



Large Heat Pumps: Carbon Reduction with Great Economics

Real World Applications and Case Studies

November 9, 2022

The power behind **your** mission

Speaker Introductions

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Agenda



Heat Pump Refresh



The Path to Electrify Existing Facilities



Heat Pump vs Conventional Performance



Heat Pump System Design



Heat Pump Selection and Installation Best Practices



The Future of Cooling and Heating Systems



Terminology Refresh

Decarbonization

Operational AND Embodied Carbon Reduction

Energy Efficiency

Electrification

Low-GWP
Refrigerants

Heat Recovery

Heat is a by-product of chilled water and controlled by leaving evaporator temperature

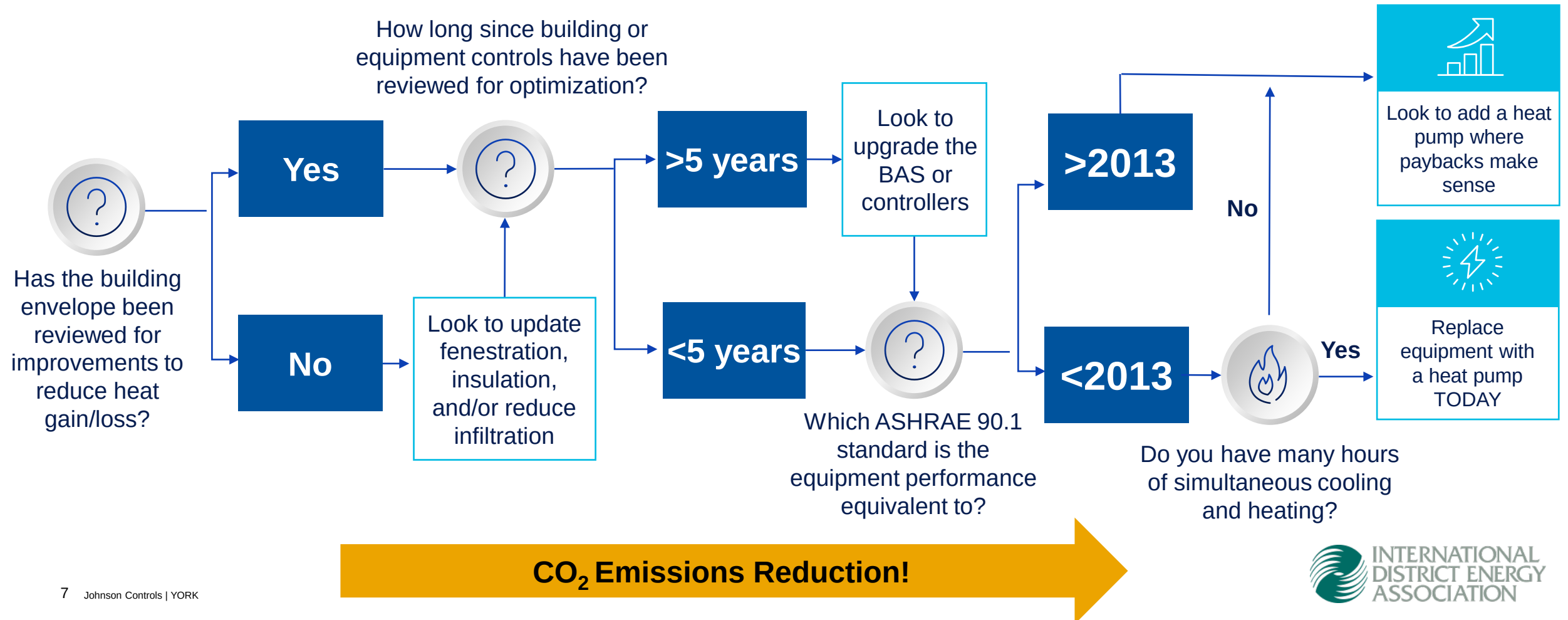
Heat Pumps

Can heat OR cool, controlled by either leaving condenser temperature or leaving evaporator temperature

The Path to Electrify Existing Facilities

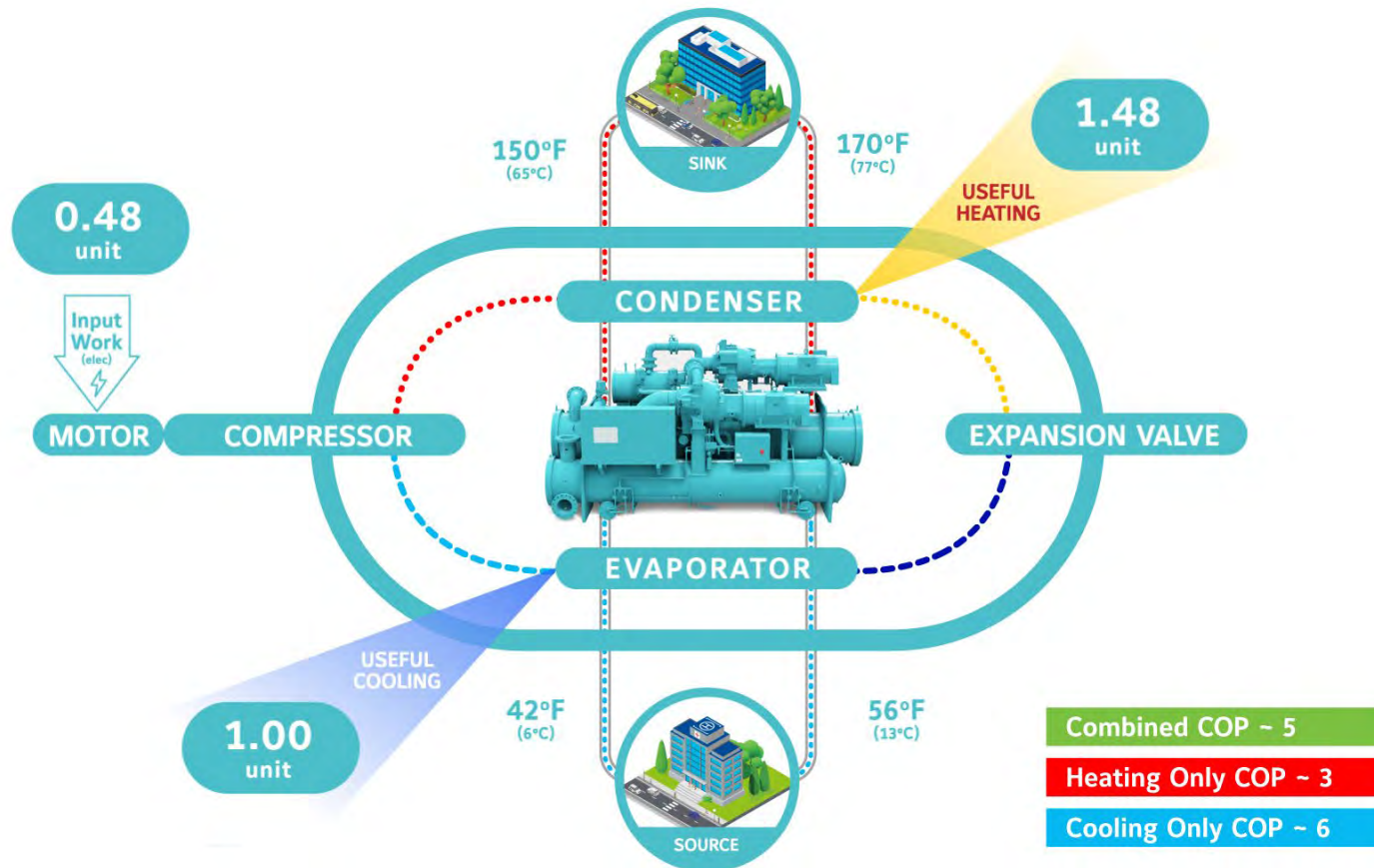
How do you prioritize the right decarbonization solutions? And what makes the most sense?

Don't assume to just “electrify”! Make sure you treat the root cause – not the symptoms!



Water-to-Water Heat Pump Refresh

Simultaneous 42°F/170°F Water, 3X ~ 4X Efficient vs. Conventional

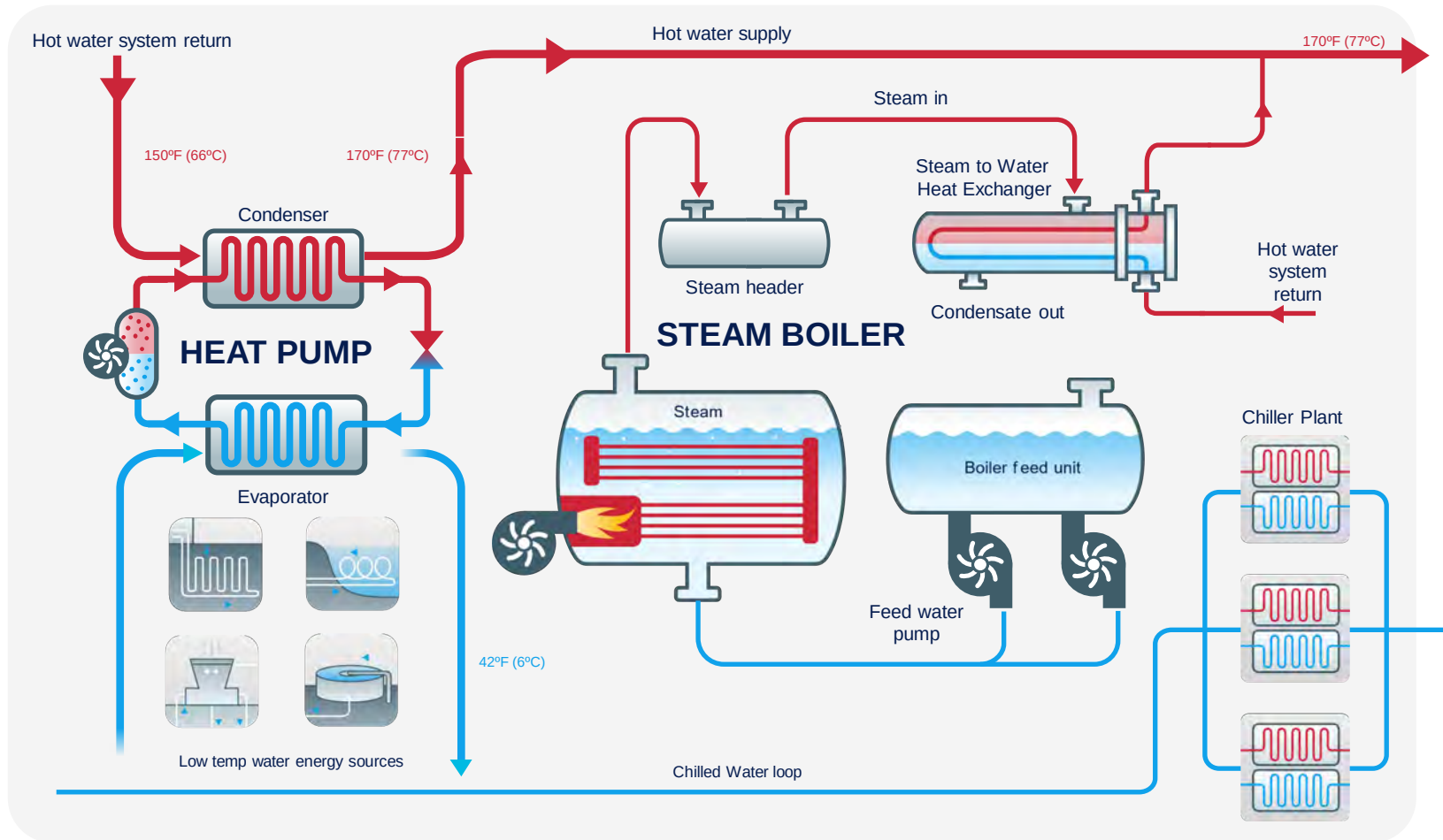


Large water-to-water heat pumps work ideally in simultaneous cooling and heating configurations

- Need adequate heat source and sink to operate optimally
- Electrically driven with best cost to performance benefit in high-lift type applications
- Low-GWP refrigerants can be applied for maximum carbon emission reduction

The Path to Electrify Existing Facilities

Steam System Example



Converting Steam Systems to Hot Water is Possible!

- Central utility heat pump plant
- Eliminate legacy steam piping losses
- Allows for the ability to do hot water reset options during summer or off-peak times of day

ASHRAE 90.1-2019 – Minimum Efficiency Requirements Aligns with AHRI 550/590

Table 6.8.1-16 Heat-Pump and Heat Recovery Chiller Packages—Minimum Efficiency Requirements (Continued)

Equipment Type	Size Category, ton _R	Cooling-Only Operation Cooling Efficiency ^a Air Source EER (FL/IPLV), Btu/W·h Water Source Power Input per Capacity (FL/IPLV), kW/ton _R		Heating Operation										Test Procedure
				Heating Source Conditions (entering/leaving water) or OAT (db/wb), °F	Heat-Pump Heating Full-Load Efficiency (COP _H) ^b , W/W				Heat Recovery Chiller Full-Load Efficiency (COP _{HR}) ^{b,c} , W/W Simultaneous Cooling and Heating Full-Load Efficiency (COP _{SHC}) ^d , W/W					
					Leaving Heating Water Temperature				Leaving Heating Water Temperature					
					Low	Medium	High	Boost	Low	Medium	High	Boost		
					105°F	120°F	140°F	140°F _i	105°F	120°F	140°F	140°F		
Water source electrically operated centrifugal	<75	≤0.6421 FL ≤0.5789 IPLV.IP	≤0.7316 FL ≤0.4632 IPLV.IP	54/44°	≥4.640	≥3.680	≥2.680	NA	≥8.330	≥6.410	≥4.420	NA	AHRI 550/590	
				75/65°	NA	NA	NA	≥3.550	NA	NA	NA	≥6.150		
	≥75 and <150	≤0.5895 FL ≤0.5474 IPLV.IP	≤0.6684 FL ≤0.4211 IPLV.IP	54/44°	≥4.640	≥3.680	≥2.680	NA	≥8.330	≥6.410	≥4.420	NA		
				75/65°	NA	NA	NA	≥3.550	NA	NA	NA	≥6.150		
	≥150 and <300	≤0.5895 FL ≤0.5263 IPLV.IP	≤0.6263 FL ≤0.4105 IPLV.IP	54/44°	≥4.640	≥3.680	≥2.680	NA	≥8.330	≥6.410	≥4.420	NA		
				75/65°	NA	NA	NA	≥3.550	NA	NA	NA	≥6.150		
	≥300 and <600	≤0.5895 FL ≤0.5263 IPLV.IP	≤0.6158 FL ≤0.4000 IPLV.IP	54/44°	≥4.930	≥3.960	≥2.970	NA	≥8.900	≥6.980	≥5.000	NA		
				75/65°	NA	NA	NA	≥3.900	NA	NA	NA	≥6.850		
	≥600	≤0.5895 FL ≤0.5263 IPLV.IP	≤0.6158 FL ≤0.4000 IPLV.IP	54/44°	≥4.930	≥3.960	≥2.970	NA	≥8.900	≥6.980	≥5.000	NA		
				75/65°	NA	NA	NA	≥3.900	NA	NA	NA	≥6.850		

a. Cooling-only rating conditions are standard rating conditions defined in AHRI 550/590, Table 1.

b. Heating full-load rating conditions are at rating conditions defined in AHRI 550/590, Table 1.

c. For water-cooled heat recovery chillers that have capabilities for heat rejection to a heat recovery condenser and a tower condenser, the COP_{HR} applies to operation at full load with 100% heat recovery (no tower rejection). Units that only have capabilities for partial heat recovery shall meet the requirements of Table 6.8.1-3.

d. Outdoor air entering dry-bulb (db) temperature and wet-bulb (wb) temperature.

e. Source-water entering and leaving water temperature.

Table 5. Full and Part-load Application Rating Conditions							
	Evaporator			Condenser			
Cooling	Water Cooled			Water Cooled			
	Leaving Temperature ¹ , °F	Temperature Difference Across Heat Exchanger ² , °F	Fouling Factor Allowance, h·ft ² ·°F/Btu	Entering Temperature ³ , °F	Flow Rate, gpm/ton ^{5,7}	Fouling Factor Allowance, h·ft ² ·°F/Btu	
	36.00 to 70.00	5.00 to 20.00	0.000 to 0.00100	55.00 to 115.00	1.000 to 6.000	0.000 to 0.00100	
				Air-Cooled			
				Entering Air Dry Bulb ³ , °F		Atmospheric Pressure ⁶ , psia	
				55.0 to 125.6		11.56 to 15.20	
				Evaporatively Cooled			
				Entering Air Wet Bulb ⁴ , °F		Atmospheric Pressure ⁶ , psia	
	50.0 to 80.0		11.56 to 15.20				
	Water Source Evaporator			Water Cooled Condenser			
Entering Water Temperature ¹ , °F	Fouling Factor Allowance, h·ft ² ·°F/Btu		Leaving Water Temperature ² , °F	Temperature Difference Across Heat Exchanger ⁵ , °F	Fouling Factor Allowance, h·ft ² ·°F/Btu		
Heating	40.00 to 80.00		0.000 to 0.00100	105.00 to 160.00	5.00 to 30.00	0.000 to 0.00100	
	Air Source Evaporator						
	Entering Air Temperature, °F	Atmospheric Pressure ⁶ , psia					
	15.00 to 60.00	11.56 to 15.20					

Notes:

1. Evaporator water temperatures shall be published in rating increments of no more than 4.00 °F.
2. Condenser water temperatures shall be published in rating increments of no more than 5.00 °F.
3. Entering air temperatures shall be published in rating increments of no more than 10.0 °F.
4. Air wet bulb temperatures shall be published in rating increments of no more than 2.5 °F.
5. Applies to design point only, not part-load points.
6. Rated altitude not exceeding 6500 ft. Measured test data will be corrected per Appendix C to the application rating atmospheric pressure.
7. The normalized flow rate is per unit of evaporator Capacity.

Notes:

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For higher condenser water temperatures, formal standard interpretation may be required

Typical Performance – Compound Electric Centrifugal Heat Pump

Examples Meet/Exceed ASHRAE 90.1 Requirements

Cooling Capacity, ton _R	Heating Capacity, MBH	Cooling-Only Operation	Heating Operation								
		Cooling Efficiency at AHRI Conditions Power Input per Capacity (FL/IPLV), kW/ton _R (COP)	Heating Source Conditions (Evaporator entering/ leaving water) °F	Heat-Pump Heating Full-Load Efficiency (COP _H)				Simultaneous Cooling and Heating Full-Load Efficiency (COP _{SHC})			
				Leaving Heating Water Temperature				Leaving Heating Water Temperature			
				High	Boost	Higher	Boost	High	Boost	Higher	Boost
				140°F (60°C)	140°F (60°C)	170°F (77°C)	170°F (77°C)	140°F (60°C)	140°F (60°C)	170°F (77°C)	170°F (77°C)
~ 400	~ 6,270	~ 0.56 FL (6.3) ~ 0.51 IPLV. (6.9)	54/44	~ 3.8	NA	~ 3.1	NA	~ 6.6	NA	~ 5.2	NA
			75/65 (Boost)	NA	~ 5.0	NA	~ 4.1	NA	~ 9.0	NA	~ 7.2
~ 1450	~ 23,330	~ 0.56 FL (6.3) ~ 0.47 IPLV. (7.4)	54/44	~ 3.6	NA	~ 3.0	NA	~ 6.2	NA	~ 5.1	NA
			75/65 (Boost)	NA	~ 4.6	NA	~ 3.7	NA	~ 8.2	NA	~ 6.5

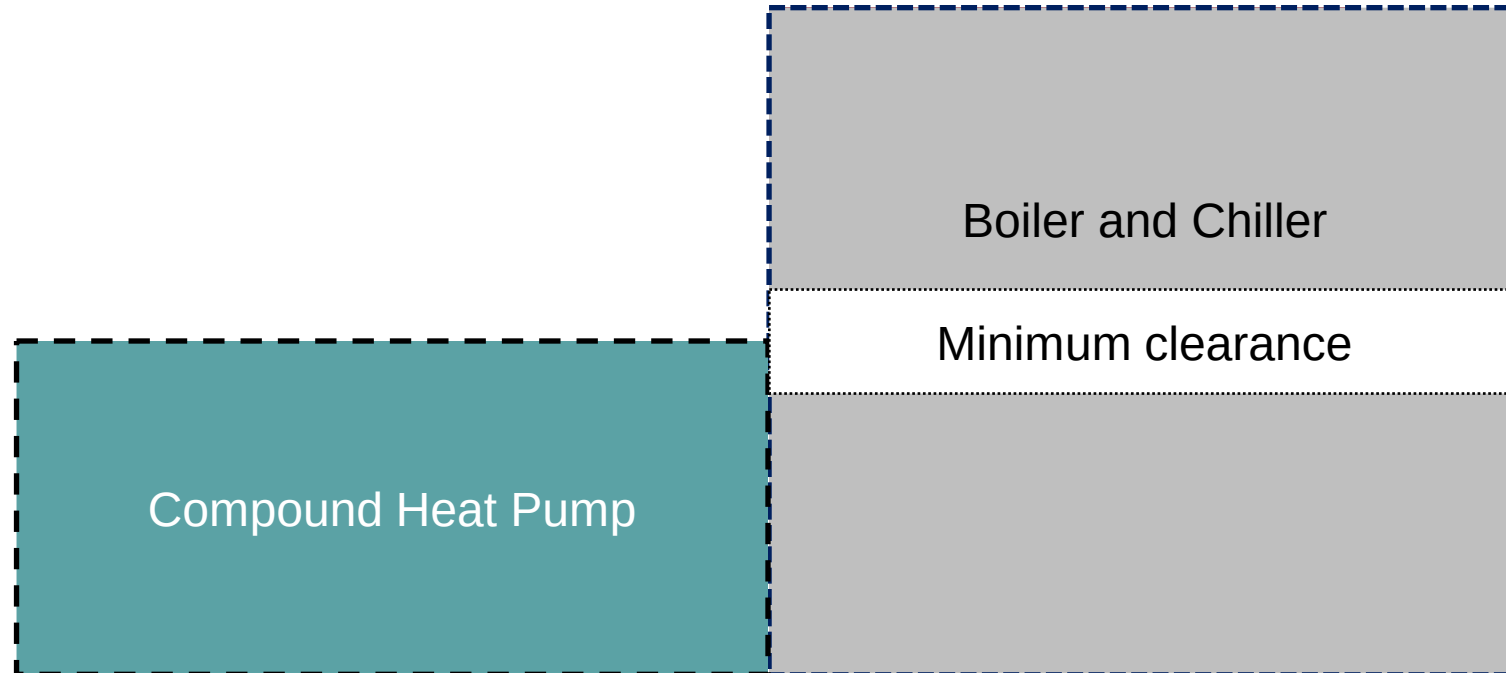


Indicative (approximate) representation

Save on your Real Estate

Compound Heat Pump may save up to 50% footprint vs. chiller + boiler

- **Stand-alone Boiler** 7,000 MBH (2,051 kW), 170°F (77°C) Hot Water
- **Stand-alone Chiller** 525 tons (1,846 kW), 42°F (5.5°C) Chilled Water
- **Heat Pump:**
 - Cooling only ~525 tons (1,846 kW) (42°F/5.5°C)
 - Simultaneous Cooling 400 tons (1,406 kW) 42°F (5.5°C) and Heating 7,000 MBH (2,051 kW) 170°F (77°C)

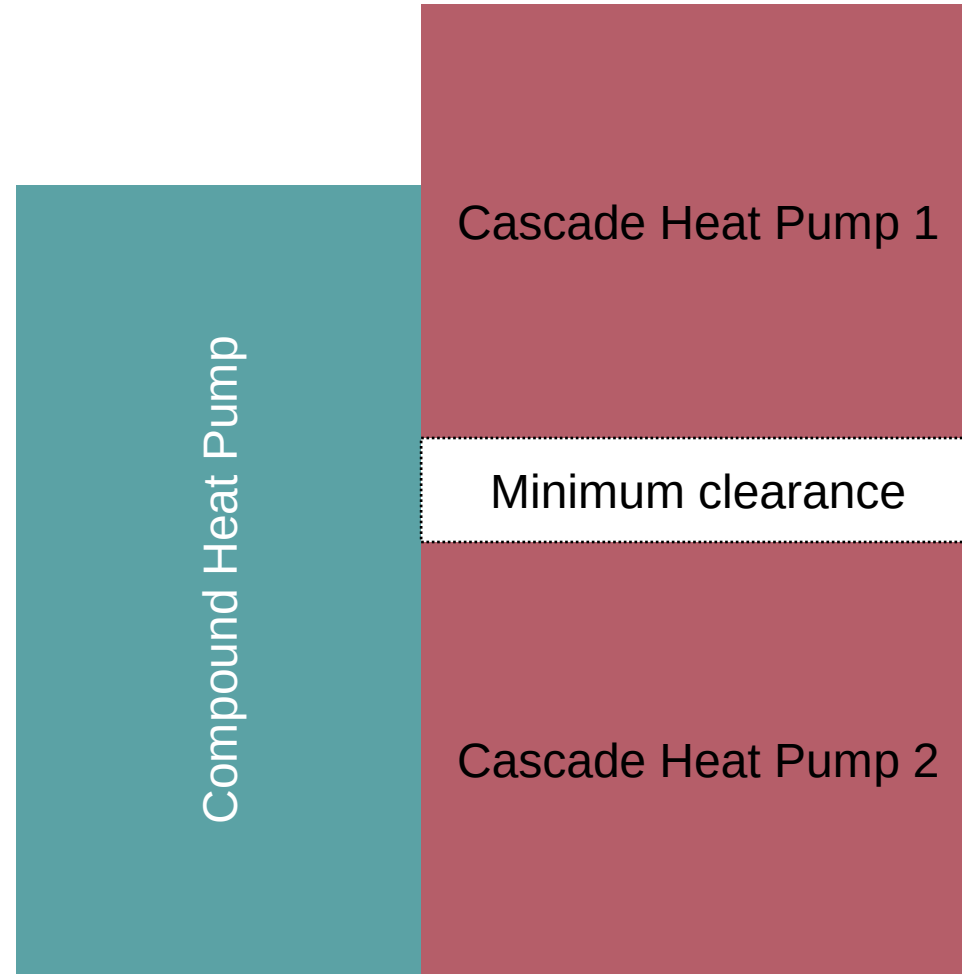


Indicative (approximate) representation

Save on your Real Estate

One Compound HP saves up to ~ 25% footprint vs. two cascaded heat pumps

- **Cooling Capacity** 1,800 Tons (6,330 kW) @ 38°F (3.3°C) Chilled Water
- **Heating Capacity** 31,250 MBH (9,159 kW) @ 170°F (77°C) Hot Water



Indicative (approximate) representation

What Do You Need to Know About Designing Heat Pump Systems?

Existing building? Use BAS trend data to establish accurate min and max loads

- Consider the potential for future load variability in your system

New Design? Need accurate on and off-peak load model

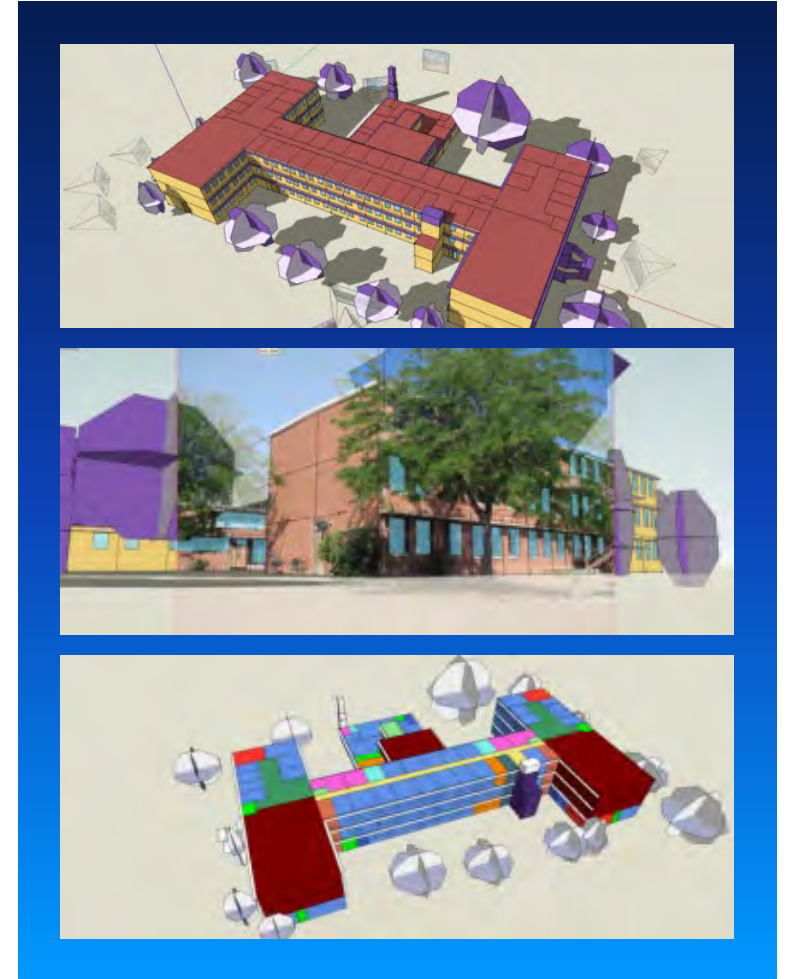
- Identify hours of simultaneous heating and cooling
- If there is a goal to fully electrify, what will be your heat source(s)?
- Is ground-source/geo-exchange viable? Validate with simulation tools

Heat Pumps Move BTUs – Be Creative

- Exhaust air in laboratories
- Airside Economizers ... Are they needed?
- Air-to-water heat pump as a supplemental heat source

Load diversity is an opportunity!

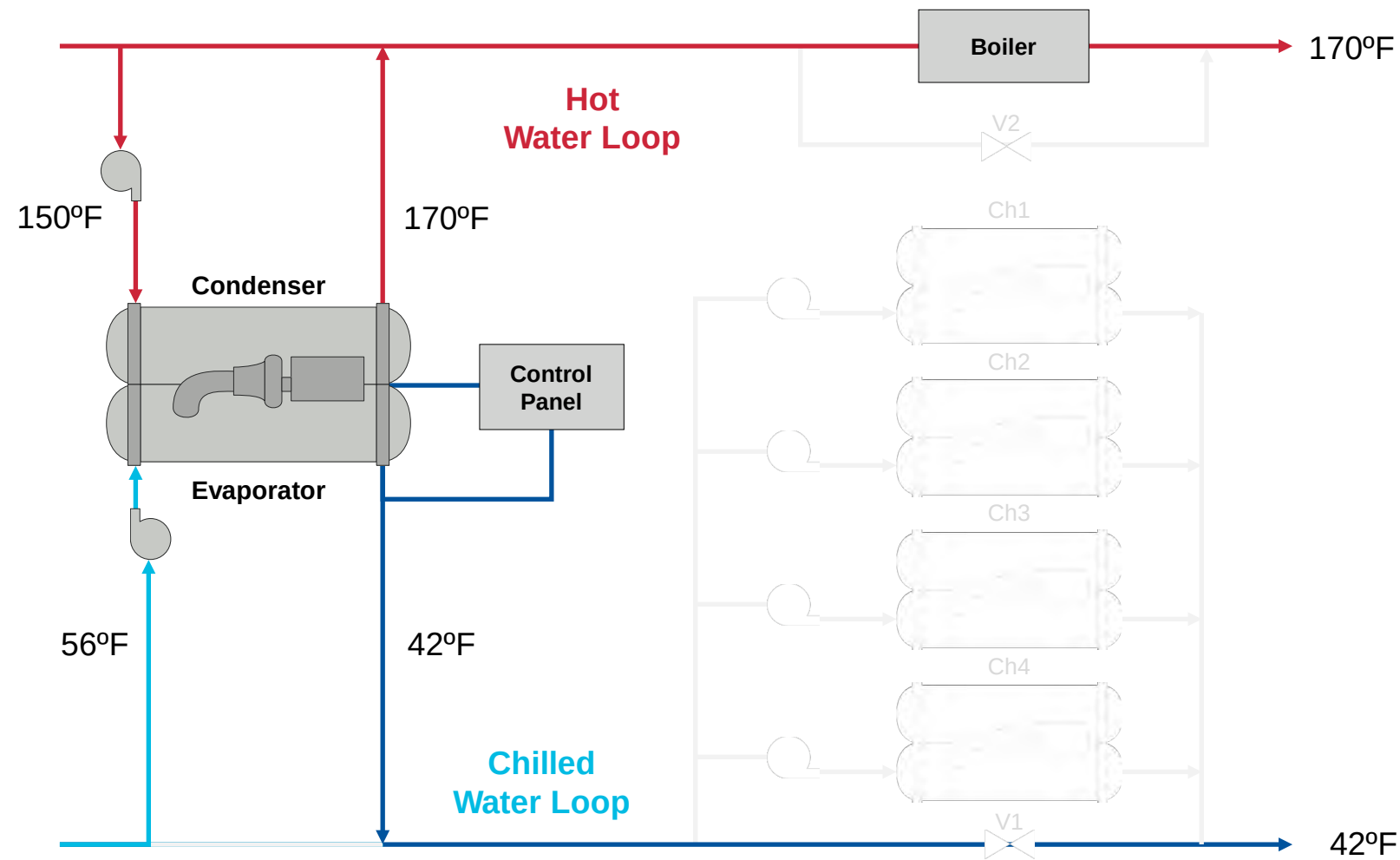
- Leverage thermal storage to capture heat you would have otherwise rejected



Heat Pump Control: Winter Mode

Typical “Side-Car” Configuration

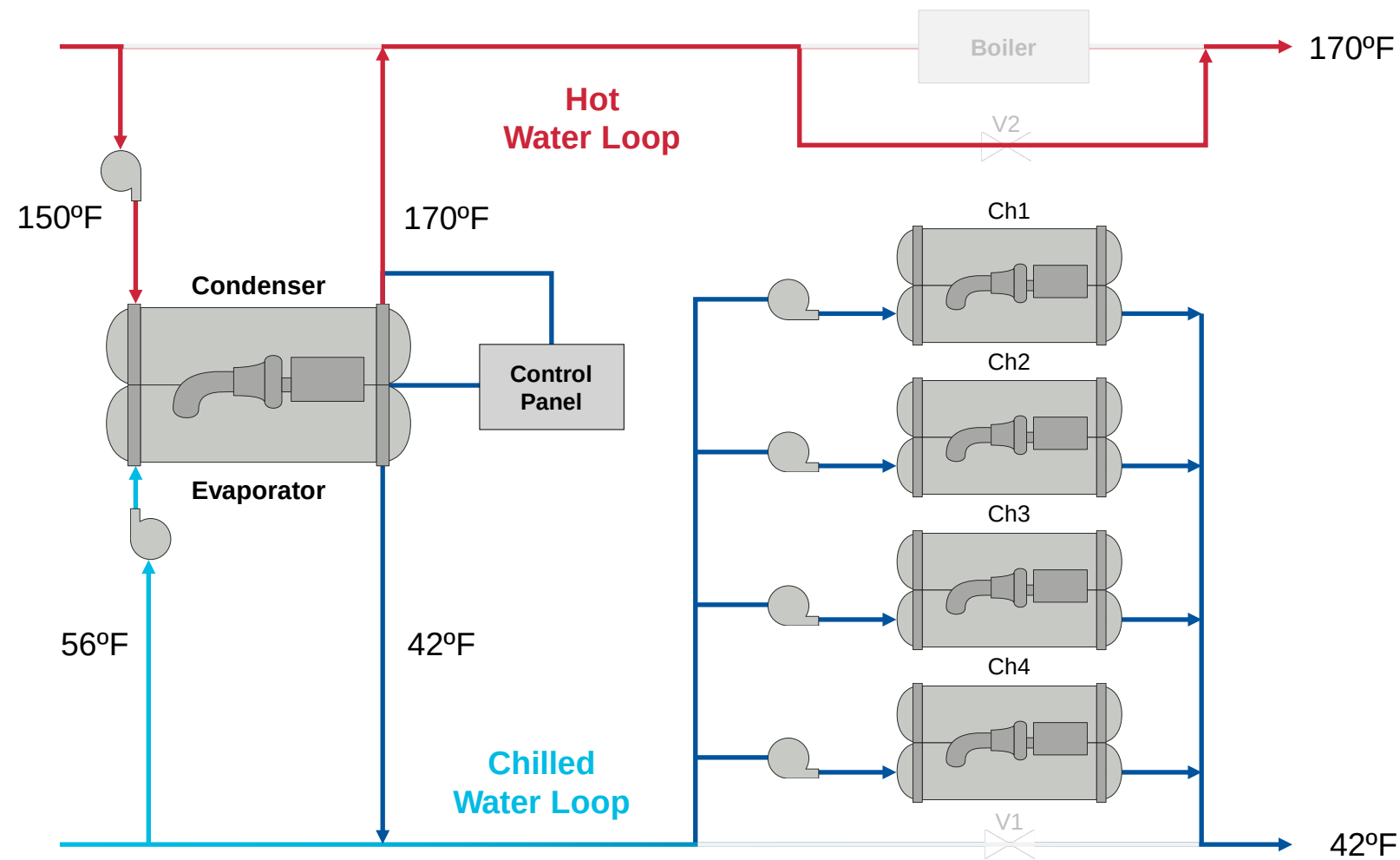
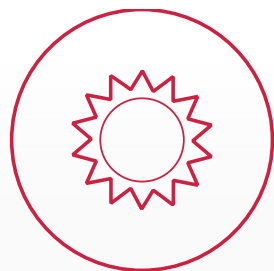
Heating load dominant
(cooling control)



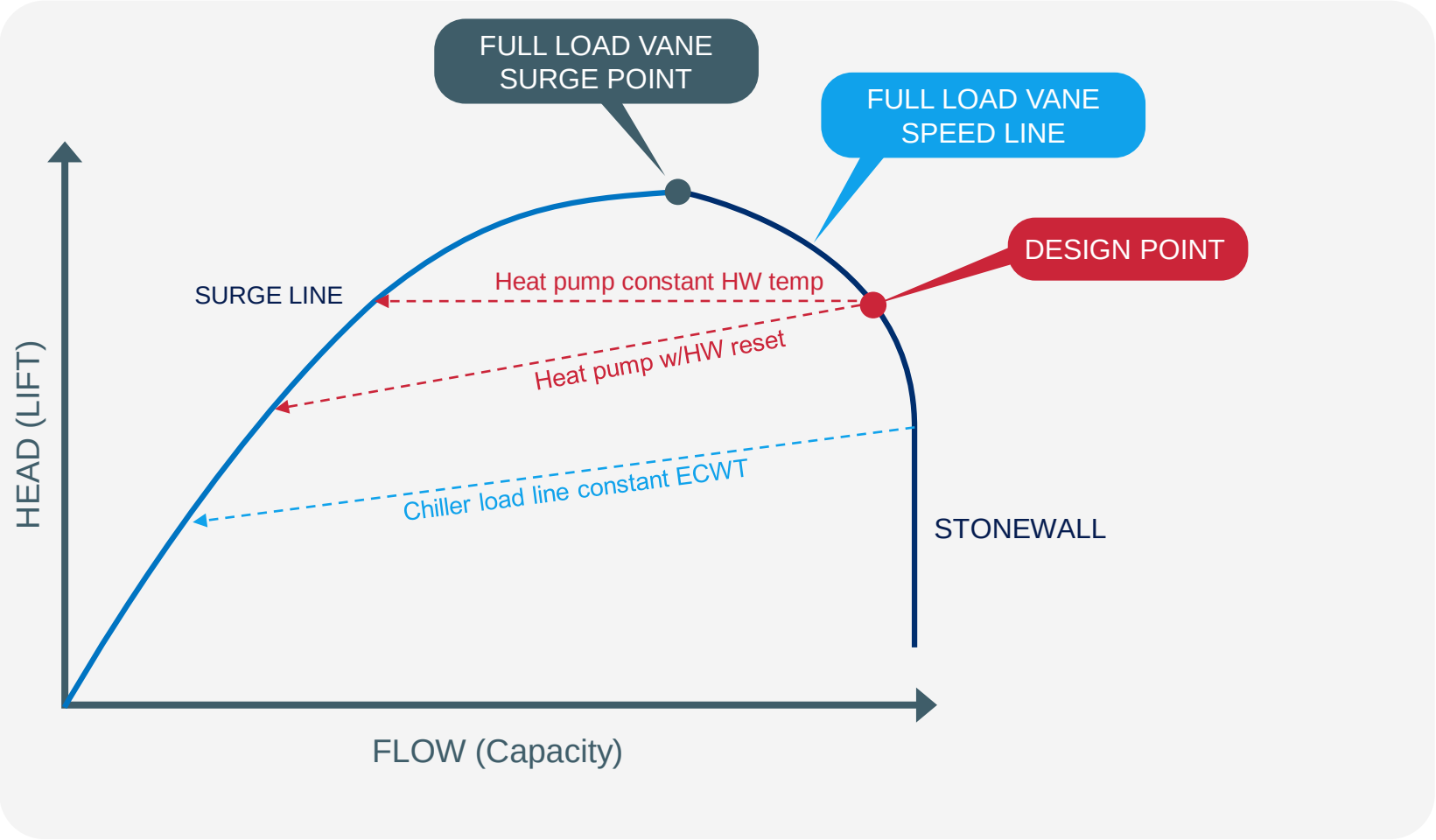
Heat Pump Control: Summer Mode

Typical “Side-Car” Configuration

Cooling load dominant
(heating control)



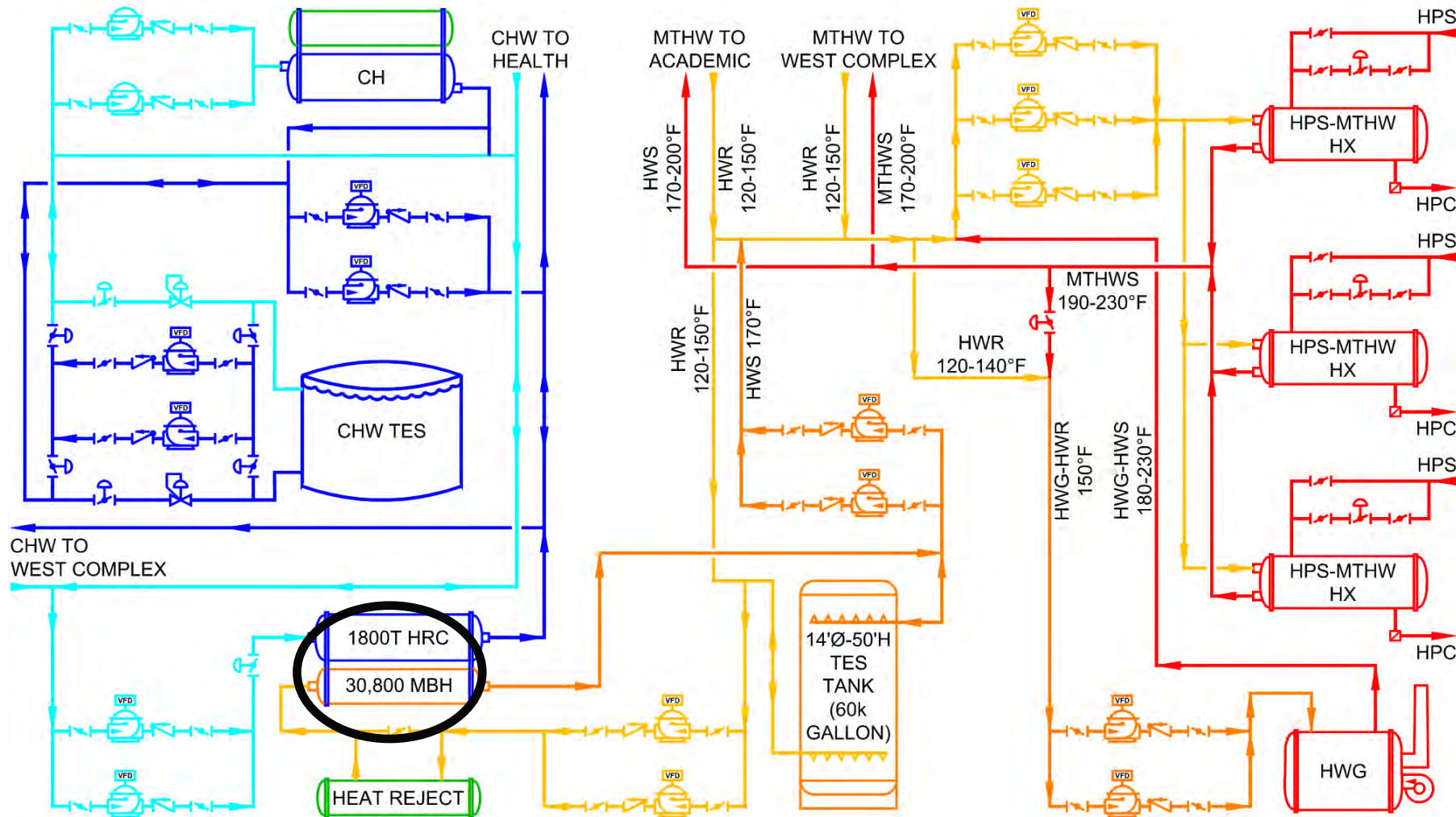
Unloading – Compound Centrifugal Heat Pump



Indicative (approximate) representation

Understanding System Components

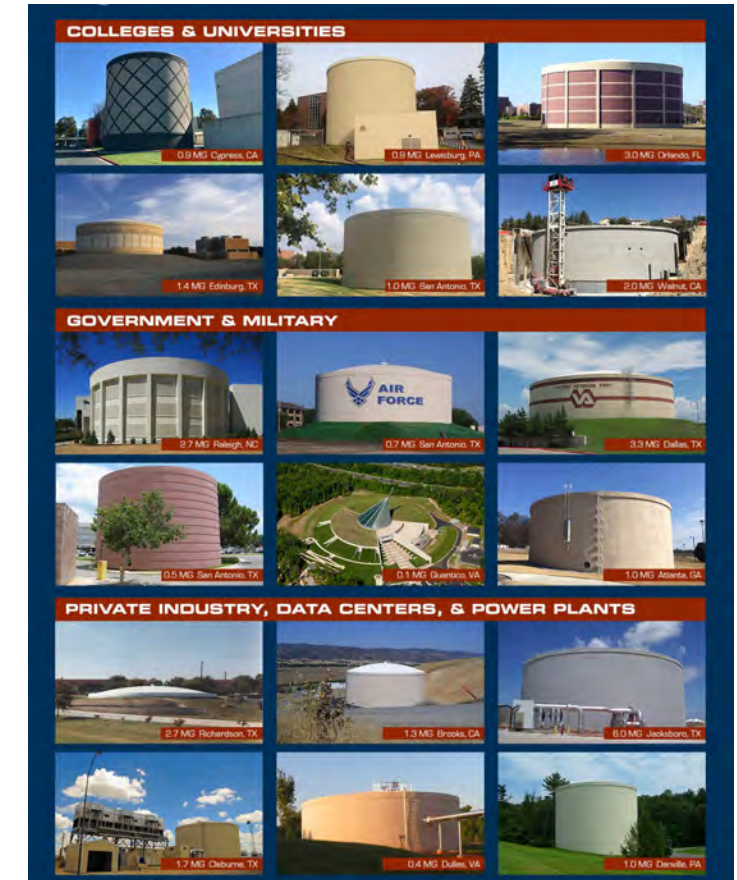
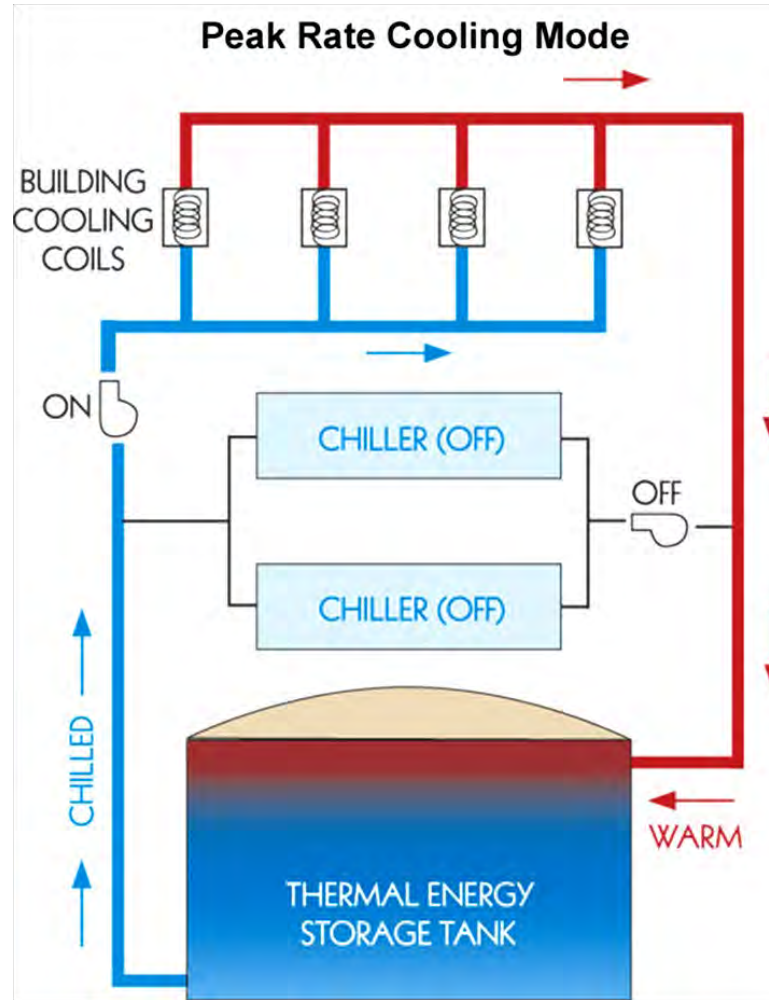
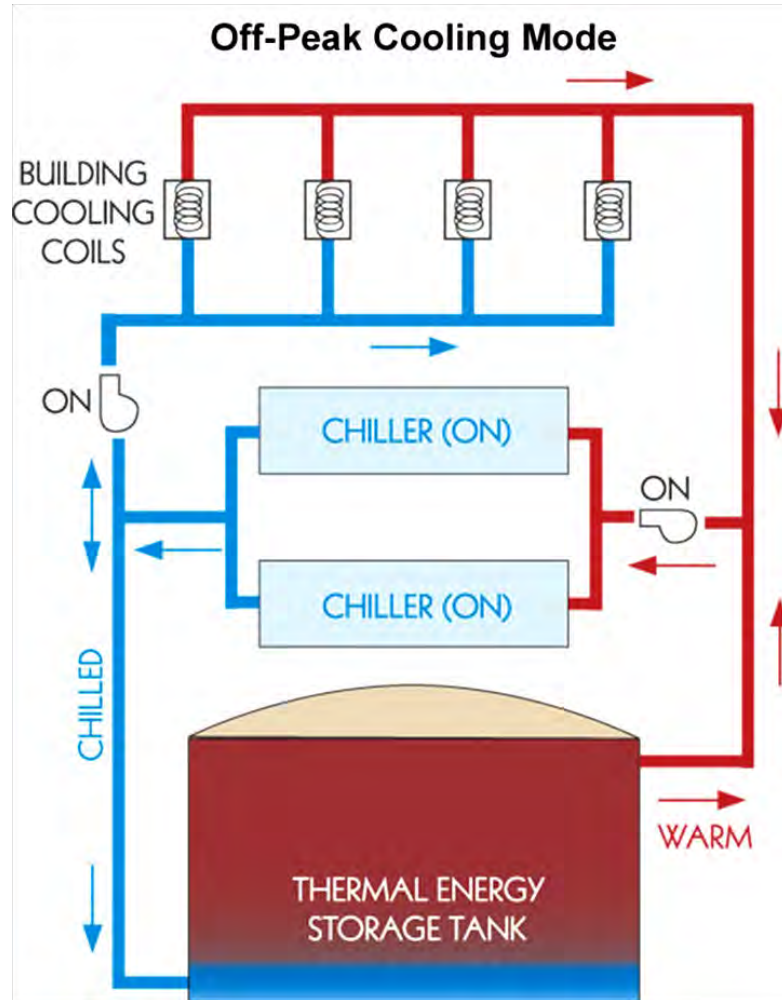
Consolidation of heating load, hot water and chilled water storage tanks



Courtesy of University of Virginia and AEI

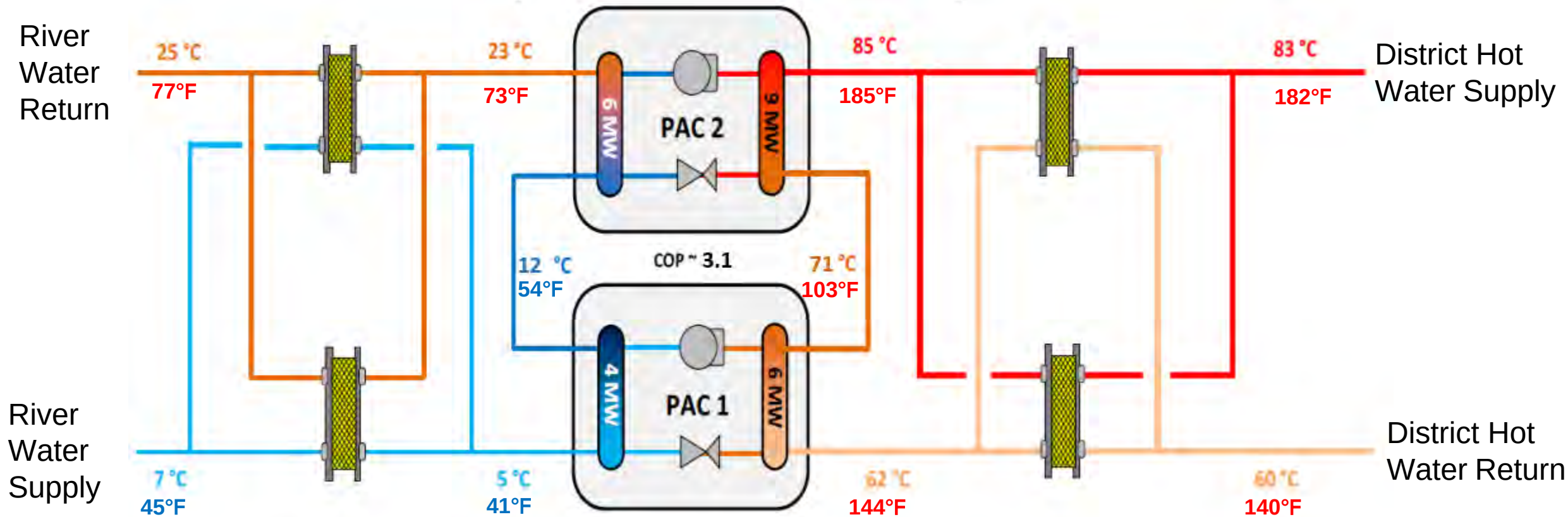
Thermal Energy Storage

Improved Operational Flexibility, Reduced Energy Costs



Series Counterflow

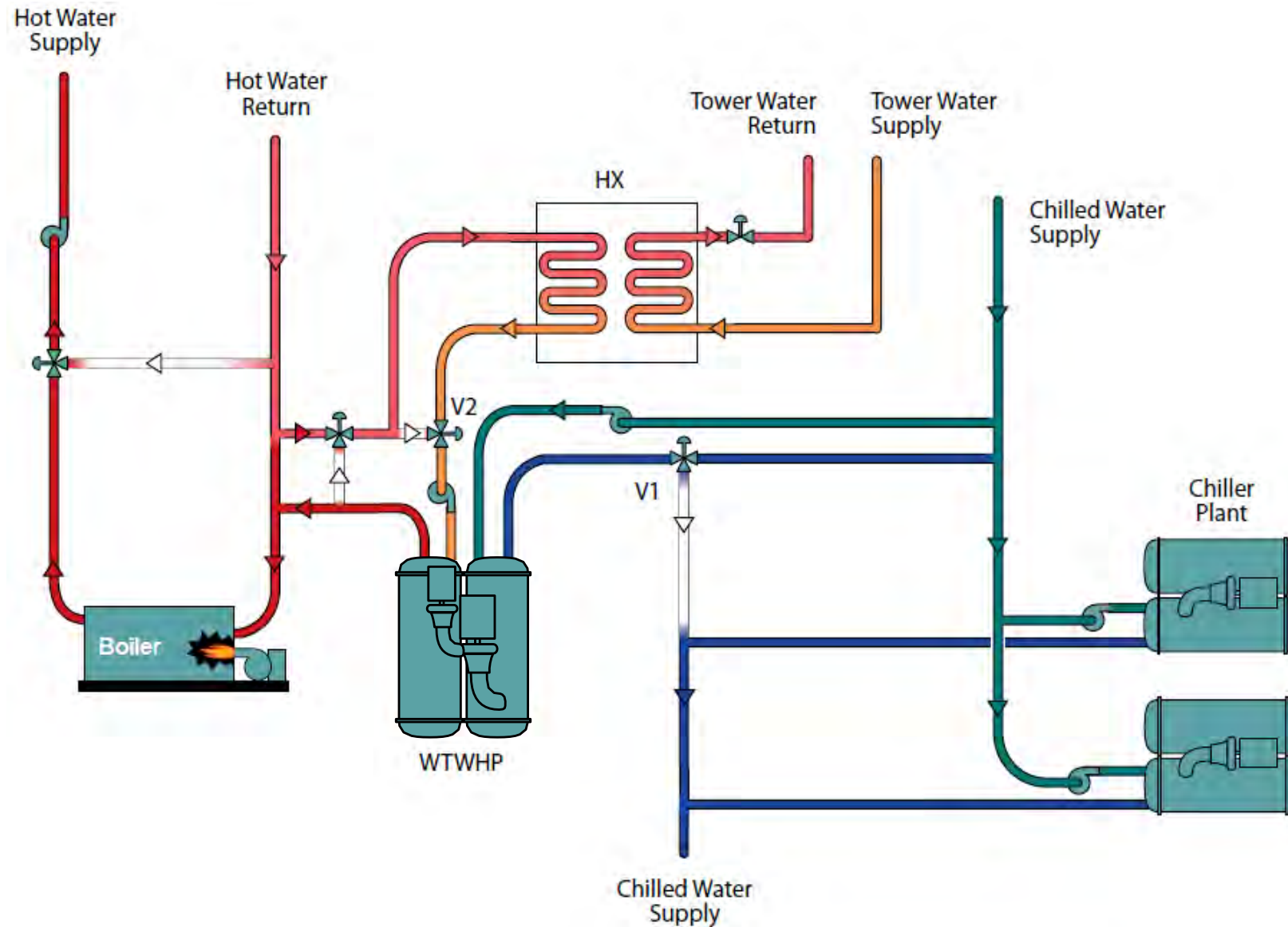
185°F Hot Water, 15% Lower Lift, 15% Higher COP vs. Parallel Arrangement



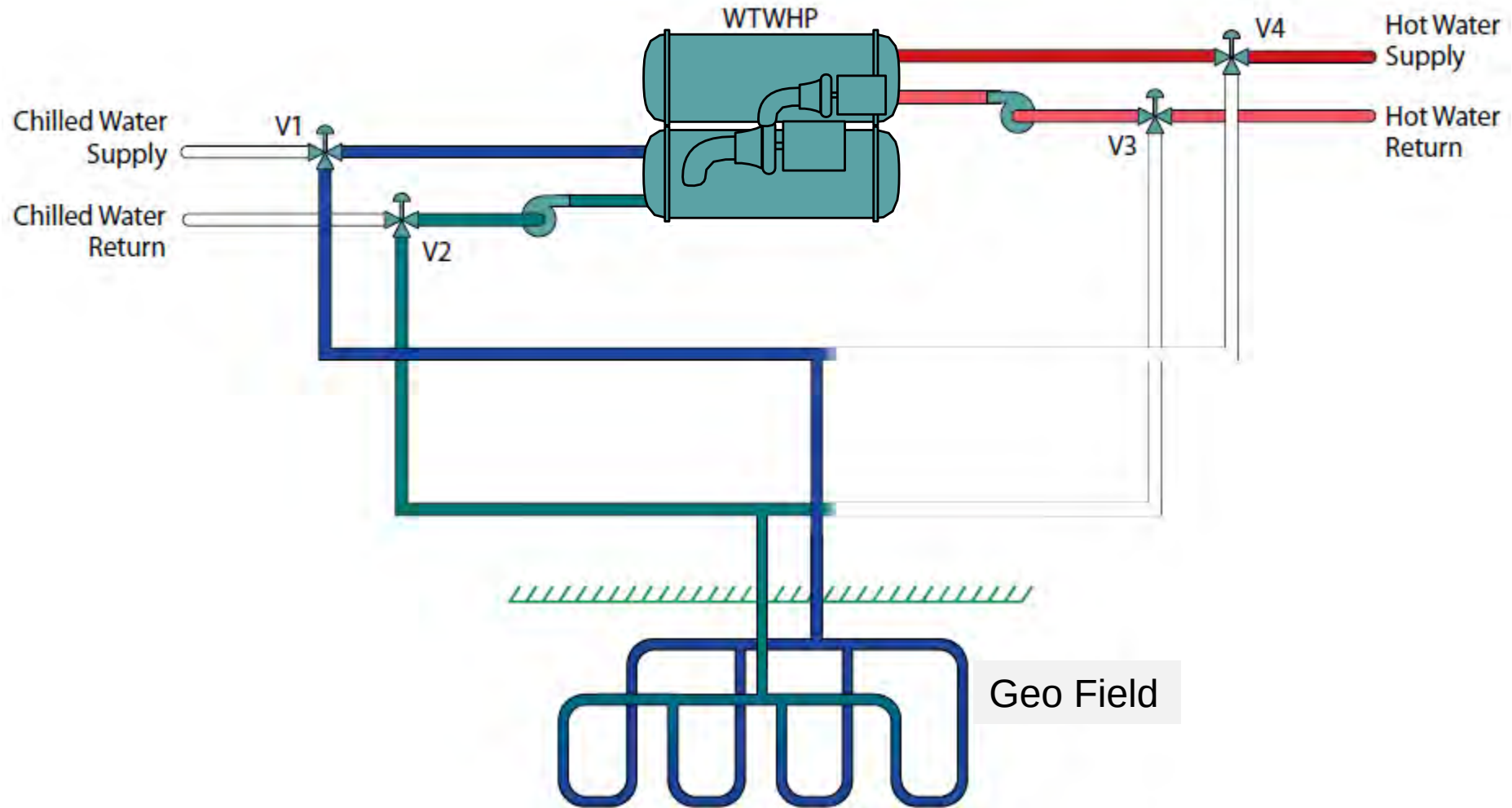
At nominal conditions :

- PAC1 : 6 MW (20,472 MBH) Heating, Lift 71-5=66°C (119°F), Heating COP ~3
- PAC2 : 9 MW (30,708) Heating, Lift 85-12=73°C (132°F), Heating COP ~3.2

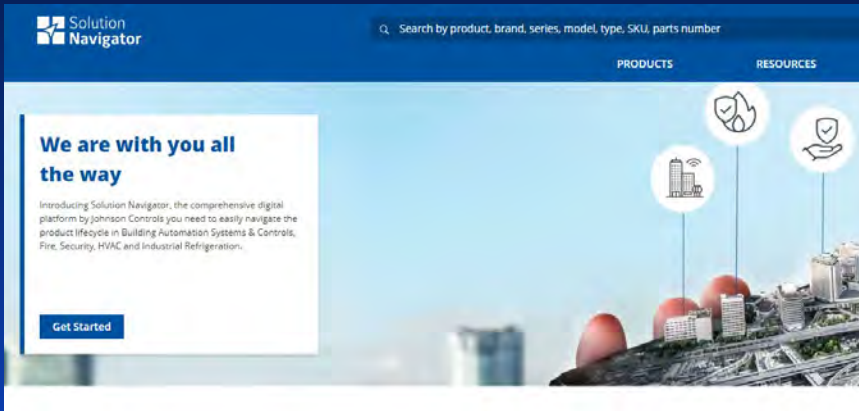
Hybrid Side-Stream / Parallel System Operating in Side-Stream Arrangement



Geothermal System for Simultaneous Heating and Cooling Operating in Heating-Only Mode.



Things to Look Out For in Heat Pump Selection and Installation



Source: Texas A&M

Full Load/Off-design Performance vs. Codes/Standards

Aggregation of heating load and ensuring that loads are not oversized

Rigging constraints?

- Split Shipments

Request a Factory Performance Test with Sound Level

Make Sure It is Working Correctly!

- Remote Monitoring by Manufacturer
- Predictive Diagnostics

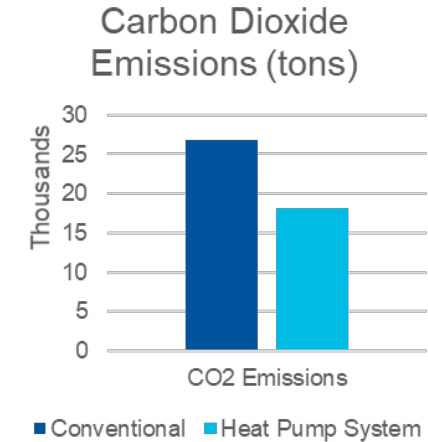
Make It Easy – Look at Specifying a Pre-Packaged Skid!

- Controls
- Pumps
- Thermal Storage Tanks

How much Energy, Water, and CO₂ can be saved per year?

1,765 tons, 30,706 MBH @ ~\$6M Install Price vs ~\$2.5M Conventional

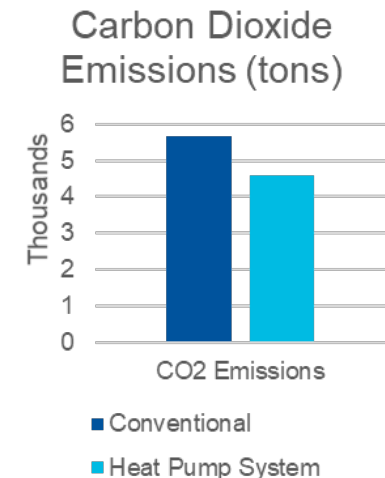
Utility Rates Electric, Gas	Total \$ Saved	Electricity \$ Increase	Natural Gas \$ Savings	Simple Payback
\$0.104/kWh \$1.274/therm	(\$2.68M)	\$1.22M	(\$3.92M)	1.2 years
\$0.15/kWh \$1.5/therm	(\$3.01M)	\$1.77M	(\$4.61M)	1.16 years
\$0.08/kWh \$0.7/therm	(\$1.37M)	\$942K	(\$2.15M)	2.5 years



20.6 million gallons water saved and 8,629 CO₂ tons of emissions avoided annually

400 tons, 6,300 MBH @ ~\$2M Install Price vs ~\$750K Conventional

Utility Rates Electric, Gas	Total \$ Saved	Electricity \$ Increase	Natural Gas \$ Savings	Simple Payback
\$0.104/kWh \$1.274/therm	(\$505K)	\$342K	(\$804K)	2.47 years
\$0.15/kWh \$1.5/therm	(\$497K)	\$493K	(\$946K)	2.52 years
\$0.08/kWh \$0.7/therm	(\$223K)	\$263K	(\$442K)	5.6 years



4.3 million gallons water saved, and 1,091 CO₂ tons of emissions avoided annually

The Future of Cooling and Heating Systems – Compound Heat Pump

PRACTICAL

- One of the most simplistic systems available for decarbonization
- Highly configurable and adaptable to many building types
- Save space, save energy, reduce carbon emissions!

ECONOMICAL

- Less than three-year payback period on most installations
- No need to change existing air-side system
- Allows for hedging against volatile fossil fuel prices

SMART

- Connected equipment allows for improved reliability and energy performance



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What's Next at IDEA?



CampusEnergy2023 registration open at <https://bit.ly/Campus23IDEA-Reg>. Early Bird Registration ends **Friday, November 18**. Join us at the Gaylord Texan Resort and Convention Center Feb 27-Mar 2, 2023.

Innovation Awards Webinar

Join IDEA and the **2022 Innovation Awards Webinar** Wednesday, December 14 at 11:00am EST. Hear from the winner and two honorable mentions and see the latest technologies at work.

Register at <https://bit.ly/Inno-IDEA>

Upcoming Workshop: *BEST PRACTICES IN DISTRICT THERMAL ENERGY NETWORKS IN NEW YORK STATE* – Tuesday Dec 6

This one-day workshop will focus on best practices in district energy system design, construction, deployment and optimization to help accelerate opportunities in New York State in support of *Utility Thermal Energy Network and Jobs Act*. Learn more at <https://bit.ly/NY-IDEA>

Submit Abstracts for IDEA2023

The deadline to submit abstracts for IDEA2023, taking place in Chicago, Illinois, from June 5-8 at the Chicago Hilton.

Submit your abstracts by Wednesday, December 14 at <https://bit.ly/IDEA2023-Abstracts>