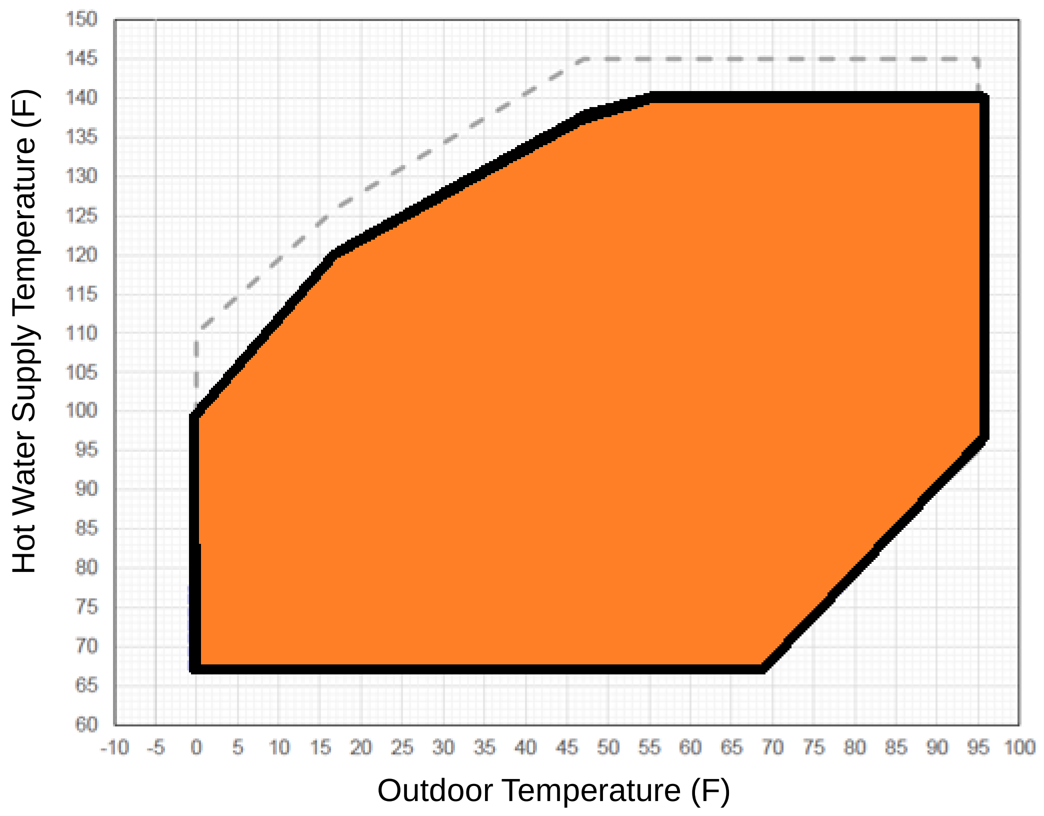
Air Source Heat pump have operating map where the maximum HWS temperature is dependent on the outdoor ambient temperature.

Typical ASHP

HWS 100-140F



Example Operating Map Ascend Heat Pump



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Hydronic Heating for HVAC: Closed Water System

Source Requirements for Hot Water Supply and Return

Heat Pumps

What is the source of heat making the hot water?

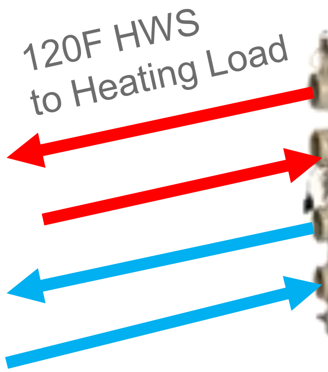
Source Heat

Water Source: Extract Heat from Water Loop

A Building (Chilled Water Loop)

The Earth (Ground Loop)

Thermal Storage(Ice Tanks)



Hydronic Heating for HVAC: Closed Water System

Source Requirements for Hot Water Supply and Return

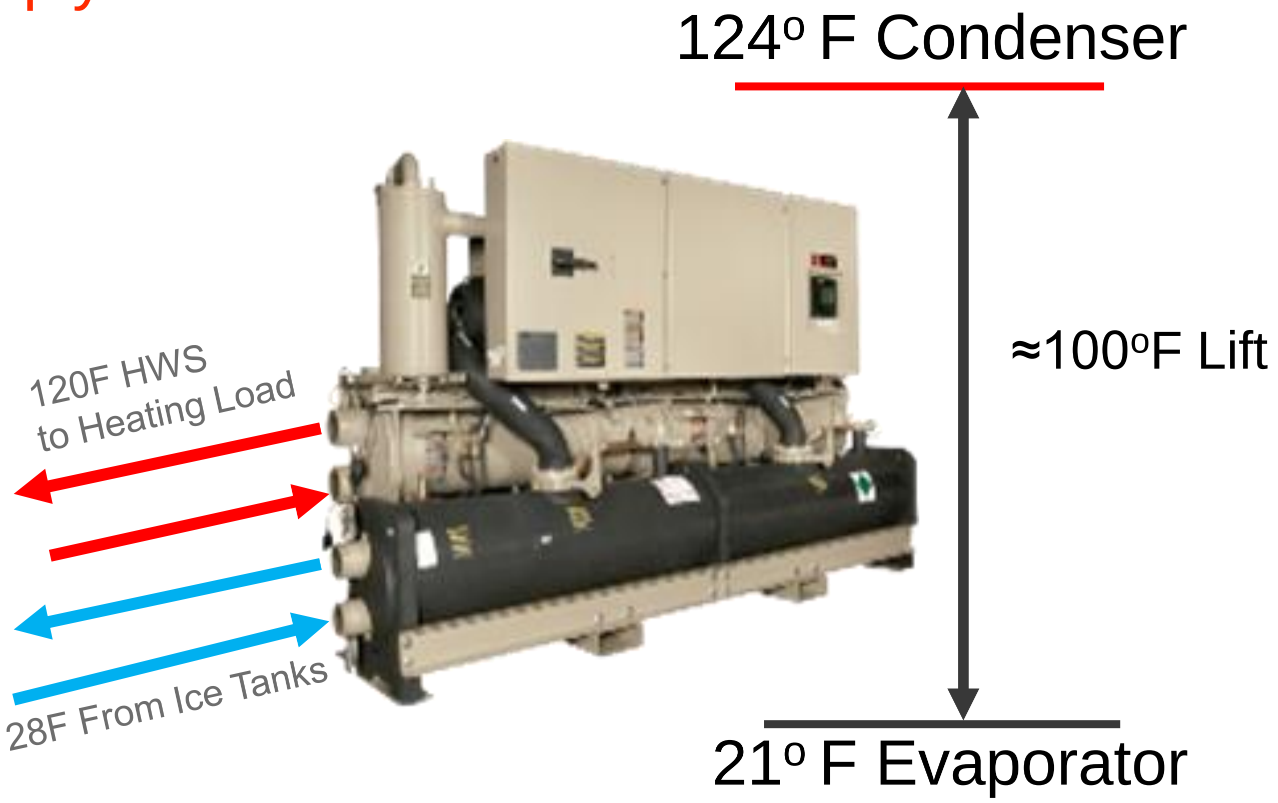
Water Source Heat Pumps

Heat source is water loop

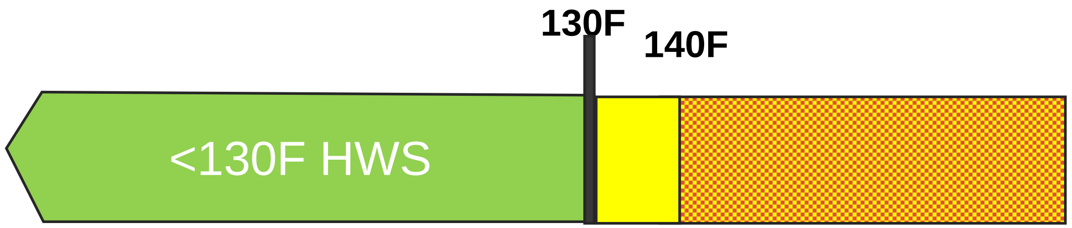
Example: Extract Heat From Thermal Storage Tank

This example, make 120F HW

COP=3.2… 320% efficient



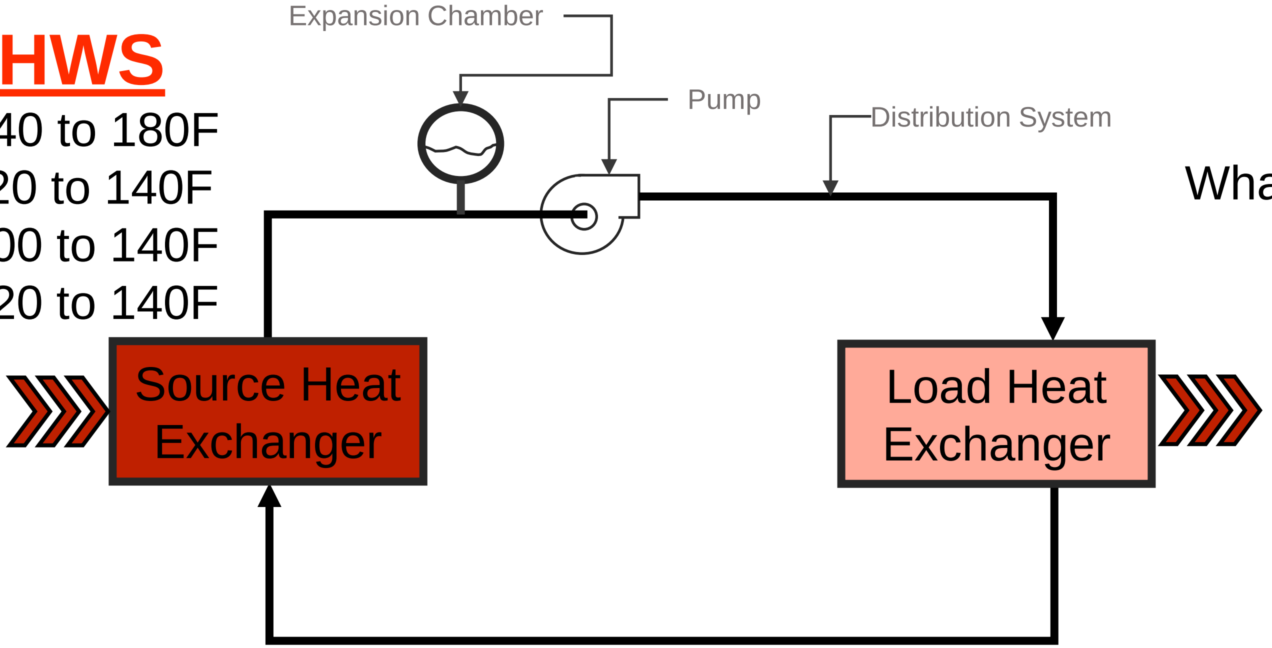
Range of Hot Water Supply Temperature for Water Source Heat Pump



Hydronic Heating for HVAC: Closed Water System
Source Requirements for Hot Water Supply and Return

Typical MAX HWS

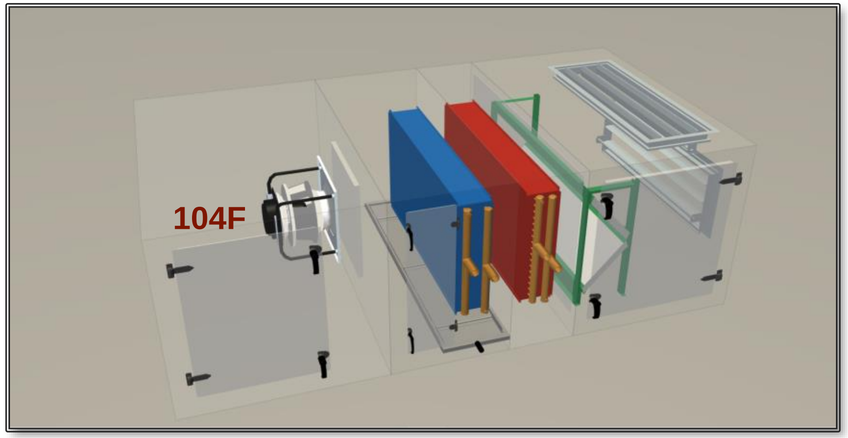
Traditional Boiler =140 to 180F
Condensing Boiler =120 to 140F
ASHP =100 to 140F
WSHP =120 to 140F



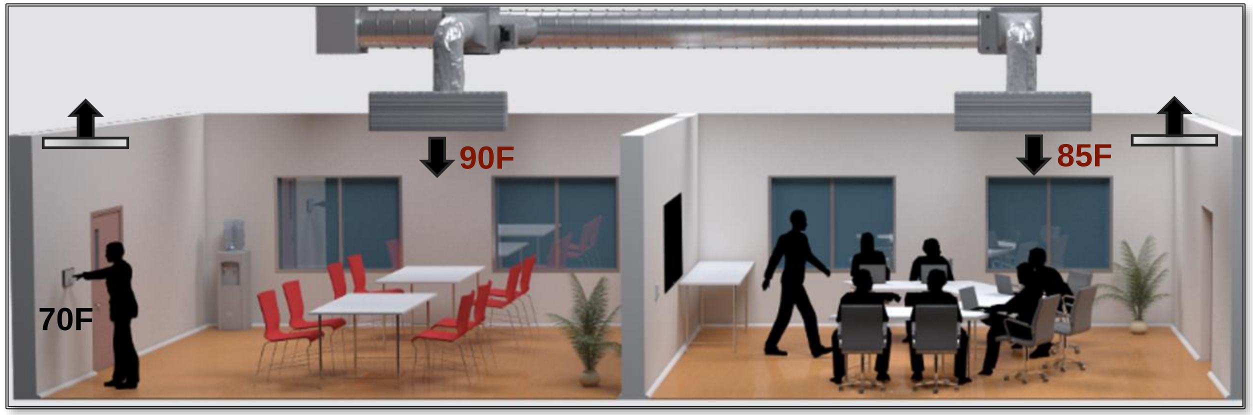
Required HWS

What Does the Load Require?

Hydronic Heating for HVAC: Closed Water System
Load Requirements for Hot Water Supply and Return
<u>supply air temperature limits</u>



<u>Draw Thru fans</u>
-UL limit of 104F air for motor
-More critical today for units with ECM fans



<u>Ceiling Return and Supply</u>

ASHRAE® 62.1 ventilation requirements

Supply air needs to be <15F from space set point or 20% more outdoor air needed!

Design Set points typically 68-70F
Max Supply to avoid penalty 83-85F

ASHRAE 90.1 zone reheat maximum

Supply air < 20F from space setpoint

Max Supply 88-90F

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Hydronic Heating for HVAC: Closed Water System
Load Requirements for Hot Water Supply and Return
<u>supply air temperature limits</u>

<u>Comfort ASHRAE ® STD 55</u>

Sitting occupants need less than 5.4F between head and ankle air temperature

Standing occupants need less than 7.2F between head and ankle air temperature

Operative temperature of space can not rise quicker than 2F in 15minutes

These are difficult to accomplish with very hot air

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Hydronic Heating for HVAC: Closed Water System
Source Requirements for Hot Water Supply and Return

Typical MAX HWS

Traditional Boiler	=140 to 180F
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ASHP	=100 to 140F
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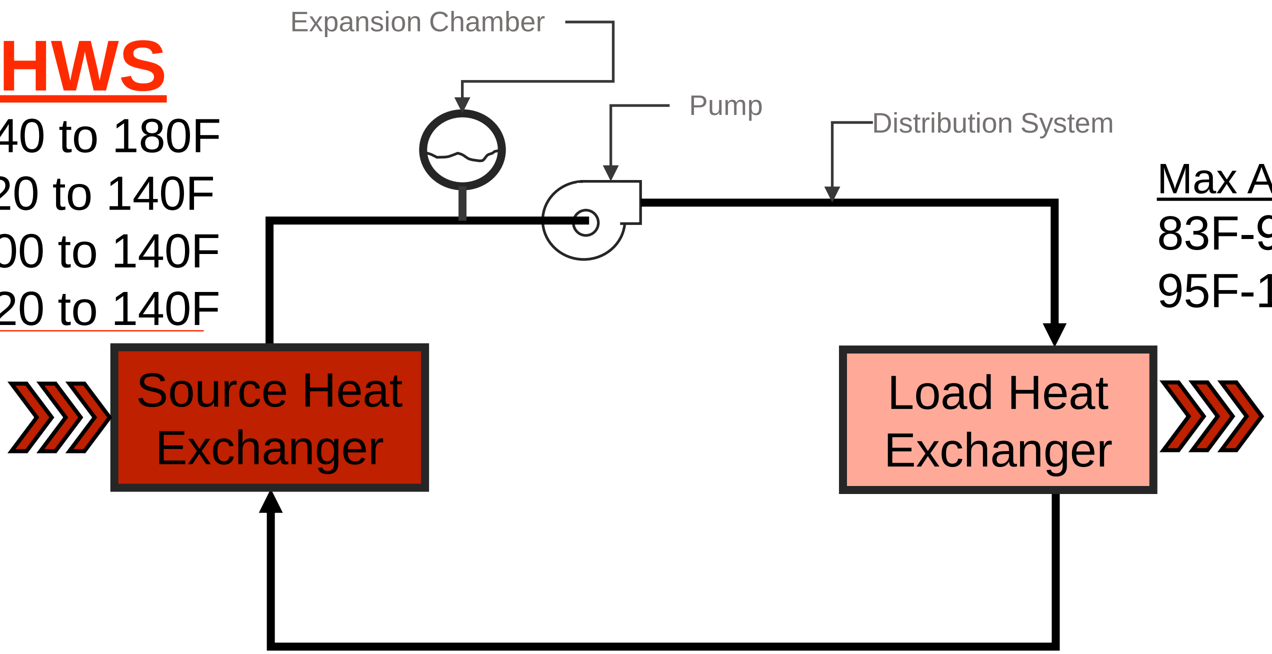


Needed HWS

Max Air Temp		HWS assume 8F Diff
83F-90F Target	≈	91-98F HWS
95F-104F Max	≈	103-112F HWS

New Buildings or New Systems
HWS temperature to match load

Reuse existing coils
HWS to match the coils

Hydronic Heating for HVAC: Closed Water System
Load Requirements for Hot Water Supply and Return

Example: Fan Coil Unit

Heating Return Air Only

EAT 65F LAT 90F

Hot-water supply temperature	180°F	140°F	110°F	105°F
Coil rows	1 (HW)	2 (HW)	2 (HW)	4
Entering fluid temperature, °F	180	140	110	105
Leaving fluid temperature, °F	103	93	103	82

Unit coil face area sized for cooling

-1Row Heating coil HWS =180F

-2Row Heating coil HWS =110 to 140F

-4Row Heat/Cool coil HWS =100 to 110F

Reusing Existing Coils

180F HWS coils are a mismatch to required supply air temp

- **Reduced Size Heat exchanger are used**
  - Coils often are not full face
  - Minimum Fin Spacing possible
- **More water flow at lower temperatures will not get design capacity**

140F HWS coils may work at design with 120-130F HWS but would require more flow.

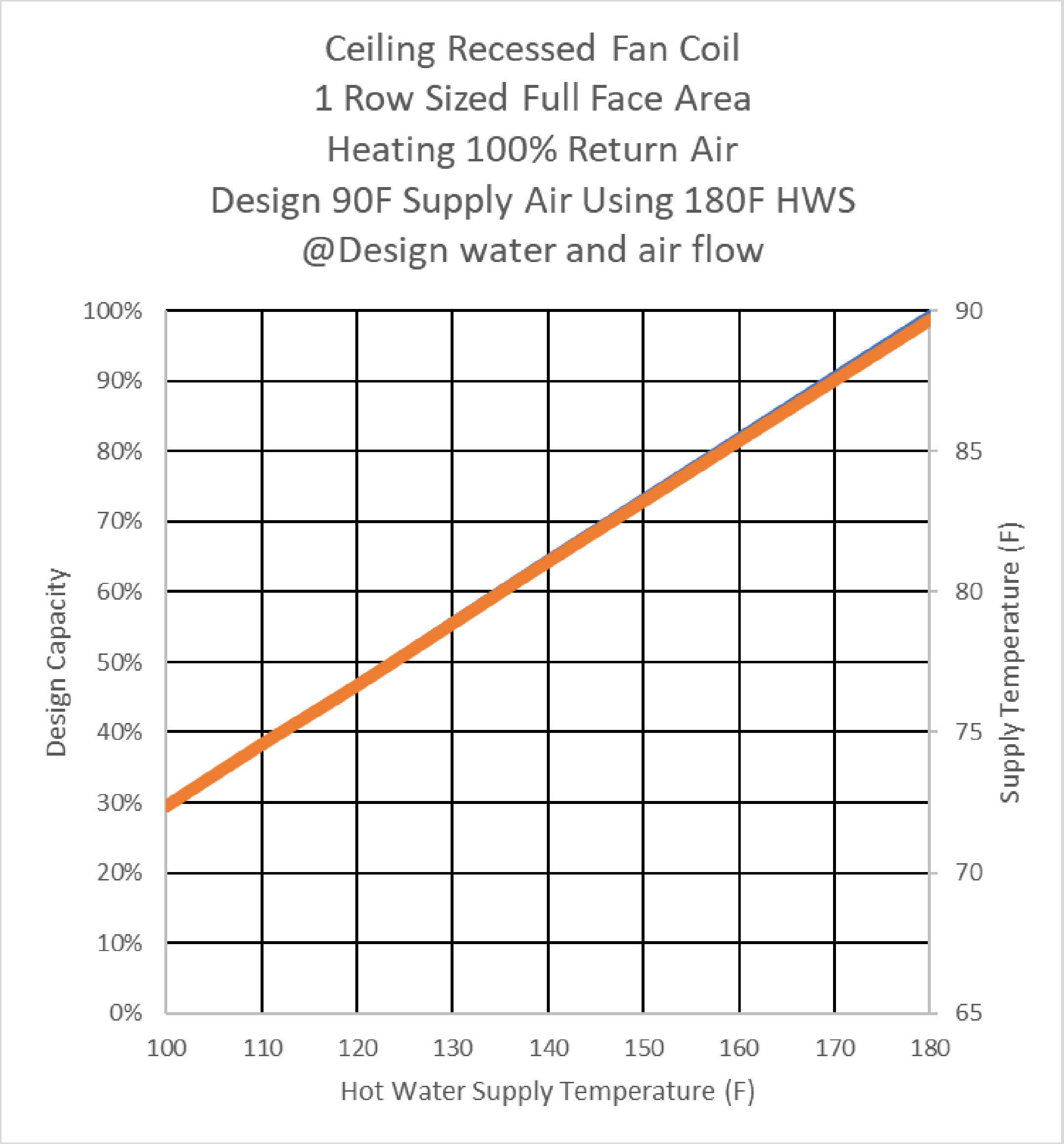
Hydronic Heating for HVAC: Closed Water System Source Requirements for Hot Water Supply and Return

How Much Capacity Can Get trying to reuse equipment sized for traditional boiler?

- Hundreds of equipment types
- Each with multiple coils and fin options
- Need water flow and close current match of equipment to select for estimate

This is an example….no “typical” !!!

Here 120F get 50% capacity in coil sized for 180F



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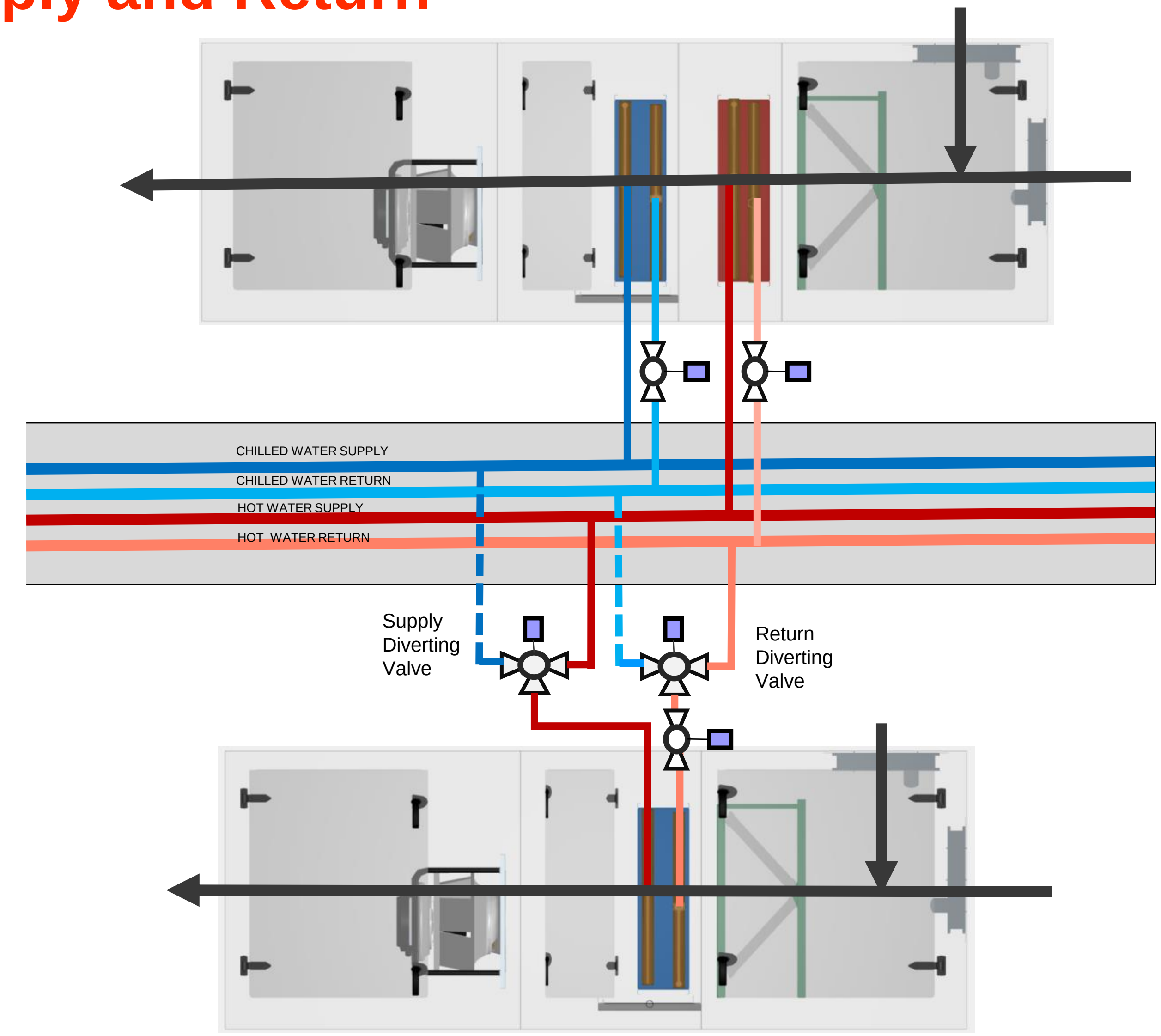
Hydronic Heating for HVAC: Closed Water System
Load Requirements for Hot Water Supply and Return

MIXED AIR SINGLE ZONE AHU

- 50F mixed air heated to 90F LAT
  - 2 Row Heating Coil HWS= 140F to 180F
  - 4 Row Heating Coil HWS= 100F to 110F
  - 0 Row Heating Coil HWS= 100F to 105F

Hot-water supply temperature	180°F	140°F	105°F
Coil rows	2 (HW) 6 (CHW)	2 (HW) 6 (CHW)	4 (HW) 6(CHW)
Coil heating capacity, Btu/h	86,800	86,800	86,800
Entering fluid temperature, °F	180	140	105
Leaving fluid temperature, °F	150	120	85
Fluid flow rate, gpm	5.78	8.7	8.7
Fluid pressure drop, ft. H_2O	0.05	0.29	1.0
Airside pressure drop in. H_2O	0.13 (HW) 0.53 (CHW)	0.17 (HW) 0.53 (CHW)	0.39 (HW) 0.53 (CHW)



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Hydronic Heating for HVAC: Closed Water System Load Requirements for Hot Water Supply and Return

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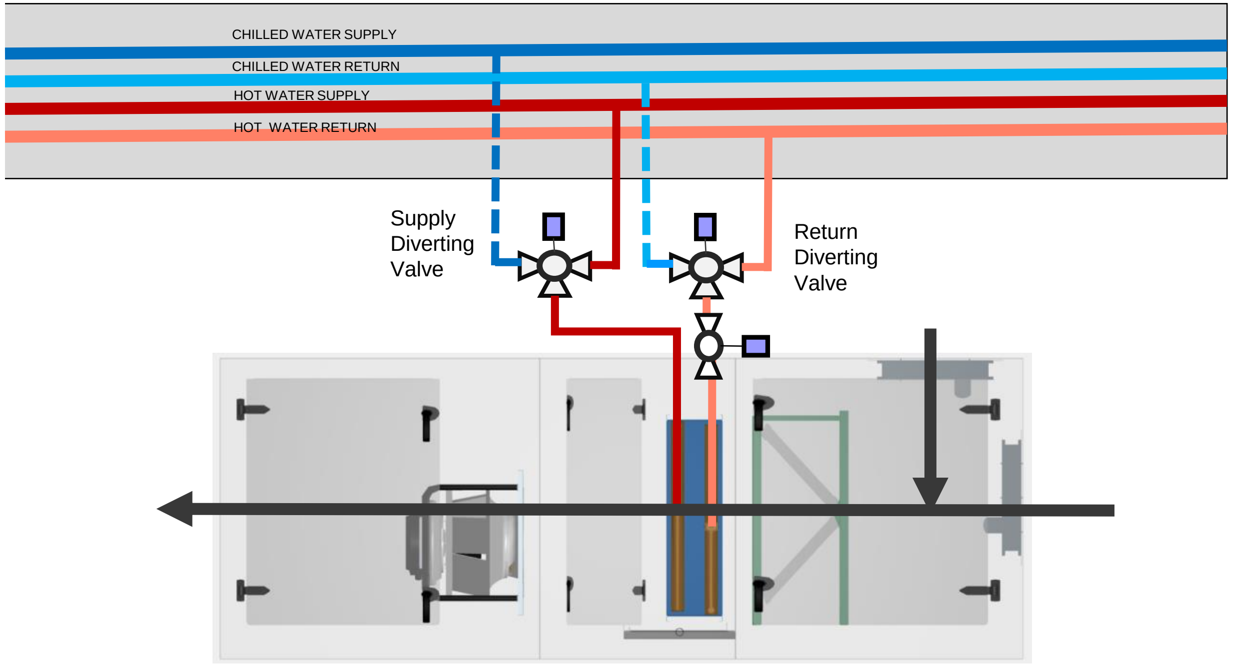

<u>4 pipe distribution system</u>

- NOT CHANGEOVER SYSTEM
- Same as air cooled chiller + boiler
- Simultaneous heat and cool system

<u>Changeover Coil</u>

- Same Coil used for heating and cooling

Why Changeover coils now work

	Air Cooled Chiller + Boiler	Air Source Heat Pump
same machines used to heat and cool	✗	✓
same fluid used to heat and cool	✗	✓
heating fluid not too hot to use in cooling coil	✗	✓

Hydronic Heating for HVAC: Closed Water System
Load Requirements for Hot Water Supply and Return

DOAS UNIT

DOAS Coils HWS= 70F to 85F

Example: BLOWER COIL

100% OA @10F

Heated to 99F

105F HWS ∆T=29F

Unit Overview

Model Number	Design Airflow	Elevation	External Dimensions			Weight	
			Length	Width	Height	Shipping	Operating
BCHE036	1200 cfm	0.00 ft	56.700 in	42.000 in	17.000 in	181.0 lb	298.0 lb

Coil Information

Coil #1	8R Auto Changeover	Cooling face velocity	450 ft/min
		Heating face velocity	450 ft/min
		Cooling fluid type	Water
		Motor heat calculation	Ignore

Coil Performance - Cooling

Total cooling capacity	100.25 MBh	Cooling ent fluid temp	42.00 F
Sensible capacity	54.30 MBh	Cooling leaving fluid temp	66.99 F
Cooling EDB	95.00 F	Cooling delta T	24.99 F
Cooling EWB	78.00 F	Cooling flow rate	8.00 gpm
Cooling LDB	54.36 F	Cooling fluid PD	7.31 ft H2O
Cooling LWB	54.26 F	Piping package PD	17.53 ft H2O
		Fluid velocity	2.00 ft/s
		APD	1.042 in H2O

Coil Performance - Changeover Heating

Total heating capacity	116.10 MBh	Heating delta T	29.09 F
Heating EAT	10.00 F	Main heating flow rate	8.00 gpm
Heating LAT	99.21 F	Heating fluid velocity	2.00 ft/sec
Heating ent fluid temp	105.00 F	Main heating fluid PD	6.73 ft H2O
Heating leaving fluid temp	75.91 F		

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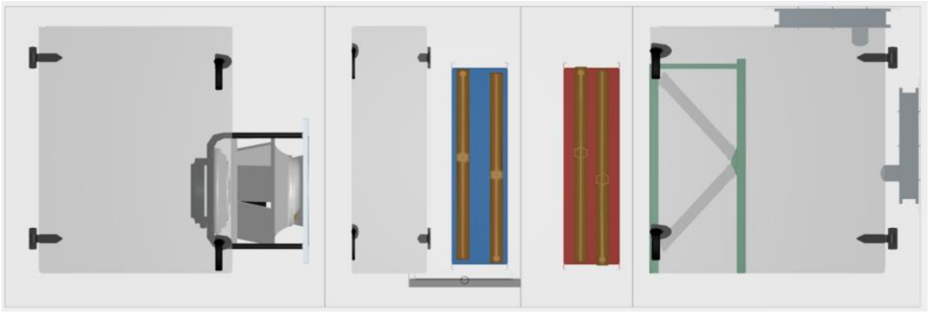
Hydronic Heating for HVAC: Closed Water System Load Requirements for Hot Water Supply and Return

MULTIPLE ZONE VAV SYSTEM

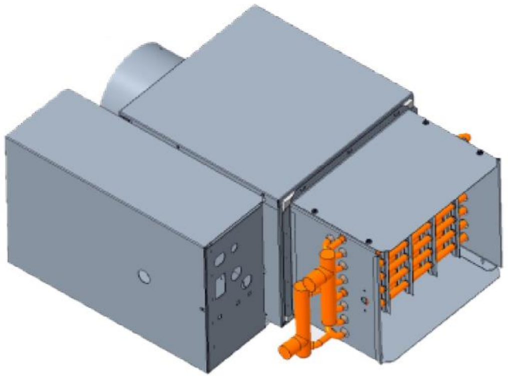
CENTRAL VAV AIR HANDLER

1 Row Coil =100F to 180F HWS



VAV SERIES BOX

1 Row HWS= 180F
2 Row HWS= 140F
3 Row HWS= 105-110F
4 Row HWS= 100-105F



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Hydronic Heating for HVAC: Closed Water System Requirements for Hot Water Supply and Return

Boilers and Heat Pump have different hot water supply temperature limitations

- **Traditional Boilers Have lower limits >>140F HWS**
- **Condenser Boilers Have upper limits < 130F HWS**
- **Air Source Heat Pumps**
  - Limits change with outdoor air conditions and models
  - Source available capacity is not limited
  - Today's typical range HWS 100-130F
- **Water Source Heat Pumps**
  - Limits does not change with outdoor air conditions, from source water temp
  - Source available capacity has a limit
  - Today's typical range HWS 120-140F

Change over coils in the airside equipment benefits heat pump systems

HVAC Heating Systems can condition buildings with 100 to 110F Hot water

- **Most new systems will have heat pump and airside equipment selected in that range**

Reusing airside equipment and heating coils sized using boiler hot water supply is not a swap out

- **Existing airside equipment will drive required HWS temperature**
  - 180F HWS size coils have limited heat exchanger capacity and will only provided limited capacity at lower HWS
  - 140F HWS size coils may work at design with 120-130F HWS but more flow will be required.

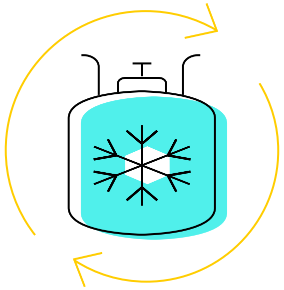
Carbon Equivalent Emissions

Where Are Emissions Generated From?

Operational Emissions

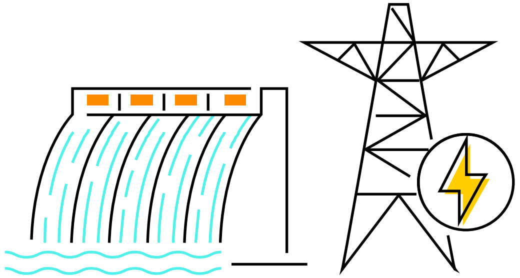
Scope 1 Emissions

Direct Fossil Fuel Combustion



Refrigerant Emissions

Scope 2 Emissions

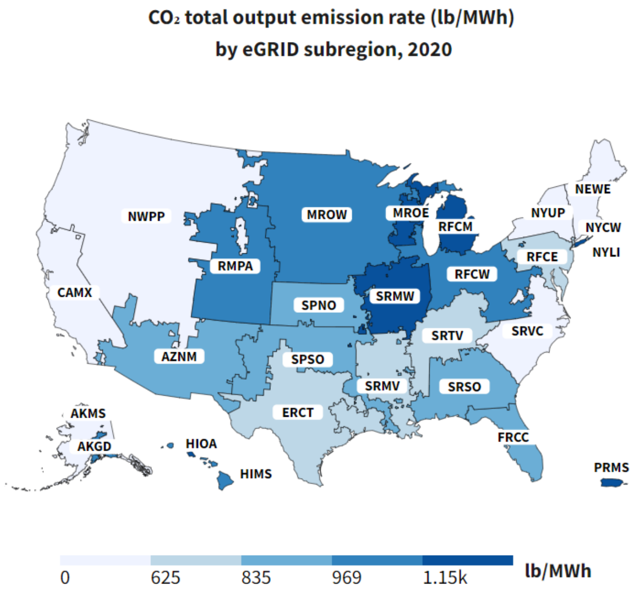


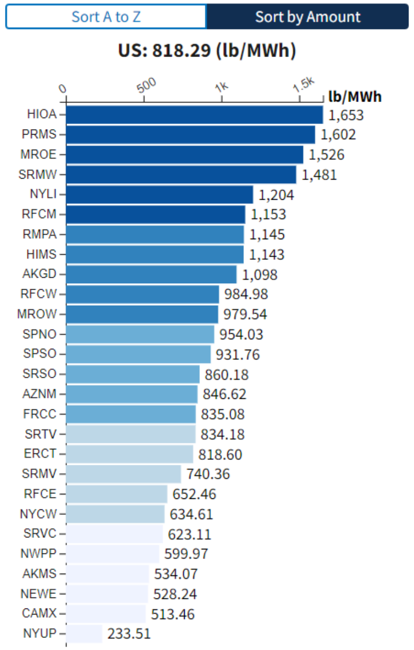
Carbon Intensive Electricity Sources

Source: Greenhouse Gas Protocol

Operational Carbon Emissions

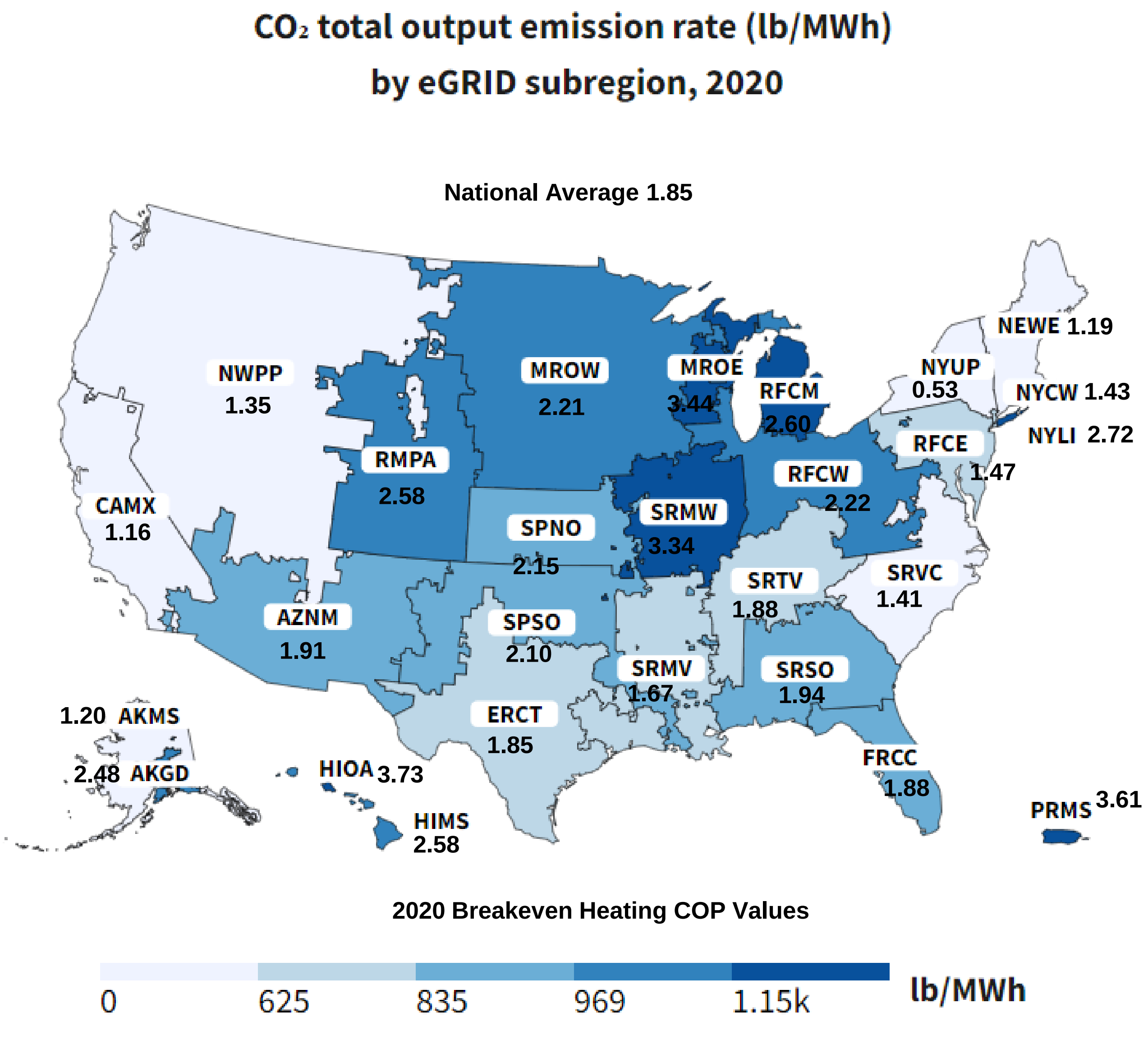
- Fuel
  - Natural Gas: 399 lbs/MWH
    - 90% efficient gas boiler, 443 lbs/MWH
  - Electricity (national average): 818 lbs/MWH
    - Resistance (2020 eGrid), 234 – 1653 lbs/MWH
- Efficiency
  - Heat pumps
    - Heating COP range 1.5 – 4.0
    - Cooling efficiency is slightly reduced
- Refrigerant
  - R-410a: 2088 GWP
  - R-32: 675 GWP
  - R-454B: 466 GWP





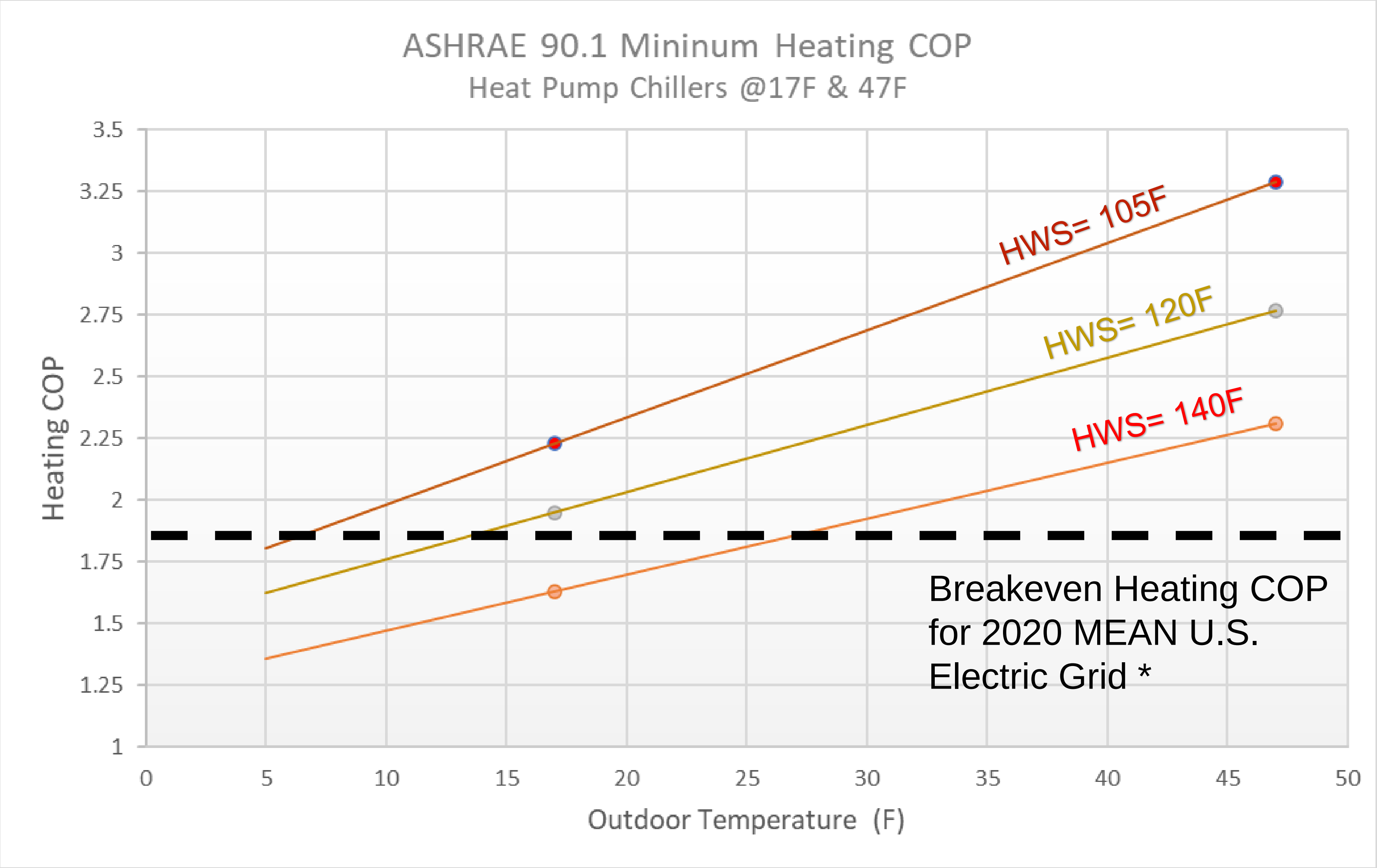
2020 eGRID CO_2e Breakeven Heating COP

Breakeven Heating COP: The minimum electrified heat source COP required to equal a 90% efficient gas boiler CO_2e emissions.



What Hot Water Supply Temperature to reduce Heating CO2 emissions?
Full Load Minimum COPs

Hotter the water and/or "dirtier" the grid the more difficult it will be to reduce carbon footprint.

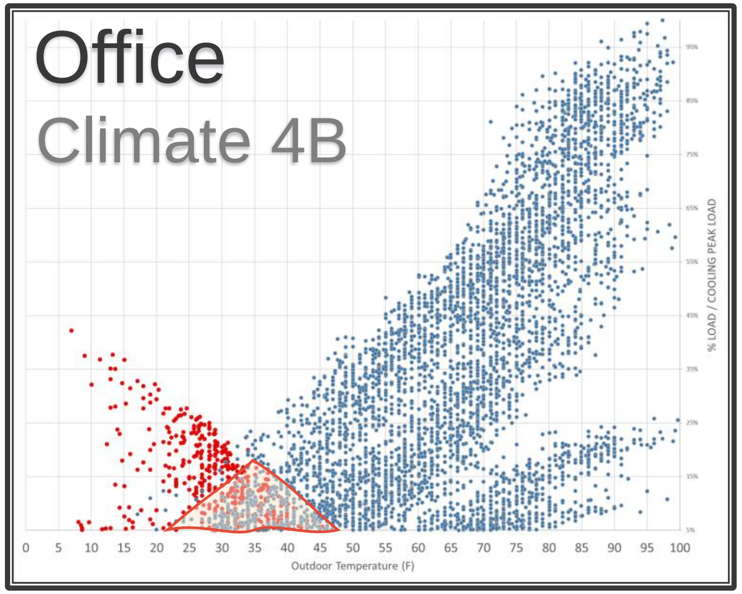


** Heat pump powered by 884lbCO2e/MWH grid vs 90% eff Natural Gas hot water heater*

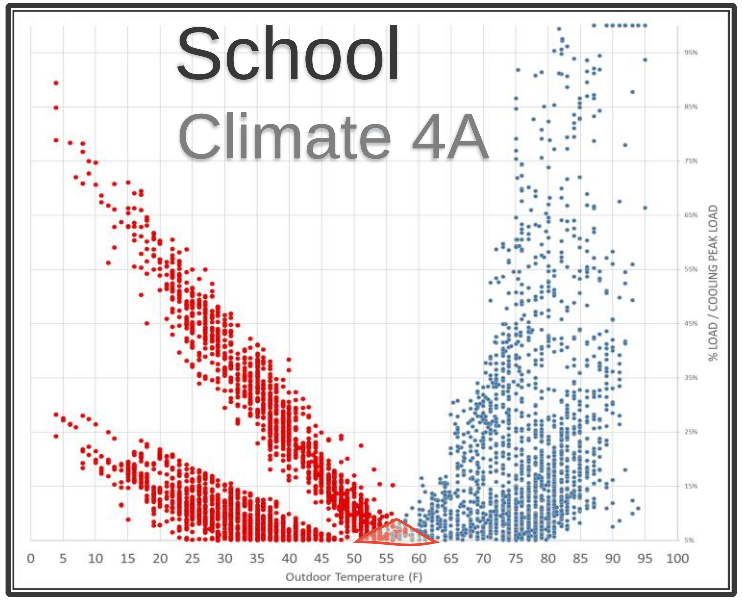
Sizing Air to Water Heat Pumps

Ventilation Matters More Than Climate

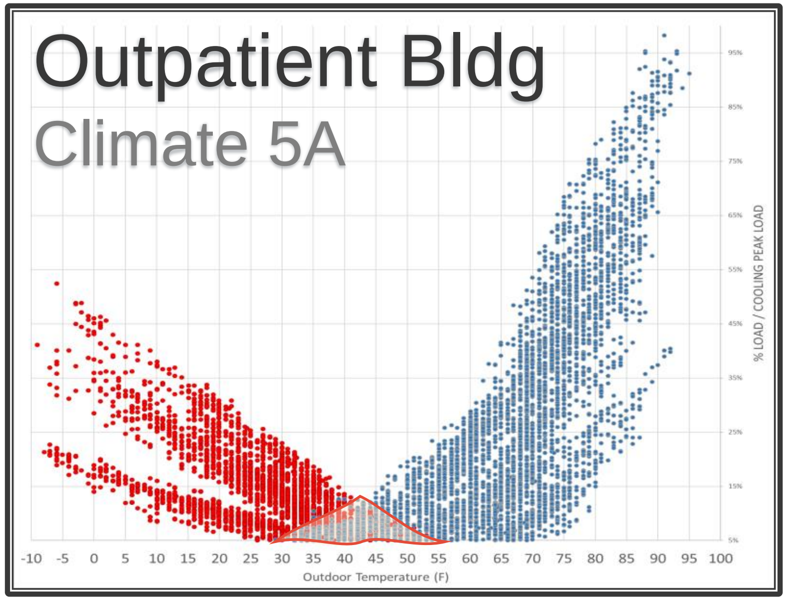
Lower Ventilation



Higher Ventilation



Mid Ventilation

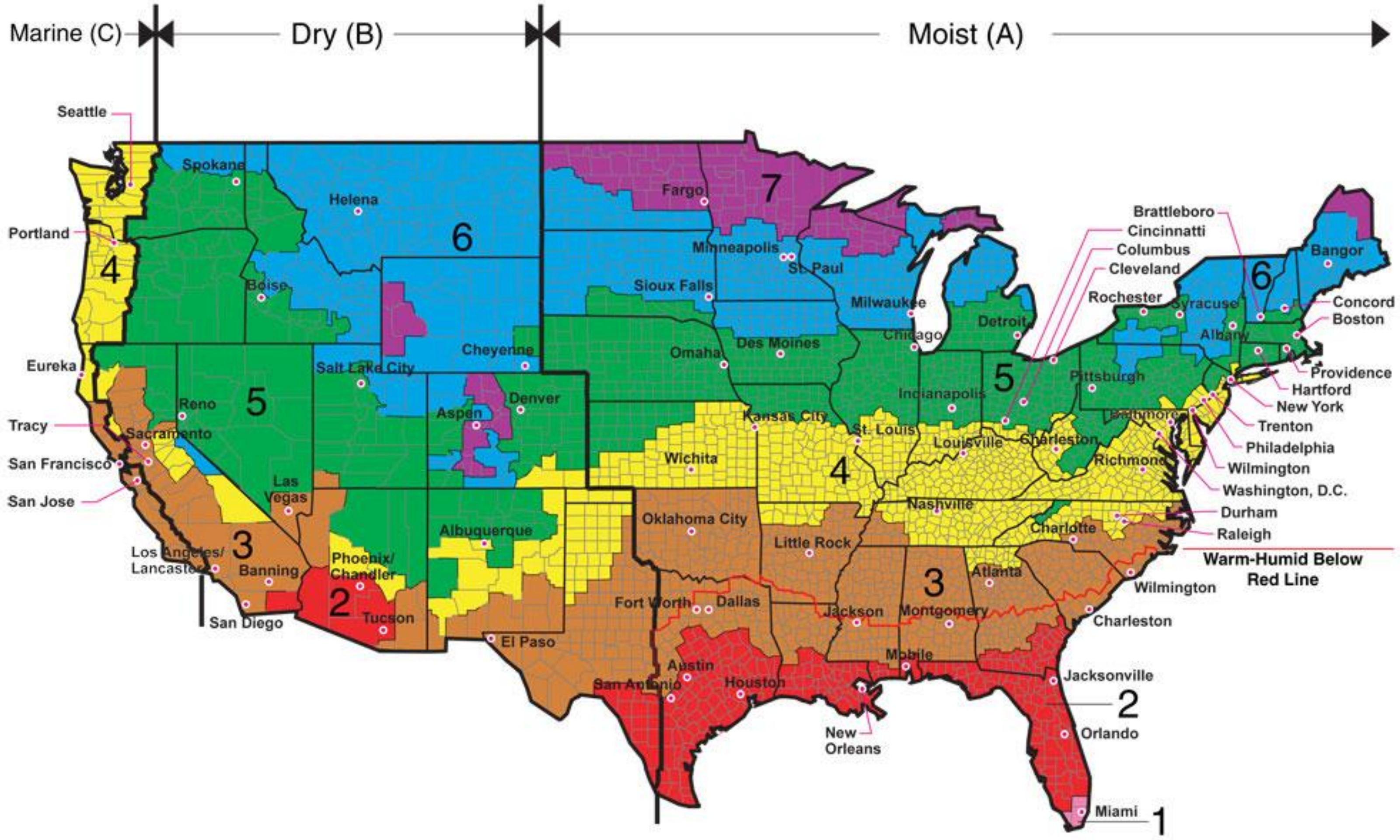


Simultaneous heating and cooling only occurs in shaded areas

Sizing Air to Water Heat Pumps

- Hours near peak heating are few
  - fewer even than near peak cooling!
- Higher the ventilation, the higher heating needs vs cooling and vice versa
- Unoccupied heating occurs many hours at lower capacity
- Hours of simultaneous heating and cooling are few and often during economizing times

ASHRAE® Climate Zones



All of Alaska in Zone 7 except for the following Boroughs in Zone 8: Bethel, Dellingham, Fairbanks, N. Star, Nome North Slope, Northwest Arctic, Southeast Fairbanks, Wade Hampton, and Yukon-Koyukuk

Zone 1 includes: Hawaii, Guam, Puerto Rico, and the Virgin Islands

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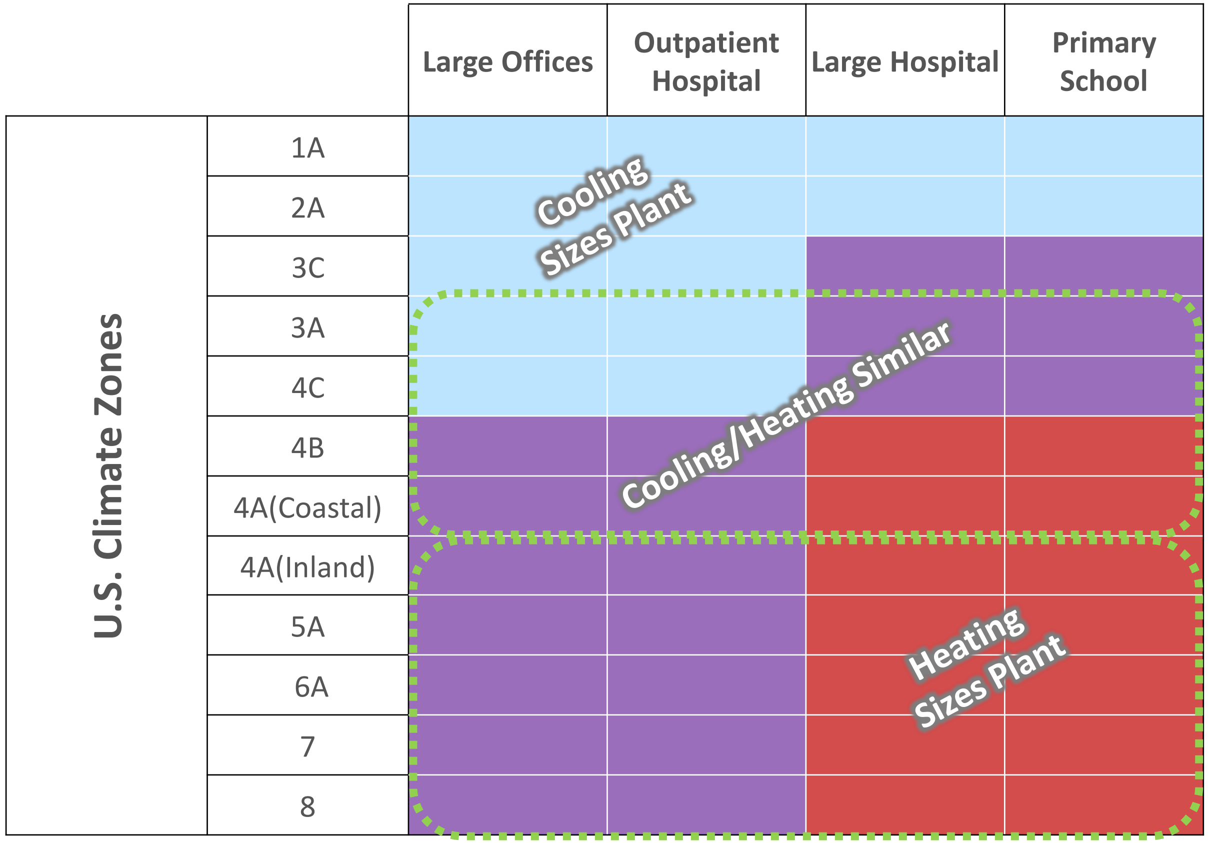
Sizing Heat Pumps for Peak Building Heating Load



Trane® Study of ASHRAE® 90.1-2019 Basis Building Models

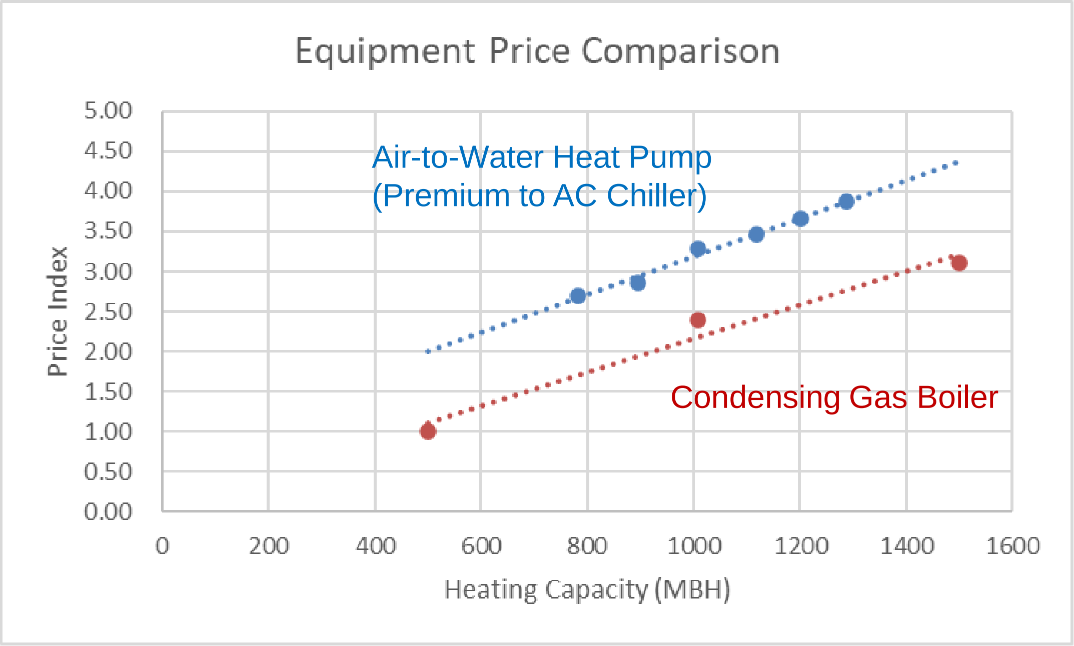
Secondary Heat Sizing

Emergency Heat
Emergency Heat sized to protect building at 20-year, or 50-year extreme below 0ºF

Auxiliary Heat
Auxiliary Heat sized to meet design loads in climates where normal operating conditions occur below 0ºF

Oversizing Heating Can Be Costly

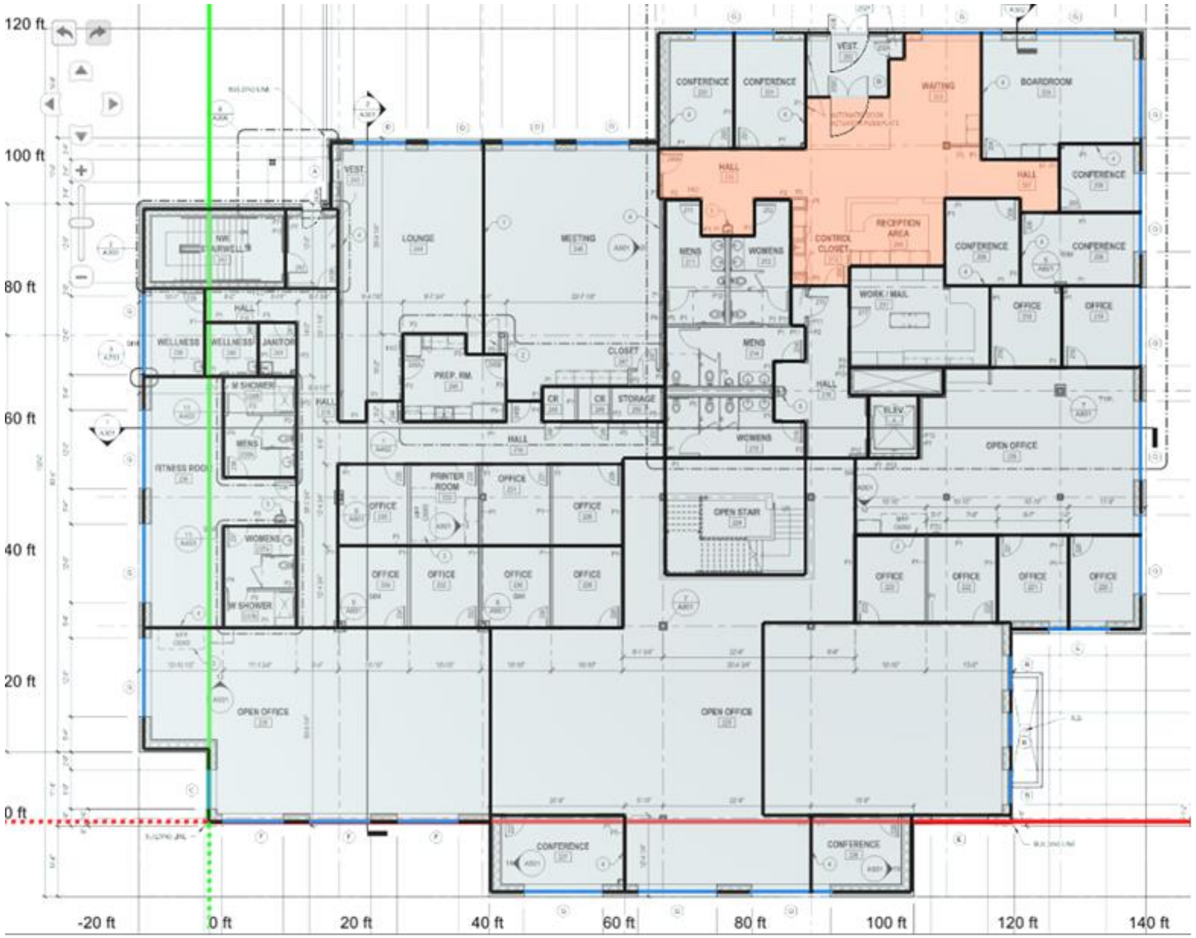
- Heating capacity is often oversized
  - Design practice not as focused or robust as cooling
  - All assumptions that go into heating design are ultra conservative
    - Don’t account for internal heat generation
    - Not incorporate airside heat recovery in heating design
  - Optimizing cooling design resulting in oversized heating airflow (standardized heating SAT)
- Oversized equipment costs more, cycles more at low loads, and requires more refrigerant.



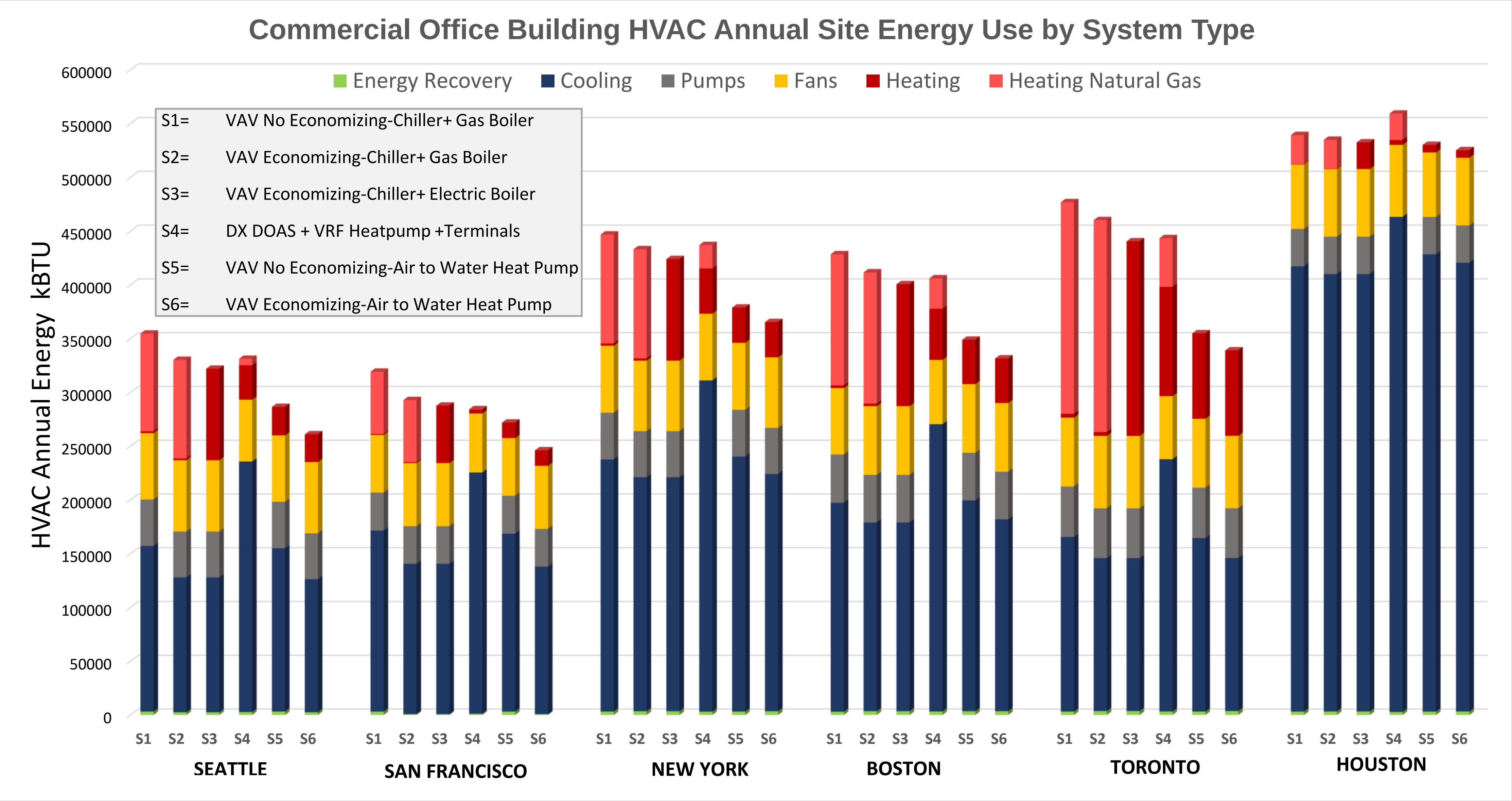
Heat Pump Capacity at 1F Ambient

Carbon Footprint – TRACE® 3D Plus study

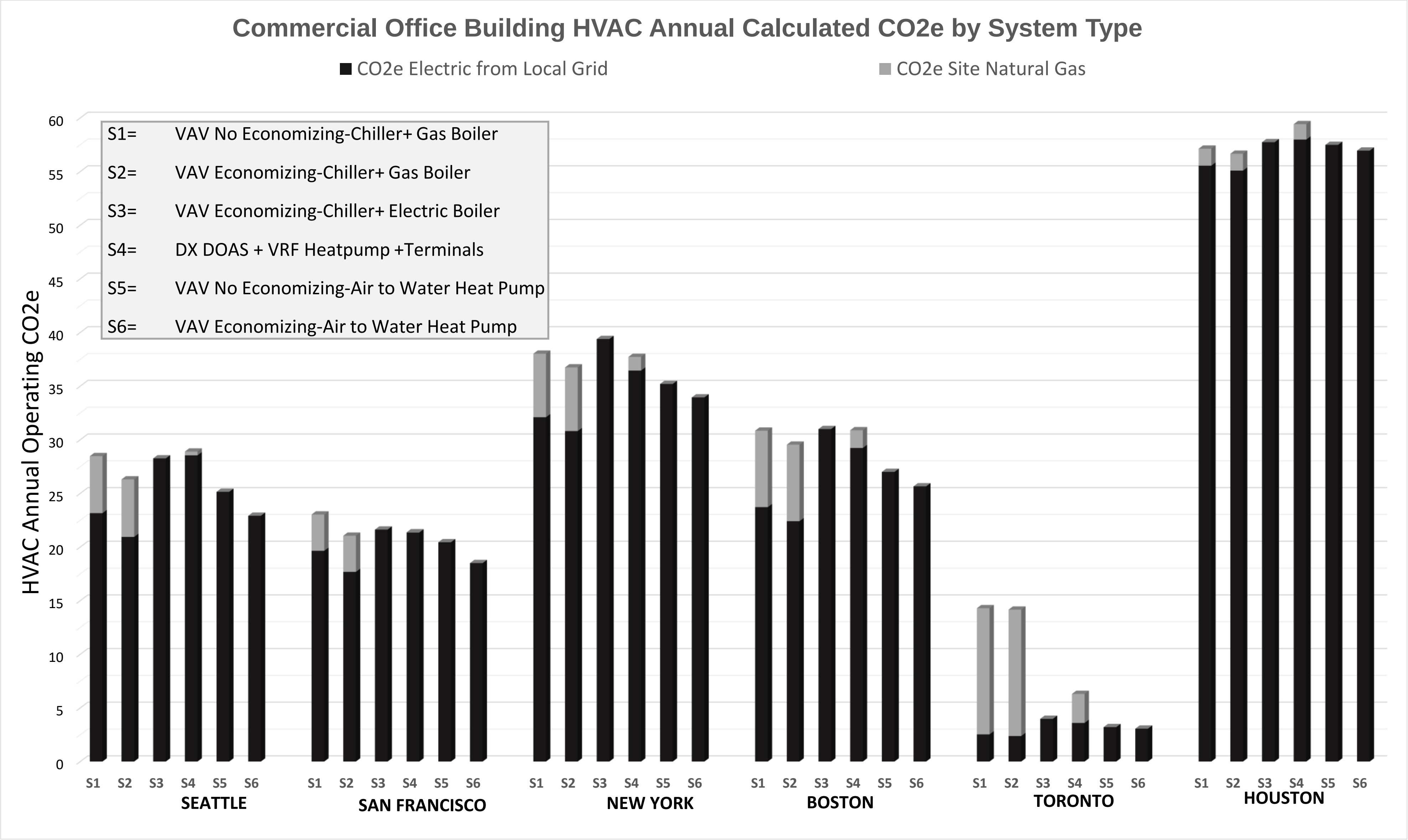
- 3 story office, ~50,000 ft² gross
- 100 rooms
- 68 thermal zones
- 12 ft Floor to Floor, 9 ft ceiling
  - 21.3 % glass
- ASHRAE® 90.1-2013 minimum construction based on weather zone
- Scope 1 and 2 carbon footprint study
  - Heat Recovery VRF + DOAS w/gas heat
  - Parallel FP VAV with HW heat (AC chiller/boiler)
  - Parallel FP VAV with HW heat (AWHP)
  - All have total energy wheels
  - VAV systems with and w/o economizer
  - VRF: 55 tons and 20 tons DOAS
  - VAV: 70 tons AC chiller or AWHP



Annual HVAC Energy for Various Systems 50,000 ft^2 Office



Annual CO_2e 50,000 ft2 office from HVAC Energy - Gas and Electric



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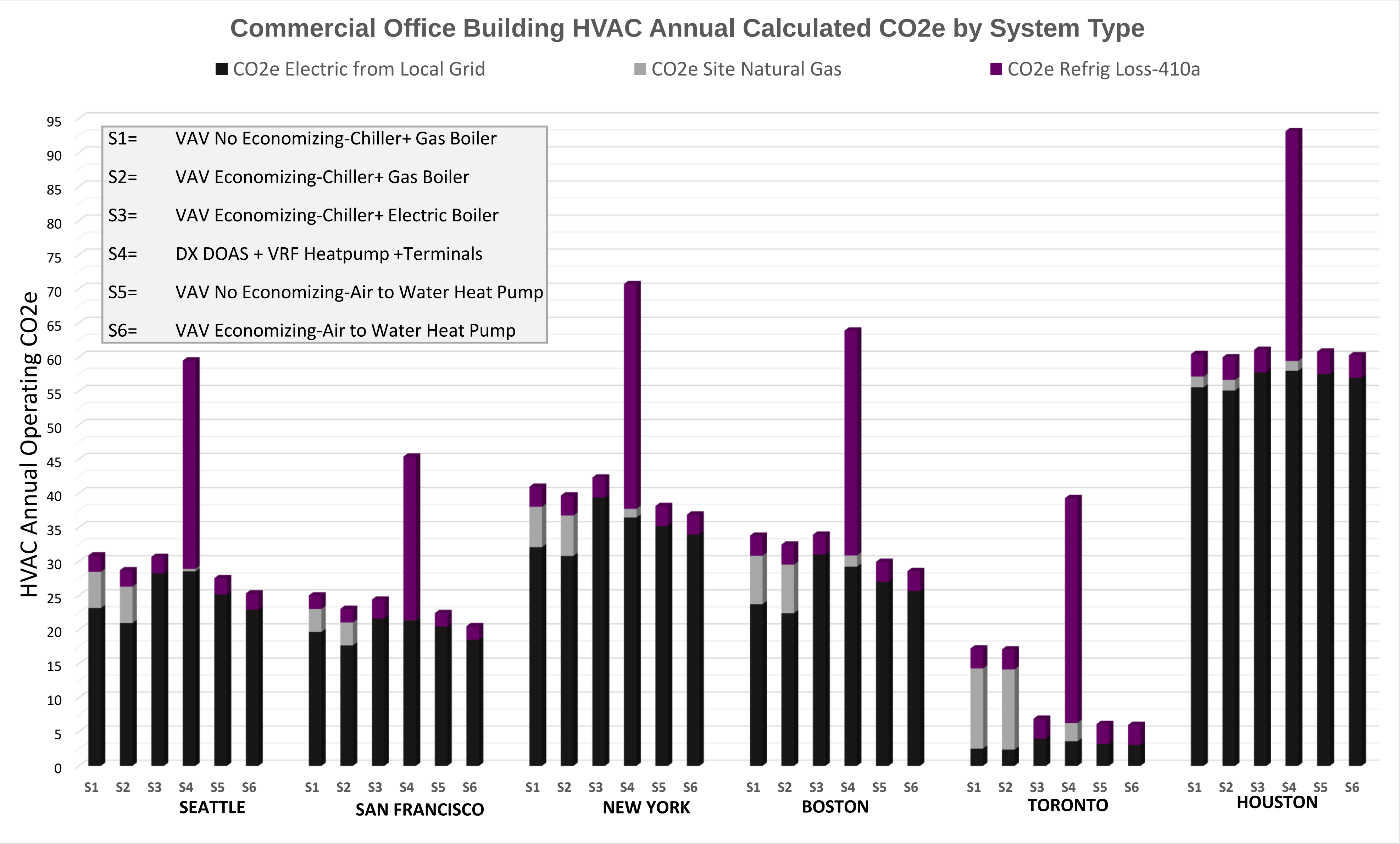
Annual CO_2e 50,000 ft2 office from HVAC Energy - Gas and Electric



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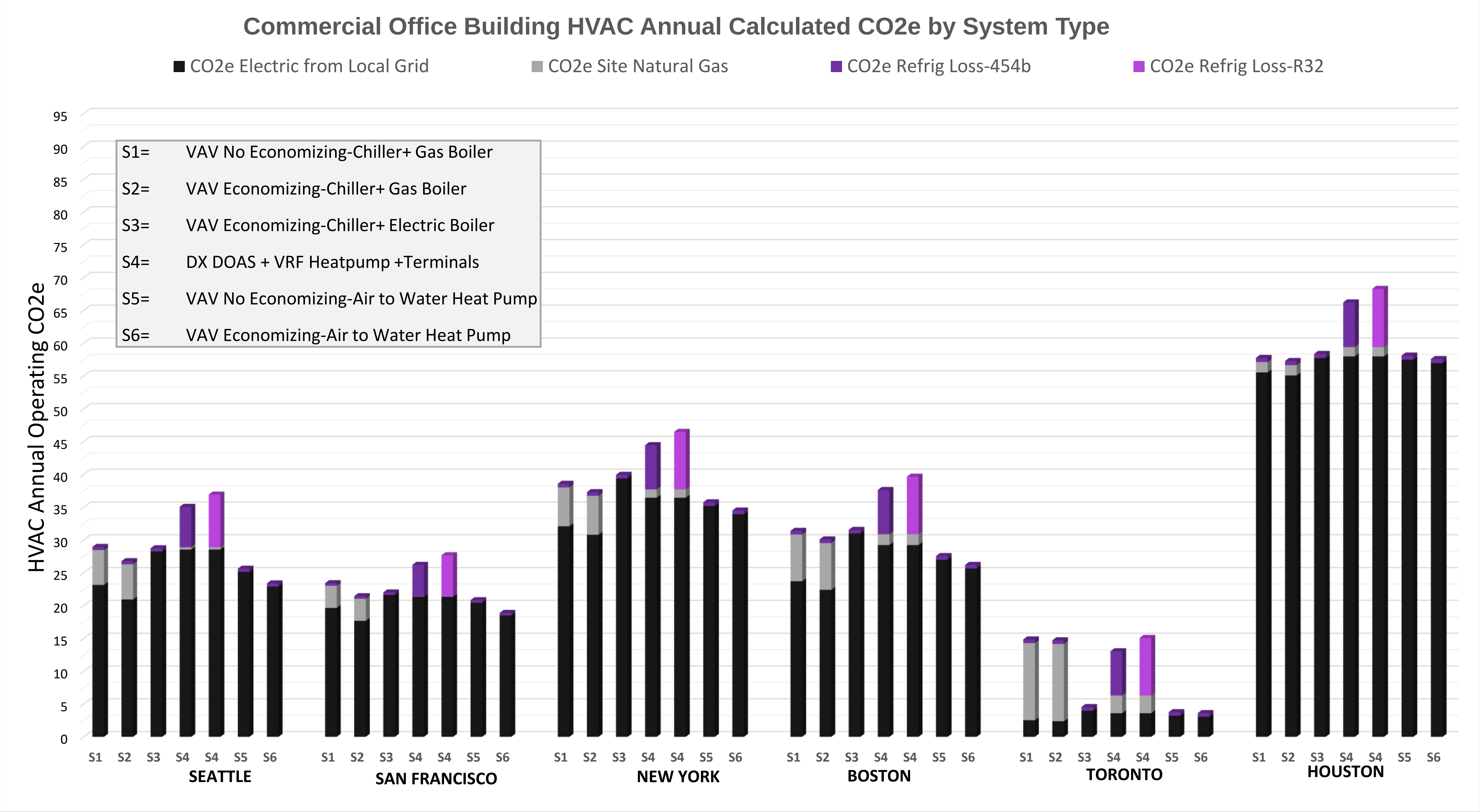
Annual CO_2e 50,000 ft2 office from HVAC Energy + Refrigerant Losses (Scope 1 or 2)

TRANE



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Applied Products

Update on hydronic heating portfolio

ASCEND® air-to-water heat pump model ACX

Capacity Range: 140 to 230 tons cooling, 1500 to 2500 MBh heating

Refrigerant: R-410A

Compressor design: scroll

Controls: Symbio® 800 with Adaptive Controls™

Factory-installed options: integrated pump & sound-reduction packages

Features and Benefits

- Ease support of electrification of heat
- Ease of installation
- Simplified service

Operating Limitations		
Chilled Water	40 to 65F	0 to 125F Ambient
Hot Water	68 to 140F	0 to 95F Ambient
Max leaving at min ambient – 100F at 0F		
Sales Sheet (AC-SLB005-EN) Catalog (AC-PRC002*-EN) IOM (AC-SVX002*-EN)		

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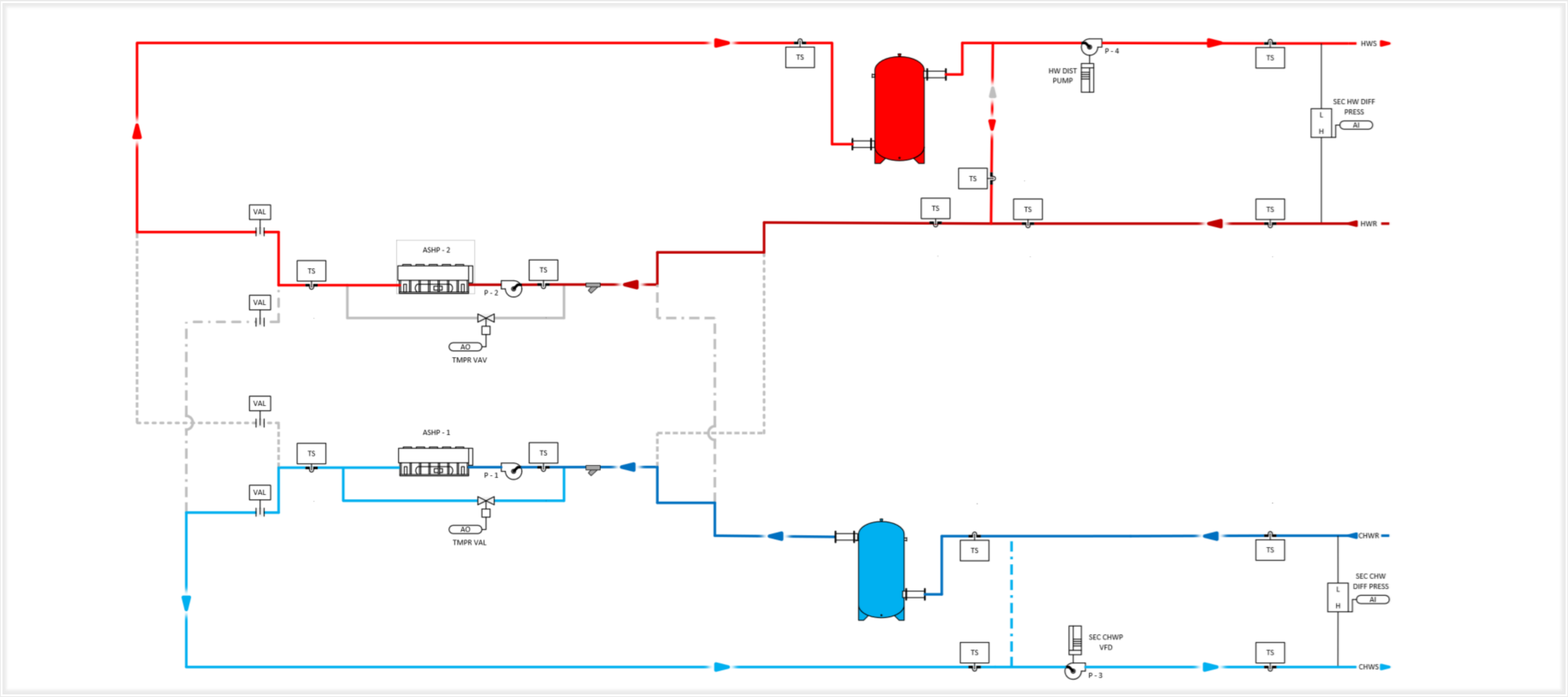
System Choices

Air to Water Heat Pump Cooling and Heating System

TRANE

TRANE TECHNOLOGIES

Air-to-Water Heat Pumps



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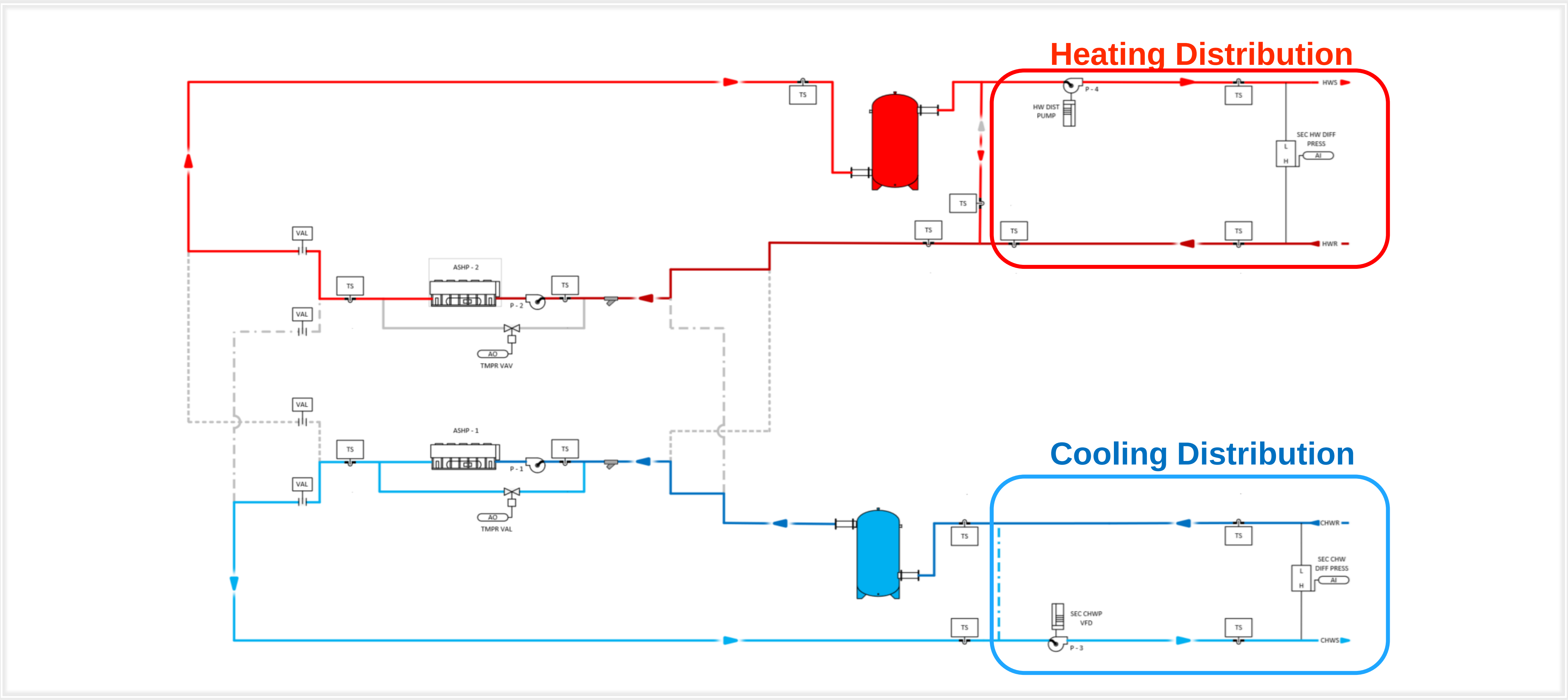
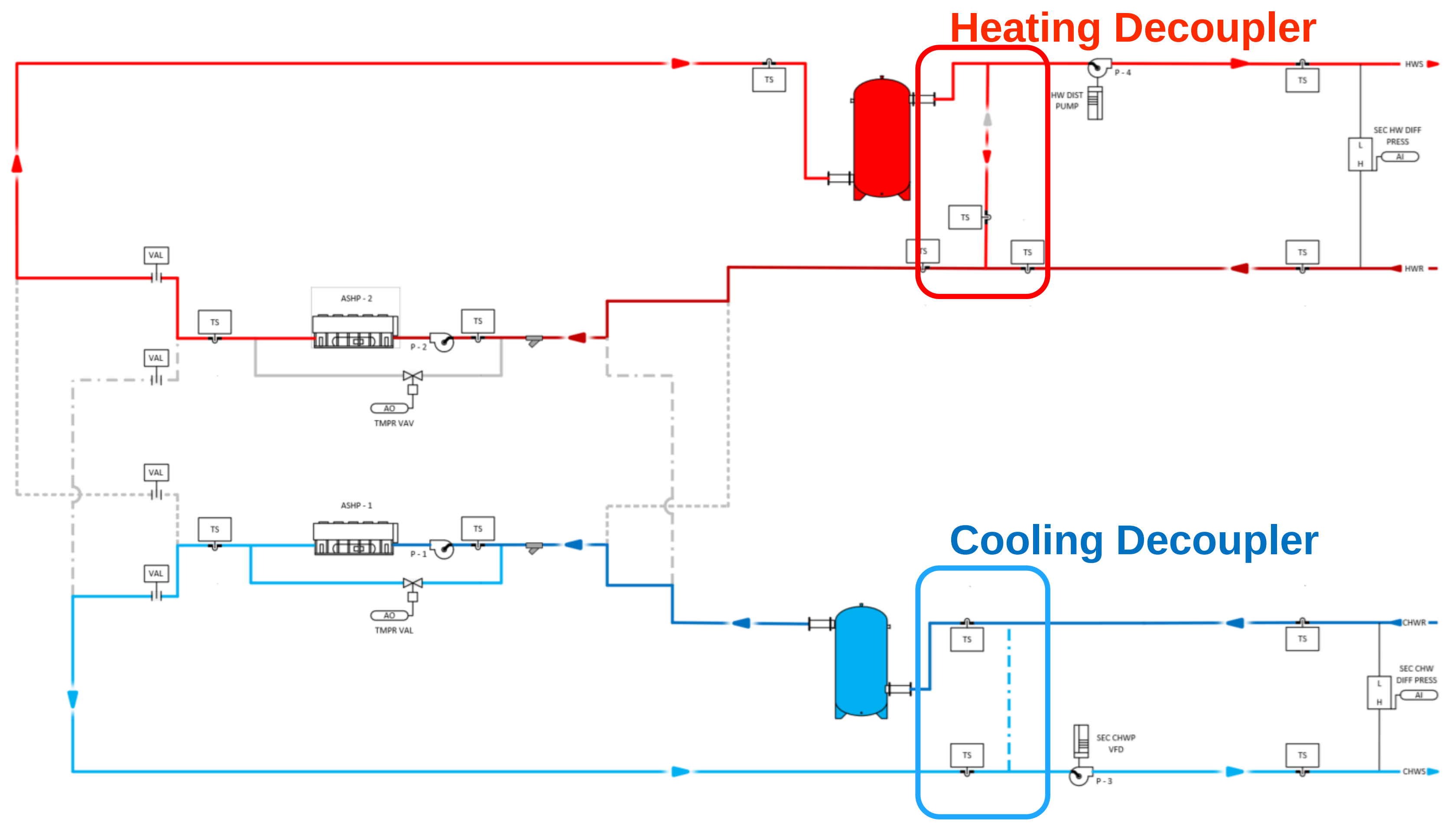
Four-Pipe Distribution



Flexible Cooling and Heating



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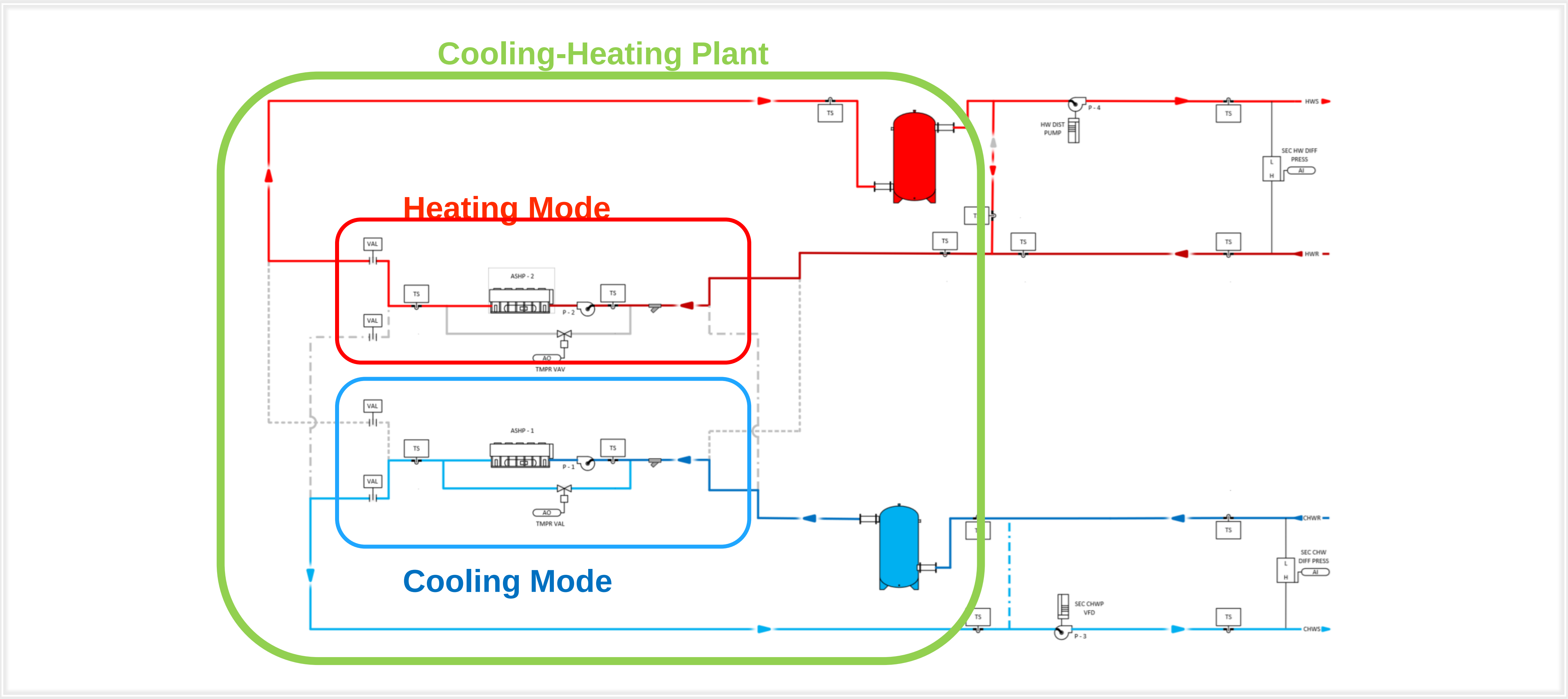
Four Pipe Production, Simultaneous Heating and Cooling



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System Choices

Storage Source Heat Pump Cooling and Heating System

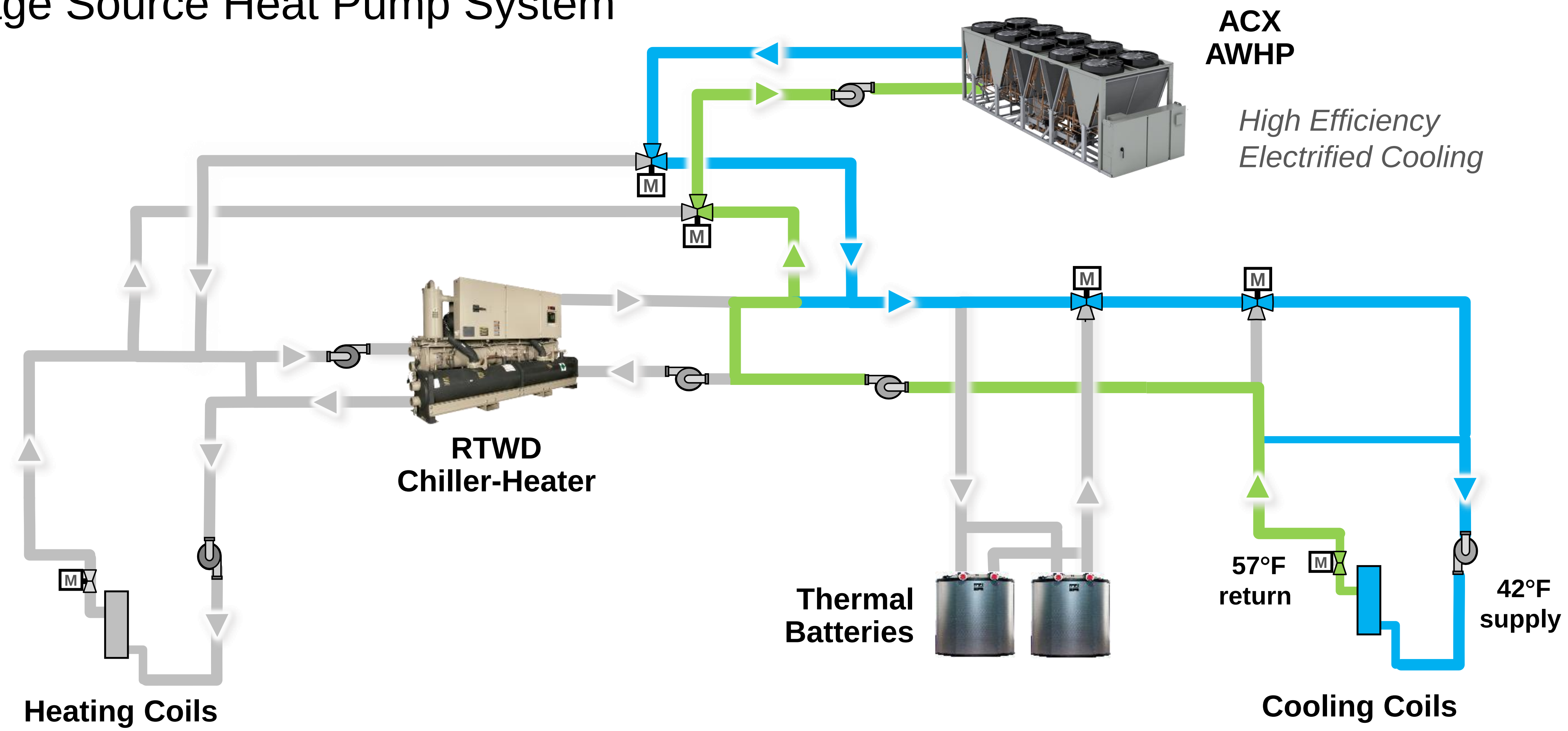
Key Ideas Regarding System Operation

- Outdoor air is the primary source of building cooling and heating using the ACX AWHP.
- Calmac Thermal Storage Batteries are an alternative source of cooling and heating when conditions favor or require it.
- ACX is able to “cool charge” (freeze water) or “heat charge” (melt ice) the Calmac Thermal Batteries when conditions are favorable.
- Calmac thermal batteries will directly cool the building (melt ice) to shift the electrical load and limit electrical demand in cooling season or to store building heat during heating season.
- RTWD units will be used for thermal battery source building heating (freezing water) during cold outdoor conditions (below 0F).
- Key benefits are:
  - Cold ambient electrified heating
  - Hot water supply (130F) when cold
  - Time independent heat recovery
  - AWHP downsizing
  - Enables demand management

Solving Decarbonization Challenges with Thermal Batteries

Cooling with Air-to-Water Heat Pump

Storage Source Heat Pump System



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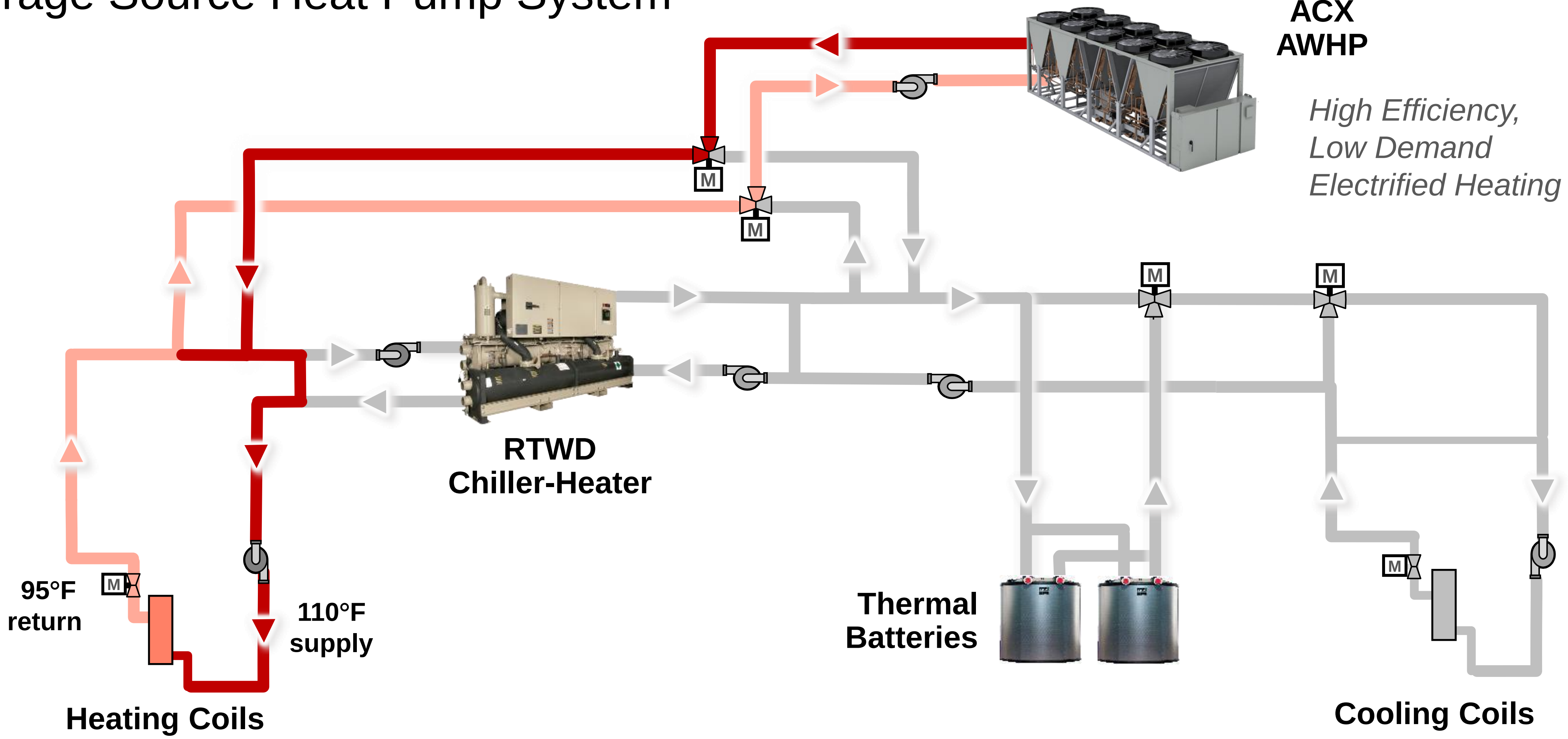
Solving Decarbonization Challenges with Thermal Batteries

Heating with Air-to-Water Heat Pump

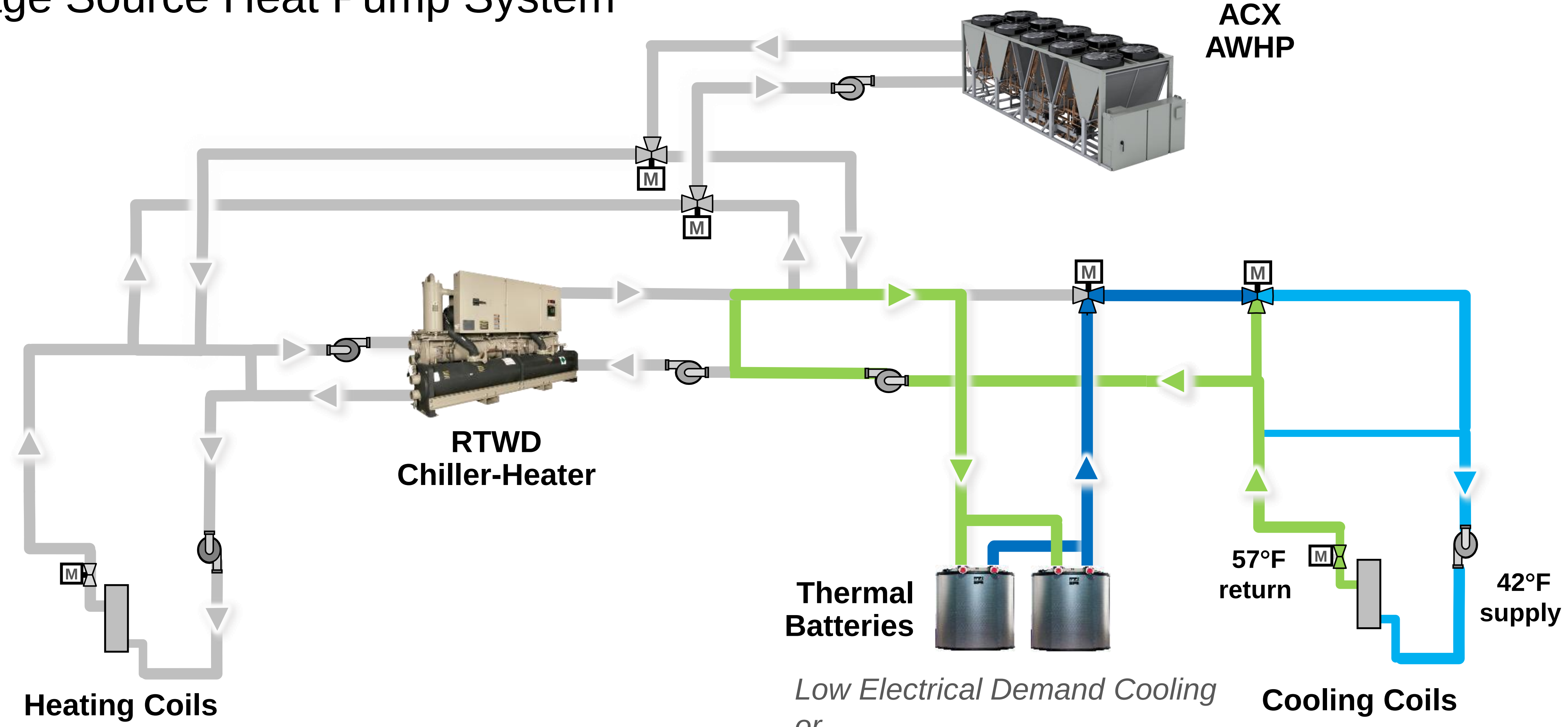
Storage Source Heat Pump System



Solving Decarbonization Challenges with Thermal Batteries

Cooling with Thermal Batteries

Storage Source Heat Pump System

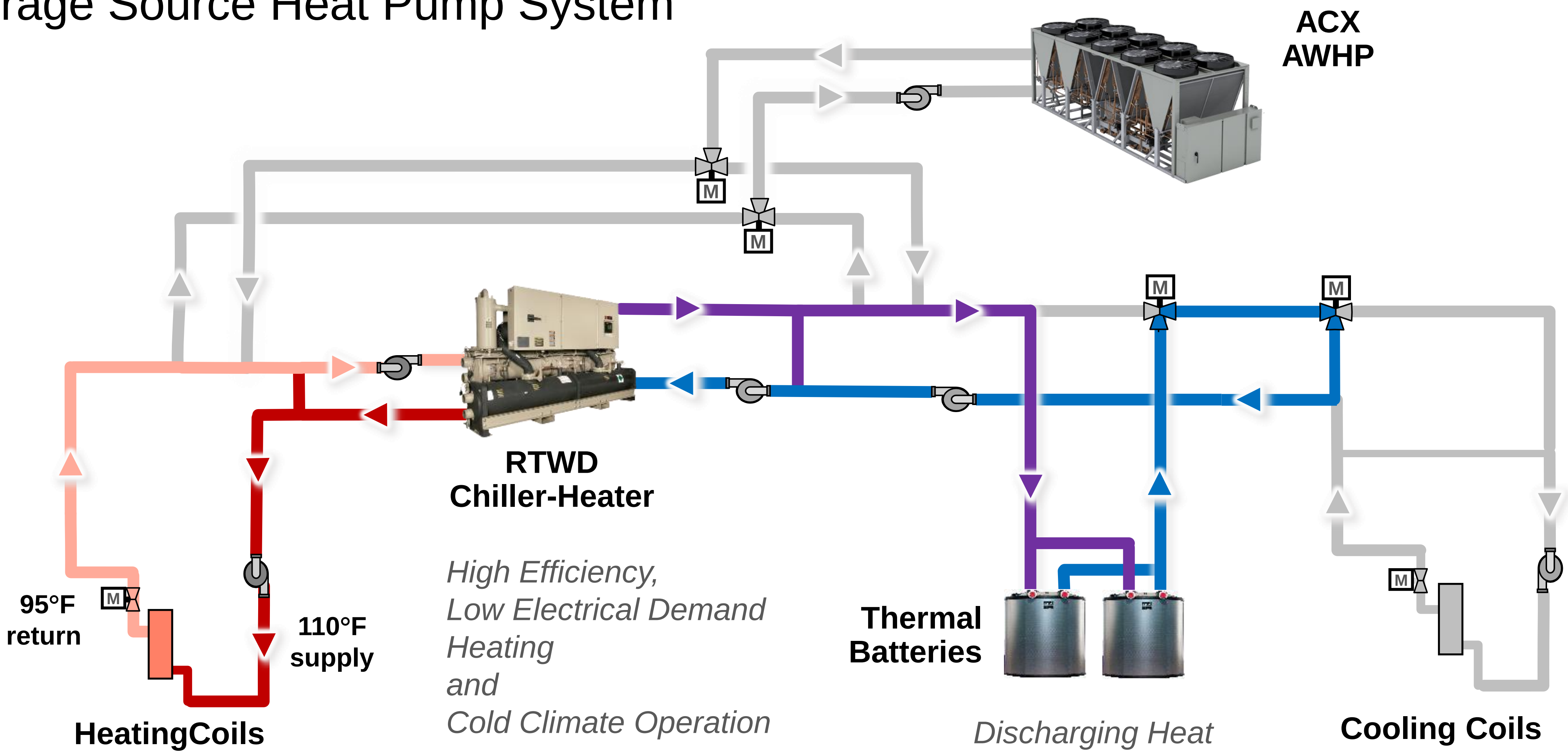


Low Electrical Demand Cooling
or
Storing Building Heat

Solving Decarbonization Challenges with Thermal Batteries

Storage Source Heating - Thermal Batteries & Chiller-Heater

Storage Source Heat Pump System



High Efficiency,
Low Electrical Demand Heating
and
Cold Climate Operation

Discharging Heat

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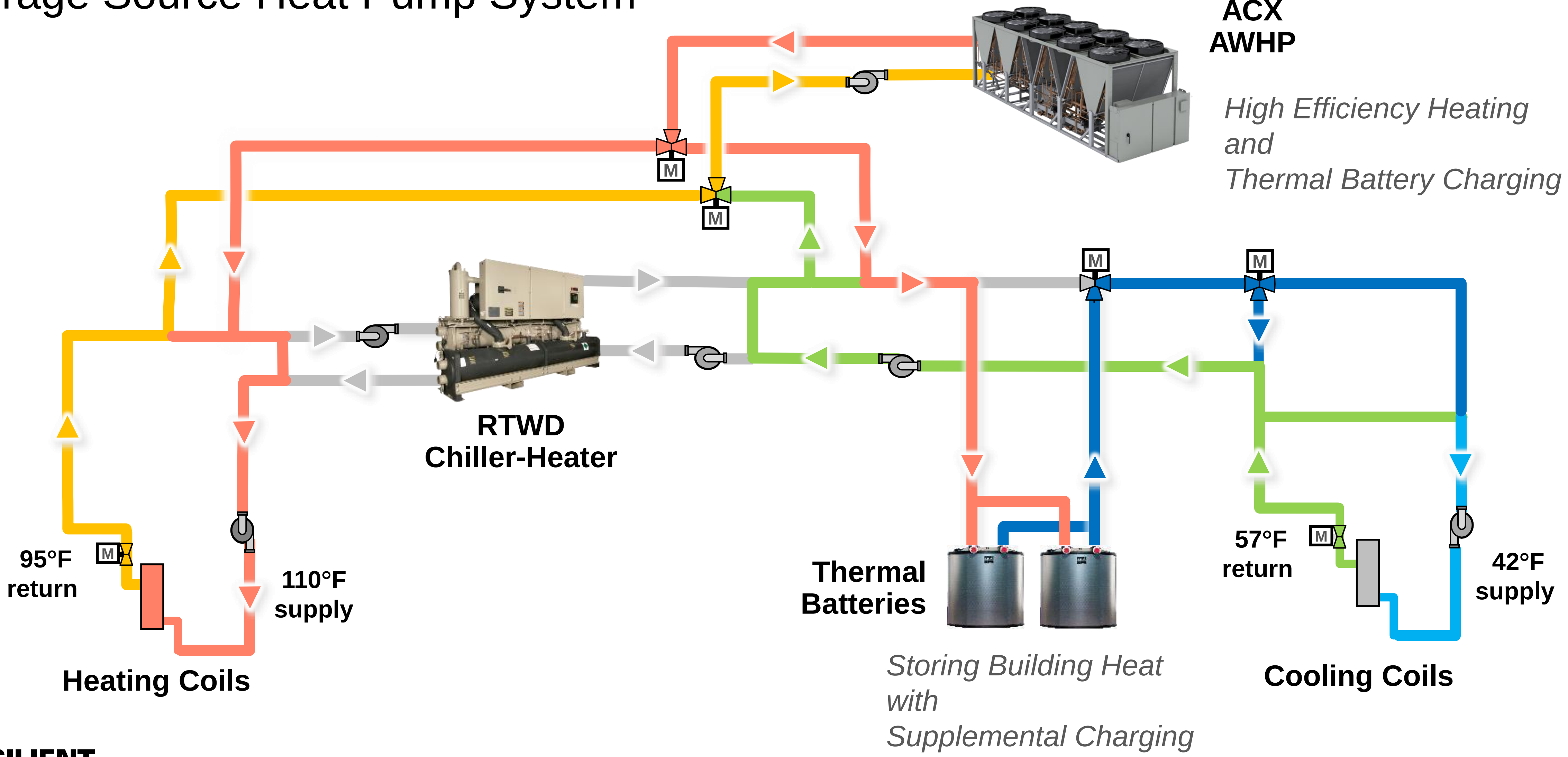
Solving Decarbonization Challenges with Thermal Batteries

Heating and Cooling with Supplemental Charging – when Ample Green Power!

Storage Source Heat Pump System



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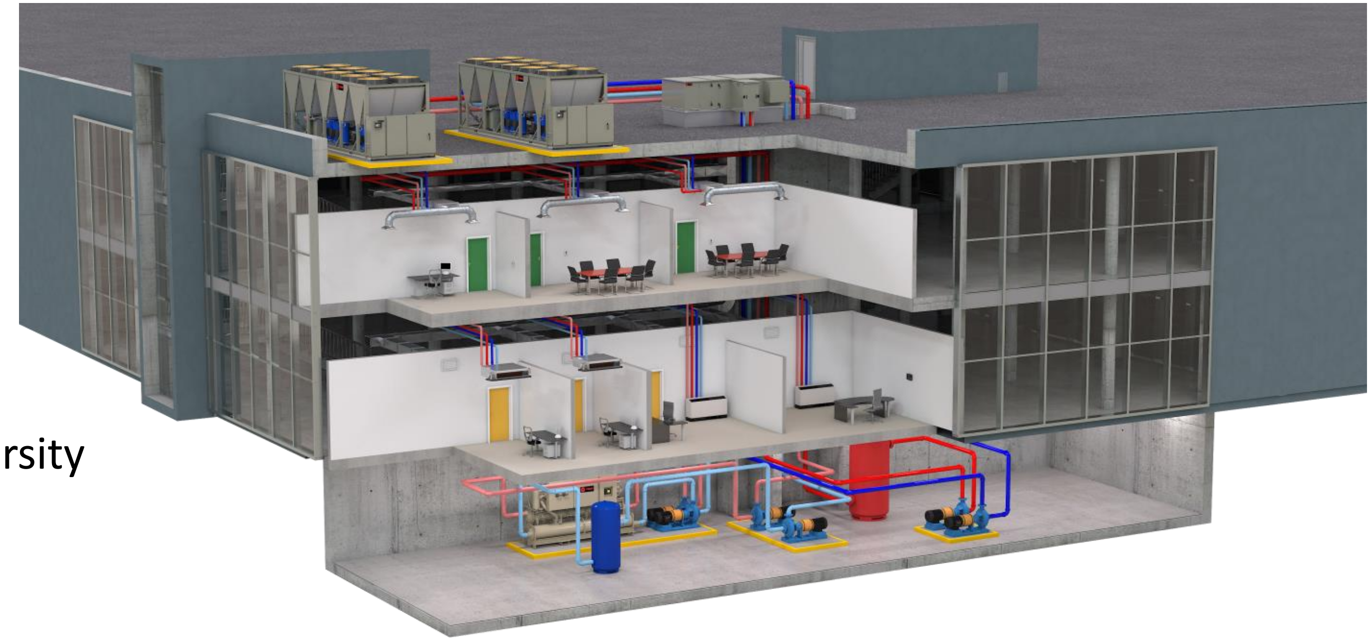
Chiller Heater Systems are Airside Flexible

- Applied to all airside systems
  - Multiple zone VAV systems
  - Fan coil systems
  - Central air handling systems
  - Single zone VAV systems
  - Sensible cooling systems
  - Any combination
- Benefits of this flexibility
  - Air economizer
  - Downsize capacity with whole building diversity
  - One integrated backup heating system
  - DOAS can heat 0F to 60F air directly



Summary

- Heat pumps move heat, they don’t create heat
- Heat pumps can successfully meet comfort applications
- Required hot water temperature is determine by the load and the available heat exchangers
- Reduced carbon emissions will increasingly influence our thinking and decision making
- Trane has a growing heating products and system offering
- Hydronic heat pump systems offer airside system flexibility

Thank You!

Any Questions?

Appendix

Air-Cooled/Air-Source Units

Future Products

All Units

AMC
CGAM
ACS (2023)

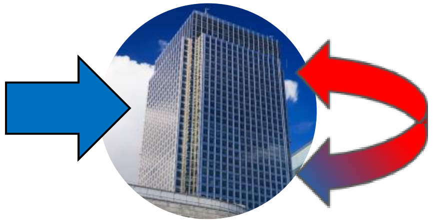
AXM
ACX

MAS

Chiller

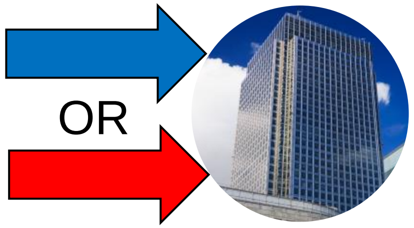
Cooling only

Chiller + Heat Recovery



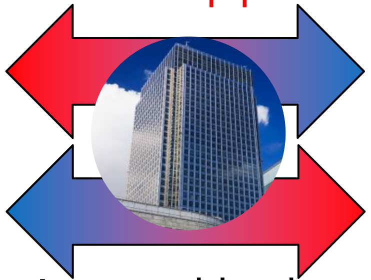
Heating while Cooling

Heat Pump



Heating or Cooling

Multi-pipe



Any combination

ASCEND® air-to-water heat pump model ACX

Capacity Range: 140 to 230 tons cooling, 1500 to 2500 MBh heating

Refrigerant: R-410A

Compressor design: scroll

Controls: Symbio® 800 with Adaptive Controls™

Factory-installed options: integrated pump & sound-reduction packages

Features and Benefits

- Ease support of electrification of heat
- Ease of installation
- Simplified service

Operating Limitations		
Chilled Water	40 to 65F	0 to 125F Ambient
Hot Water	68 to 140F	0 to 95F Ambient
Max leaving at min ambient – 100F at 0F		
Sales Sheet (AC-SLB005-EN) Catalog (AC-PRC002*-EN) IOM (AC-SVX002*-EN)		

Thermafit™ AXM modular air-to-water heat pump

Capacity range: 30 tons cooling, 390 MBh heating

Max of 10 modules per bank

Refrigerant: R-410A

Compressor design: vapor injection scroll

Factory-installed options: coated coils, compressor wraps, BMS integration, single frame / beam assembly

Features and Benefits

- True redundancy
- Easy expandability
- Extreme flexibility
- Simplified service
- Small footprint/easy access

Operating Limitations		
Chilled Water	40 to 65F	0 to 125F Ambient
Hot Water	68 to 140F	0 to 95F Ambient
Max leaving at min ambient – 130F at 0F		
Available literature Catalog (ARCTC-PRC001*-EN) IOM (ARTC-SVX001*-EN)		

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Water-Cooled / Water-Source Units

All Chillers

**CTV/ECTV
RTWD/RTHD
MWC**

WXM

MWS

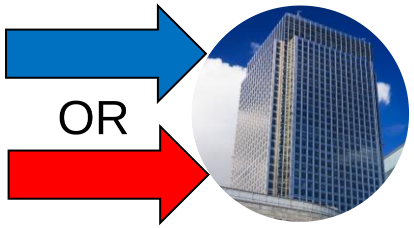
Chiller

Cooling only

Chiller + Heat Recovery

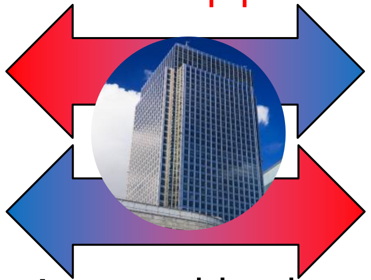
Heating while Cooling

Heat Pump



Heating or Cooling

Multi-pipe



Any combination

Thermafit™ WXM Modular Water-Source Heat Pump

Capacity range: 15 to 80 tons cooling, 270 to 1120 MBh

Max of 10 modules per bank

Refrigerant: R-410A, 134a

Compressor design: scroll

Factory-installed options: low sound and pump/tank package

Features and Benefits

- Easy expandability
- Extreme flexibility
- Simplified service
- Small footprint/easy access

Operating Limitations	
Chilled Water	38 to 65F
Hot Water	60 to 175F
42 F minimum LWT and 140 F maximum LWT	
Available literature Catalog (ARCTC-PRC002*-EN) IOM (ARTC-SVX002*-EN)	

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Thermafit™ MWS Modular Multipipe water-cooled unit

Simultaneous Heating and Cooling

Capacity range: 30 to 60 tons cooling, 1275 to 2690 MBh

Min of 3, max of 8 modules per bank

Refrigerant: R-410A

Compressor design: fixed scroll

Factory-installed options: single-point power, low sound panel package

Features and Benefits

- Single system to meet varying heating and cooling demands
- Fluids from different loops do not mix
- Geothermal support

Operating Limitations		
Cooling only	Chilled water 54-44F	Source 85-95F
Heating only	Hot water 100-120F	Source 54-44F
Simultaneous	Chilled water 54-44F	Hot water 100-120F

Available literature
Catalog (ARCTC-PRC003*-EN)
IOM (ARTC-SVX005*-EN)

Common Concerns when Decarbonizing Heat with Electricity

TRANE

Common Concerns	The Storage Source Heat Pump (SSHP) System Solution
Heating load peaks occur when green power generation is at its lowest.	Thermal batteries can be charged when low carbon energy is available.
Building cooling and heating load peaks occur at different times limiting instantaneous heat recovery effectiveness.	Storage of cooling load energy for use during heating.
In cold climates the outdoor air can get cold enough that Air-Water Heat Pumps cannot run requiring high electrical demand or fossil full backup.	Thermal battery energy is used to carry the building through periods of extreme cold weather with efficient heat pumps.
Emerging electrified heating electricity demand strains electric grid	Thermal energy storage enables building electric demand management
Rapid discharge and charge cycles impact the life of expensive electric battery technologies.	SSHP uses low-cost water to store energy which has infinite freeze / thaw cycles.