Chiller Applications for Electrification with Geothermal Benefits

ASHRAE Iowa Chapter

De-carbonization of Buildings

- Increasing attention on embodied carbon in buildings
- Consulting Engineers focused on designing efficient, effective building systems that don't use fossil fuels
- Driven by local initiatives and legislations:
  - Local law 97 (of 2019) in NYC – Climate Mobilization Act https://www.urbangreencouncil.org/content/projects/all-about-local-law-97
  - University of California – Carbon Neutrality Initiative https://ucop.edu/carbon-neutrality-initiative/index.html
  - Clean Energy D.C. Omnibus Act of 2018
  - Net Zero Building Codes in Massachusetts
  - Local gas moratoriums and others
- Clear need for sustainable equipment with low GWP refrigerants, rapidly expanding market demand
- Heat Pump options eliminate boiler, eliminate cool tower

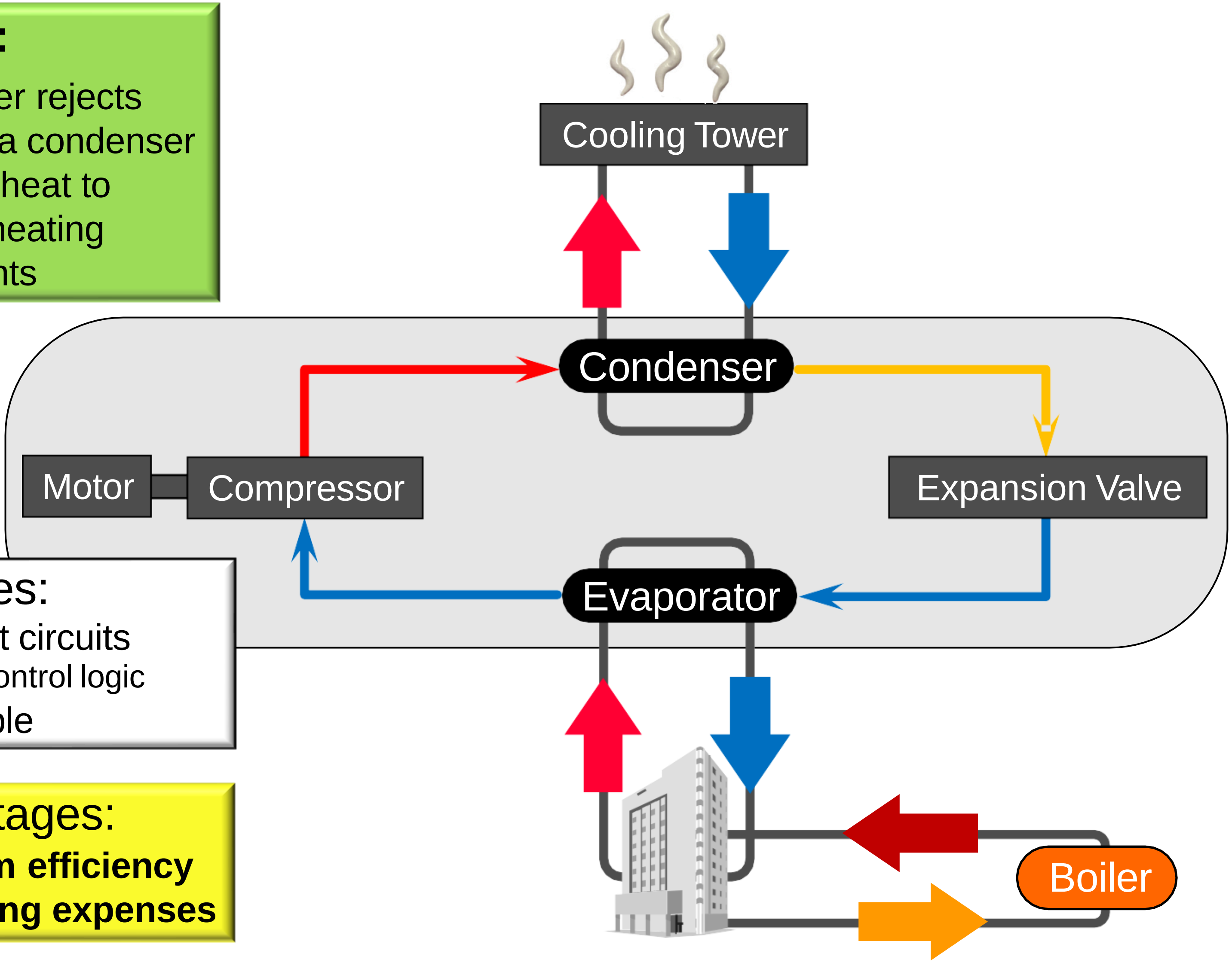
Agenda

- Heat Pump Solutions
  - What is a heat pump and why use one?
  - Control & Sizing
  - Application Benefits
- Application Considerations
- Conclusion

Traditional building configuration

Logic:

- Cooling tower rejects building heat via condenser
- Boiler provides heat to meet building heating requirements



Advantages:

- Independent circuits
- Simple control logic
- Reliable

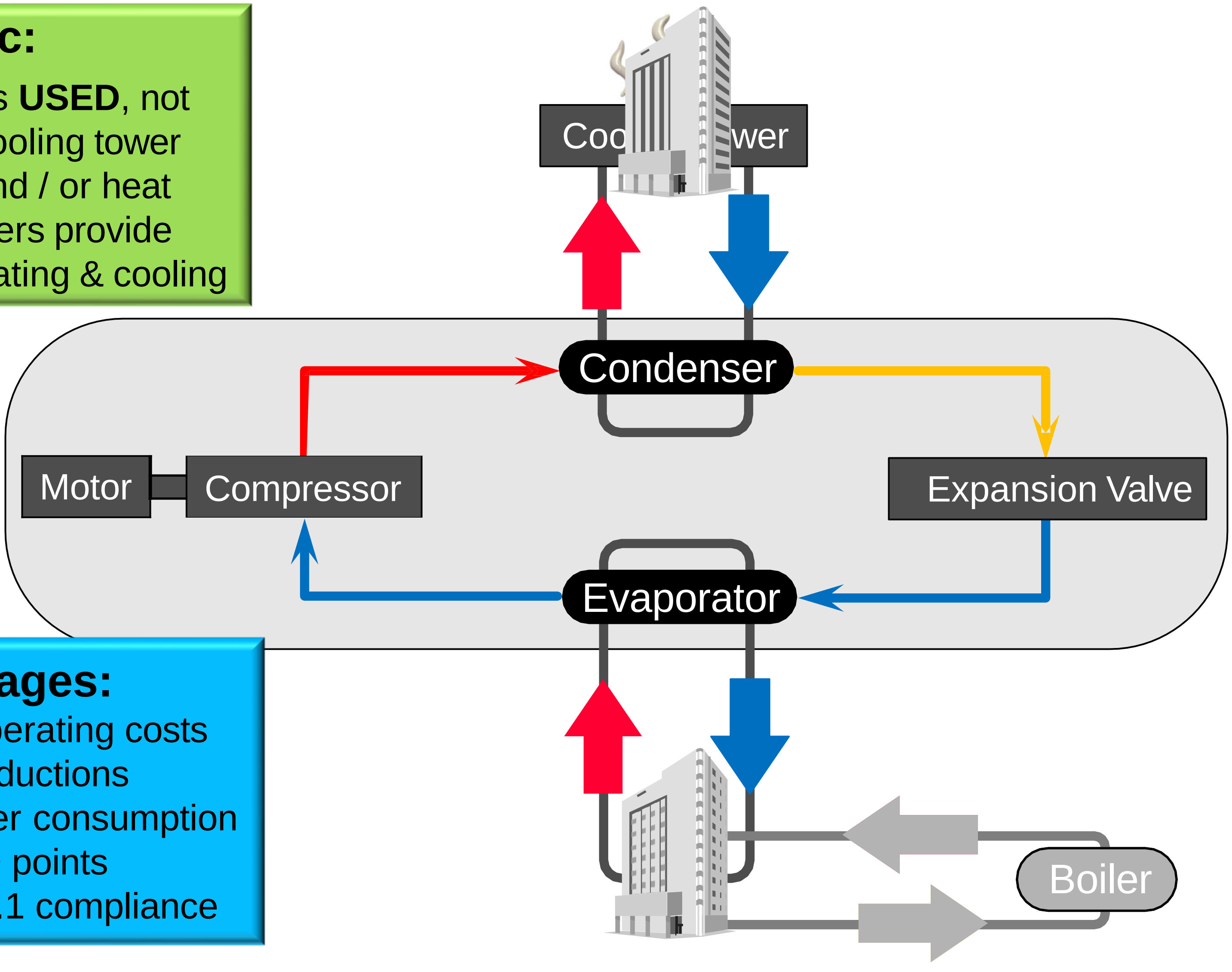
Disadvantages:

- **Low system efficiency**
- **High operating expenses**

Increase efficiency & lower your operating costs

Logic:

- Building heat is **USED**, not rejected via cooling tower
- Heat pump and / or heat recovery chillers provide simultaneous heating & cooling



Advantages:

- Reduced operating costs
- CO_2 reductions
- Reduced water consumption
- LEED points
- ASHRAE 90.1 compliance

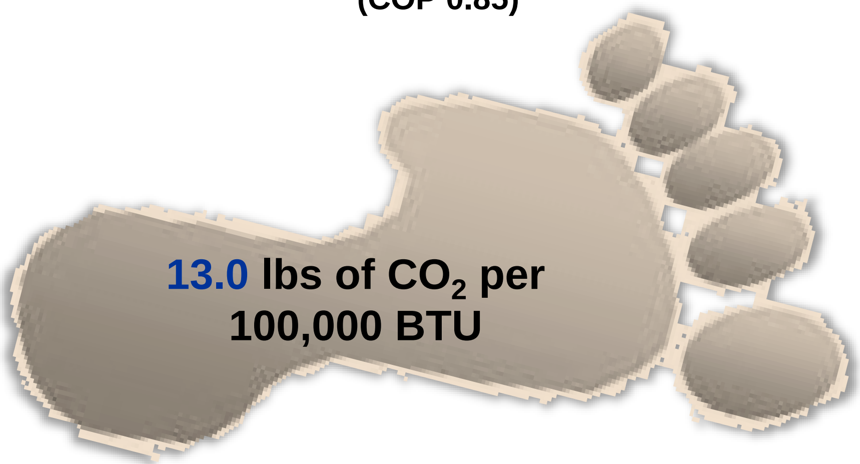
Heat Pump Benefits – Social / Environmental

How much CO_2 would a 600 Ton Heat Pump (at 65% average load) offset, compared to a natural gas boiler?

1467 Tons of CO_2 annually

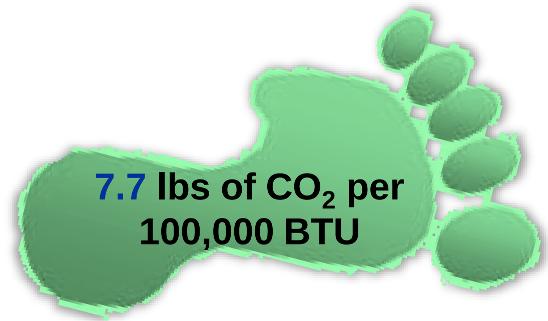
Natural Gas Boiler

(COP 0.85)



Heat Pump

(COP 6.70)



This is the equivalent of removing 244 cars from the road!

Heat Pump Benefits – Social / Environmental

How much water would a 600 Ton Heat Pump (at 65% average load) save by not sending it to the cooling tower?

22,500 gallons (85,171 L) per DAY!

+ Water treatment & sewer savings

Assumptions:

- *Cooling tower consumption per evaporation rate of 1% & blow-down of 0.3% (4 cycles of concentration)*
- *3 gpm/ton (0.054 L/s) condenser water flow*

Definitions

ASHRAE Handbook:

- “A Heat Pump extracts heat from a source and transfers it to a sink at a higher temperature”
- “In engineering, however, the term Heat Pump is generally reserved for equipment that **heats for beneficial purposes**, rather than that which removes heat for cooling only”

Heat Pump

Intent:

Specifically designed to provide 100% of heat as **hot** water

→ Typically 120-180ºF (49-82ºC)

Control:

Compressor capacity is controlled by **Leaving Condenser Water** set point

Heat Recovery

Intent:

Designed to chill water and provide a percentage of heat as **warm** water

→ Typically 95-105ºF (35-40.5ºC)

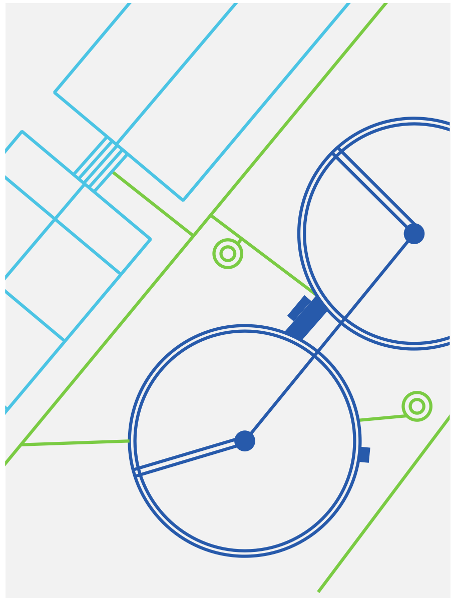
Control:

Compressor capacity is controlled by **Leaving Chilled Water** set point

Heat Sources and Sinks: You need to have both…Simultaneously

Sources

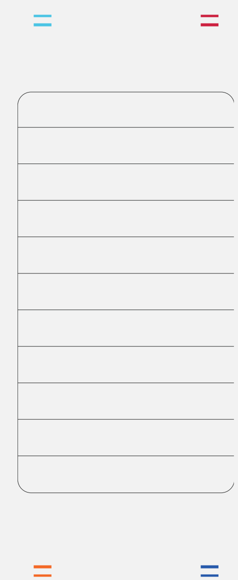
- Large body of water at a relatively constant temperature
- Geothermal system
- Exhaust air
- Cooling tower water
- Sewage effluent
- Low grade waste heat
- Chilled water loop
- Air



Wastewater Treatment

Sinks

- Space heating
- Reheat for humidity control
- Domestic hot water requirements
- Process heating
- Air



Heat Exchanger

Think in terms of COP for Hot Water Applications

COOLING

Full Load **Cooling** kW/Ton

$$\frac{\text{Electrical Power Input}}{\text{Refrigeration Capacity}} = \frac{\text{kW}}{\text{Ton}} \rightarrow 0.576 \text{ kW/Ton}$$

Lower is Better

Full Load **Cooling** Coefficient of Performance (COP)

$$\frac{\text{Refrigeration Capacity}}{\text{Electrical Power Input}} = \frac{\text{kW}}{\text{kW}} \rightarrow 6.1 \text{ (unitless)}$$

Higher is Better

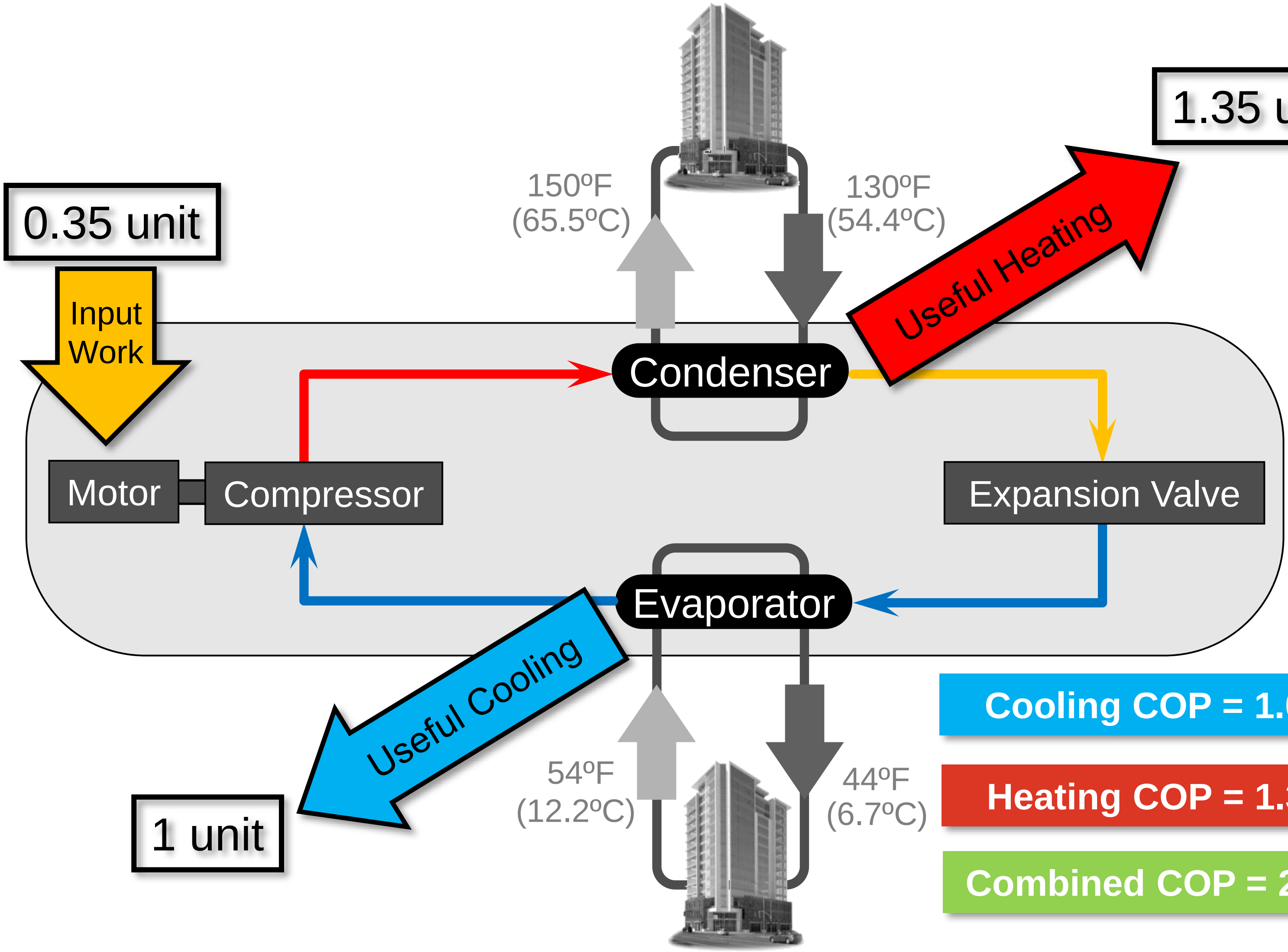
HEATING

Full Load **Heating** Coefficient of Performance (COP)

$$\frac{\text{Desired Heat Power Output}}{\text{Electrical Power Input}} = \frac{\text{kW}}{\text{kW}}$$

Higher is Better

Heat Pump Benefits – Economic Advantages

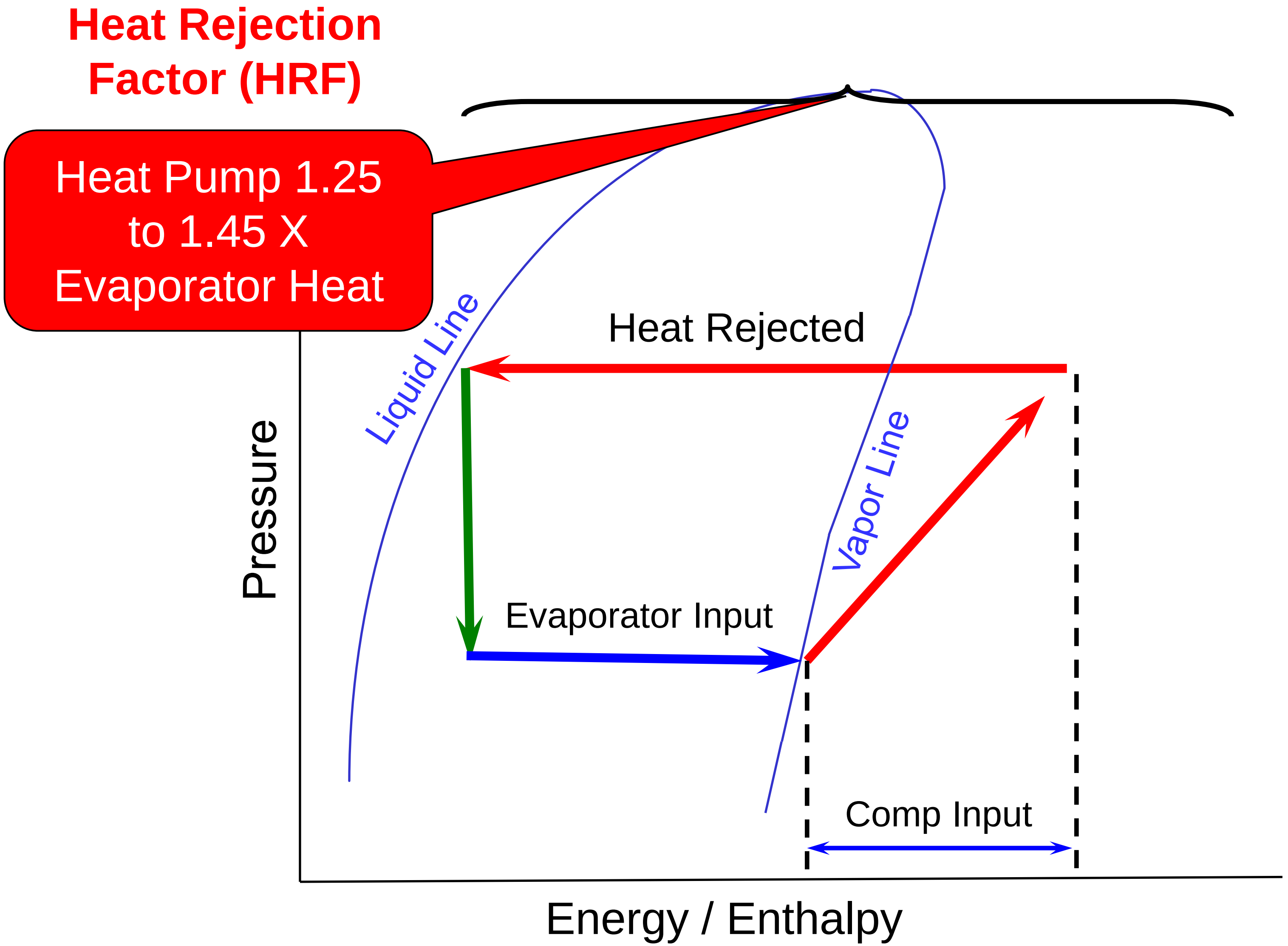


Cooling COP = 1.00 / 0.35 = 2.9

Heating COP = 1.35 / 0.35 = 3.8

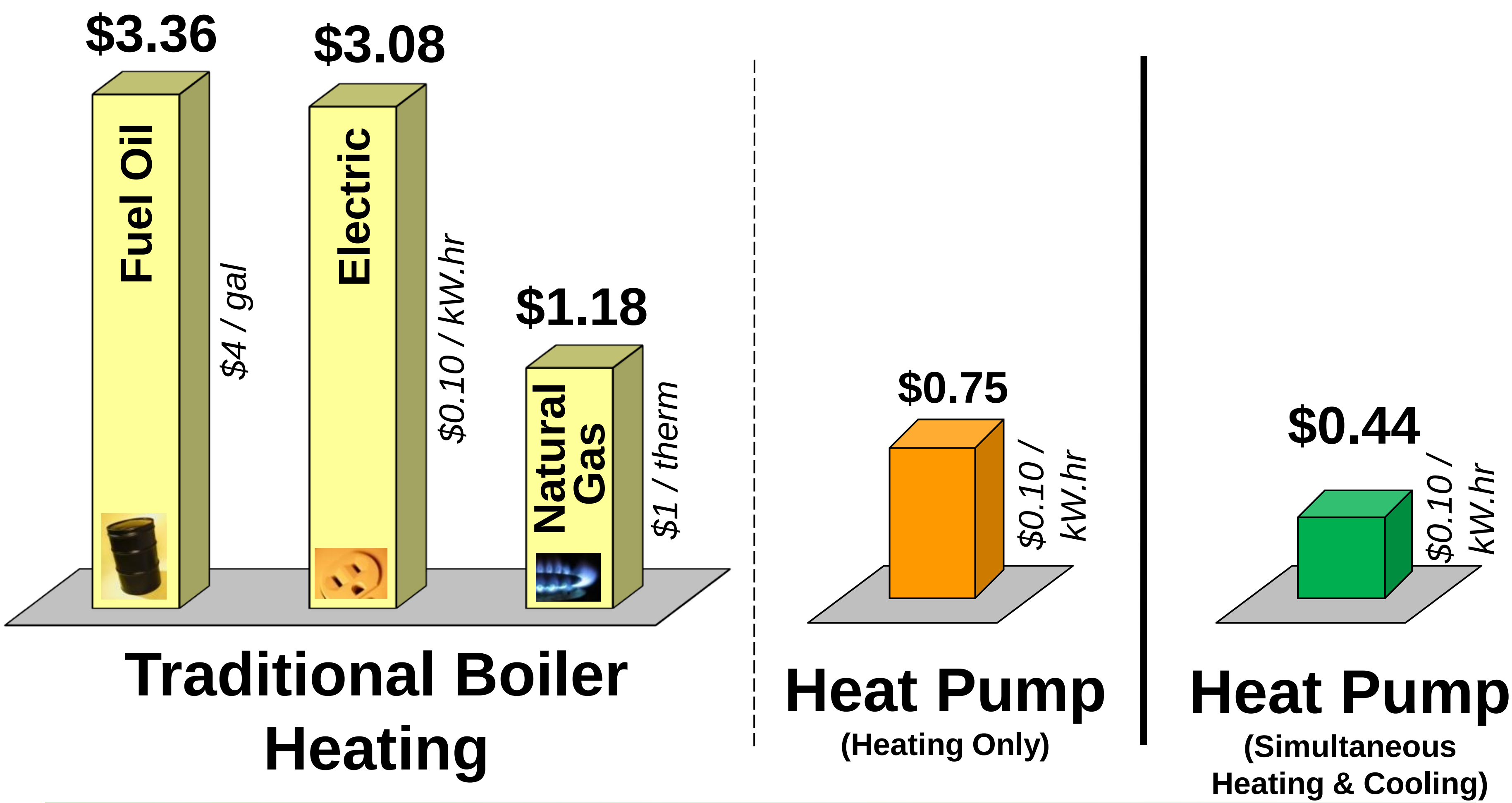
Combined COP = 2.35 / 0.35 = 6.7

What is a Heat Pump? – Refrigerant P-H Diagram



Heat Pump Benefits – Economic Advantages

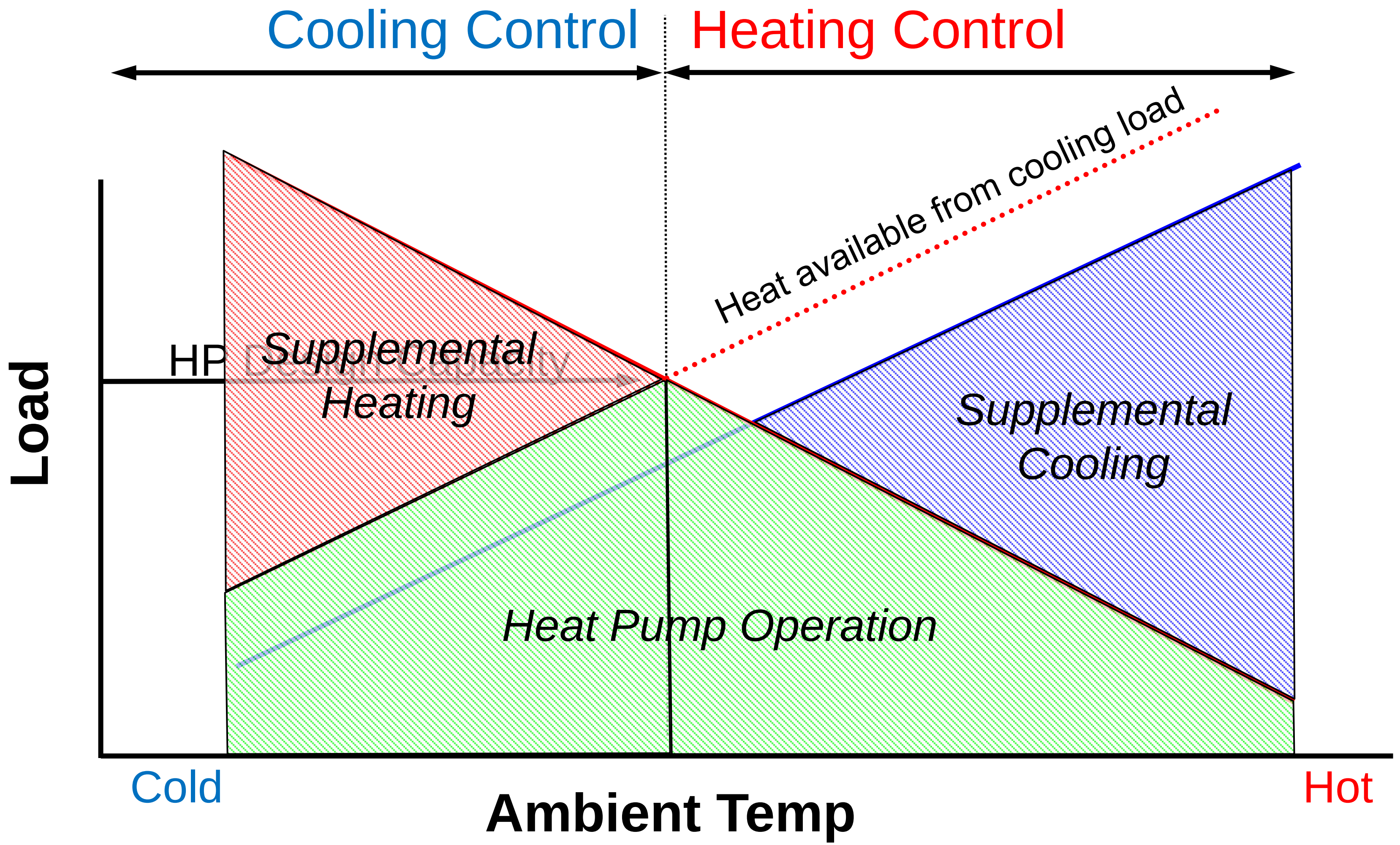
How much would it cost to produce 1 therm of heat?



APPLICATION CONSIDERATIONS

- Max. and Min. Heating and Cooling Loads
- Fluid Temperatures
- Flow Rates
- System Volume
- Equipment Turn Down

Heat Pump Control & Sizing



Application considerations

Heat Recovery — **Heat Pump**

Lower Temperature Requirements — **Higher** Temperature Requirements

OFFICE BUILDINGS (Perimeter reheat, domestic HW preheat)

SCHOOLS (VAV hot water, cooking/dishwashing)

HOTEL /CASINO (Laundry, showers, swimming pools)

HOSPITALS (Laundry, boiler preheat)

UNIVERSITIES (Dorms, boiler preheat)

PROCESS / MANU. (Boiler preheat)

Quickest Payback: Applications where there are large simultaneous heating and cooling loads!

HEAT PUMP CONSIDERATIONS

- Flow Rates
  - Flow Rates Reflect Typical Chiller Flow Rates
- System Volume
  - System Volume Requirements Tend To Reflect Process Volume Requirements
- Type of Compressor and Turndown
  - Centrifugal – 40 to 50%
  - Screw – 25%
  - Scroll – 15% or Stage

Sizing the Heat Pump is Critical

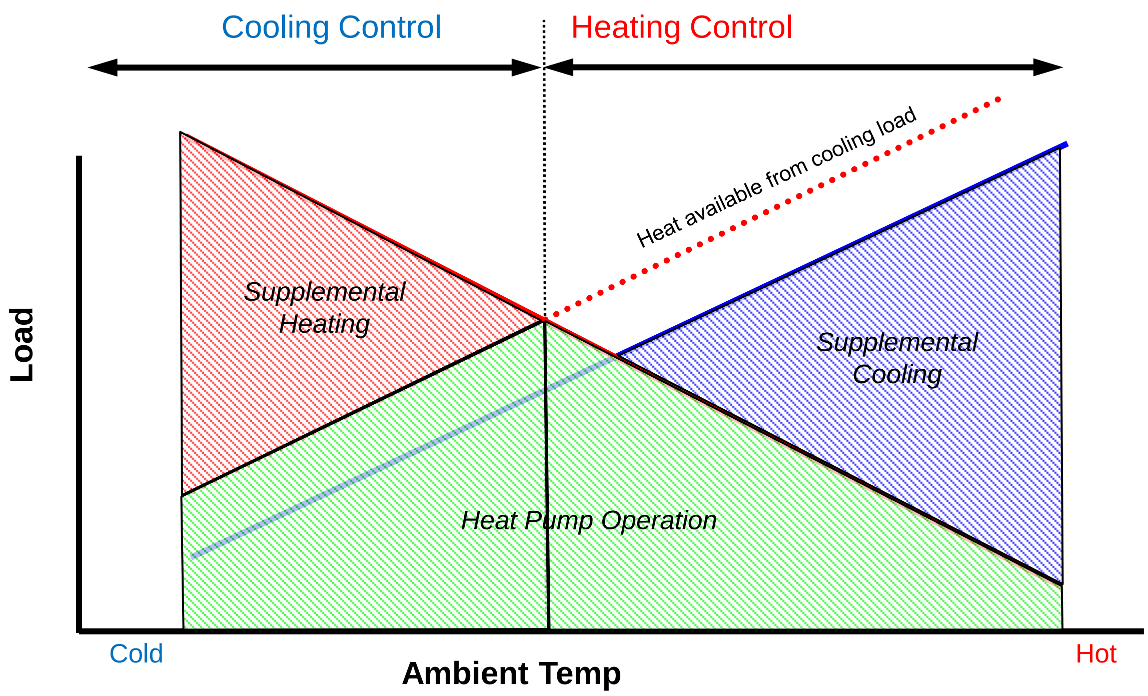
Keys to Success:

Remember that every application is different. Understanding what the facility's heat loads are (required temperatures and MBH) and when they occur is paramount.

1) Does your customer operate chillers and boilers simultaneously throughout the year?

2) What hot water temperature(s) does the system require to be able to meet the heating demand?

3) Is there building automation system (BAS) trend data establishing the minimum / maximum cooling and heating loads?



Temperature Grades and Tradeoffs

170°F

Advantages

- Little to no retrofit needed from boiler-based system
- Non-industrial options are entering the market

Disadvantages

- Equipment complexity and cost likely to be greater

140°F

Advantages

- Better COP than boiler-grade temperature equipment
- Can be achieved with many newer products on the market

Disadvantages

- Airside system will need analysis and likely retrofit
- New buildings will see airside equipment cost increase

120°F

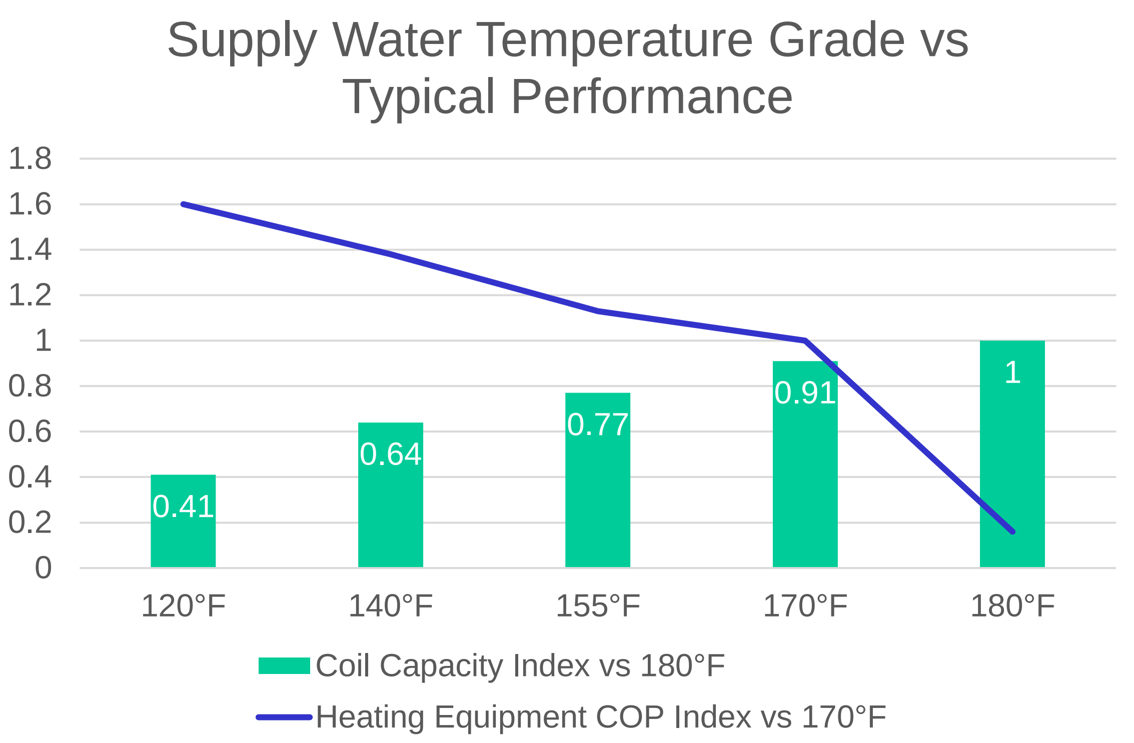
Advantages

- Highest COP potential from heat pump equipment
- Can be met by most commercial cooling products

Disadvantages

- Notable airside retrofit replacement and risk for existing systems
- Airside cost and energy increase for new buildings

Temperature Grades and Tradeoffs

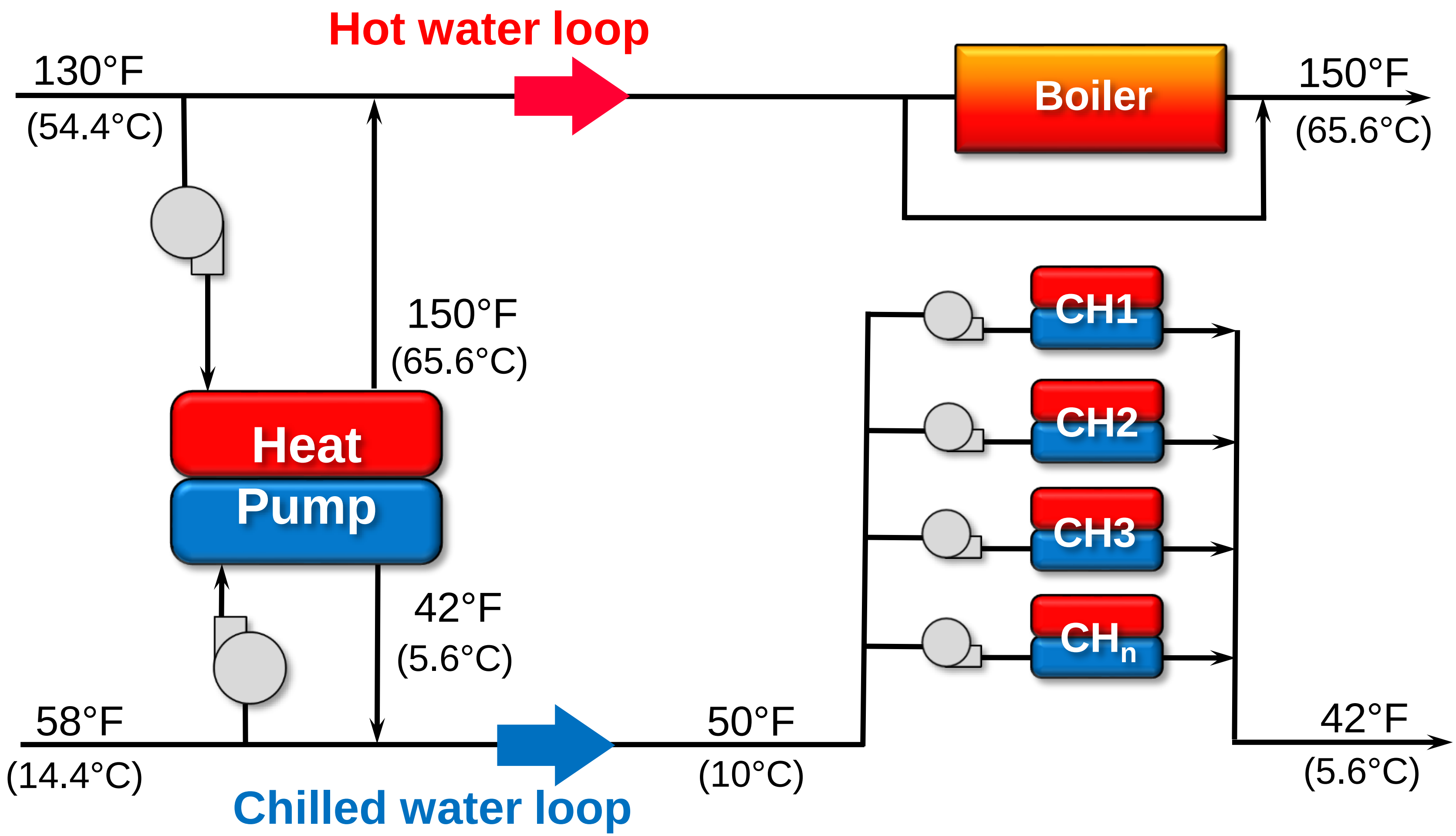


Tradeoffs with temperature grade can be extreme

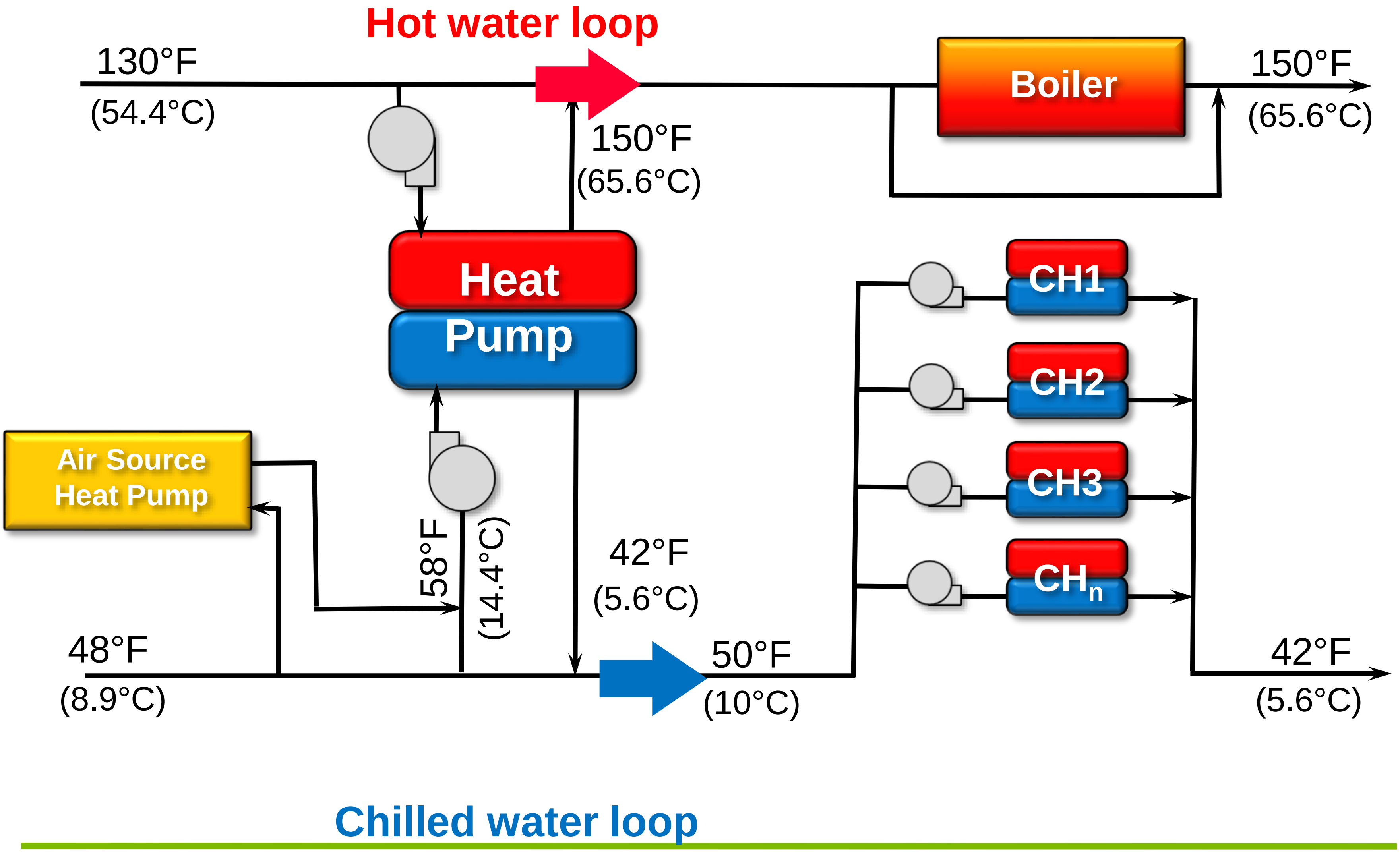
- Lower grade heat dramatically reduces a given coil's capacity to deliver heat and achieve a leaving air temperature
- Higher grade heat can consume 20-40% more electricity
  - Boiler-grade heat pumps are still 3-6x more efficient than boilers

Heat Pump Arrangements

Typical Arrangement: "Side-car"



Arangement with Air / Water Heat Pump



Heat Pump Arrangements

Arrangement: Geothermal

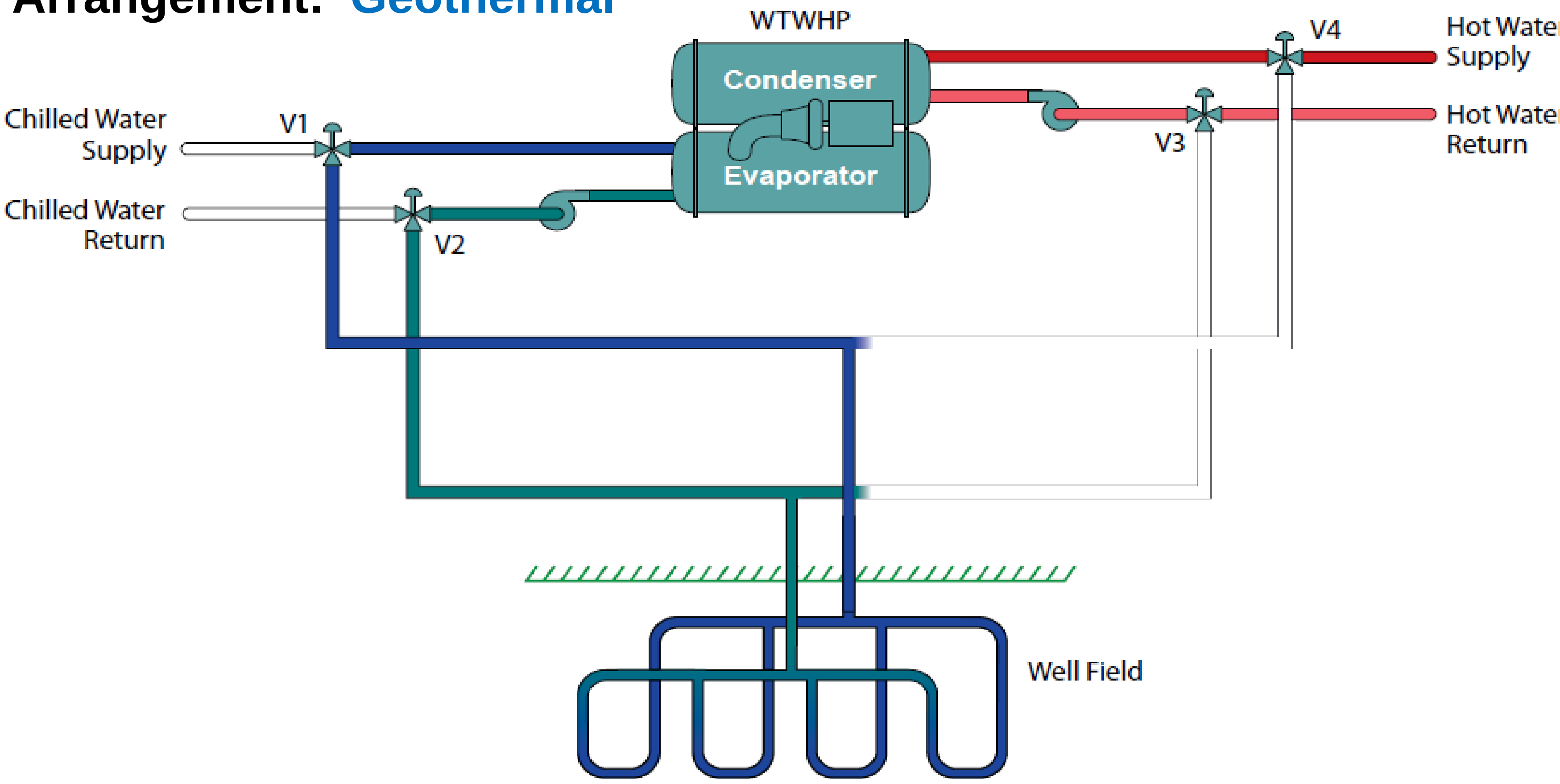


FIGURE 6 – GEOTHERMAL SYSTEM FOR SIMULTANEOUS HEATING-AND-COOLING, OPERATING IN HEATING-ONLY MODE.

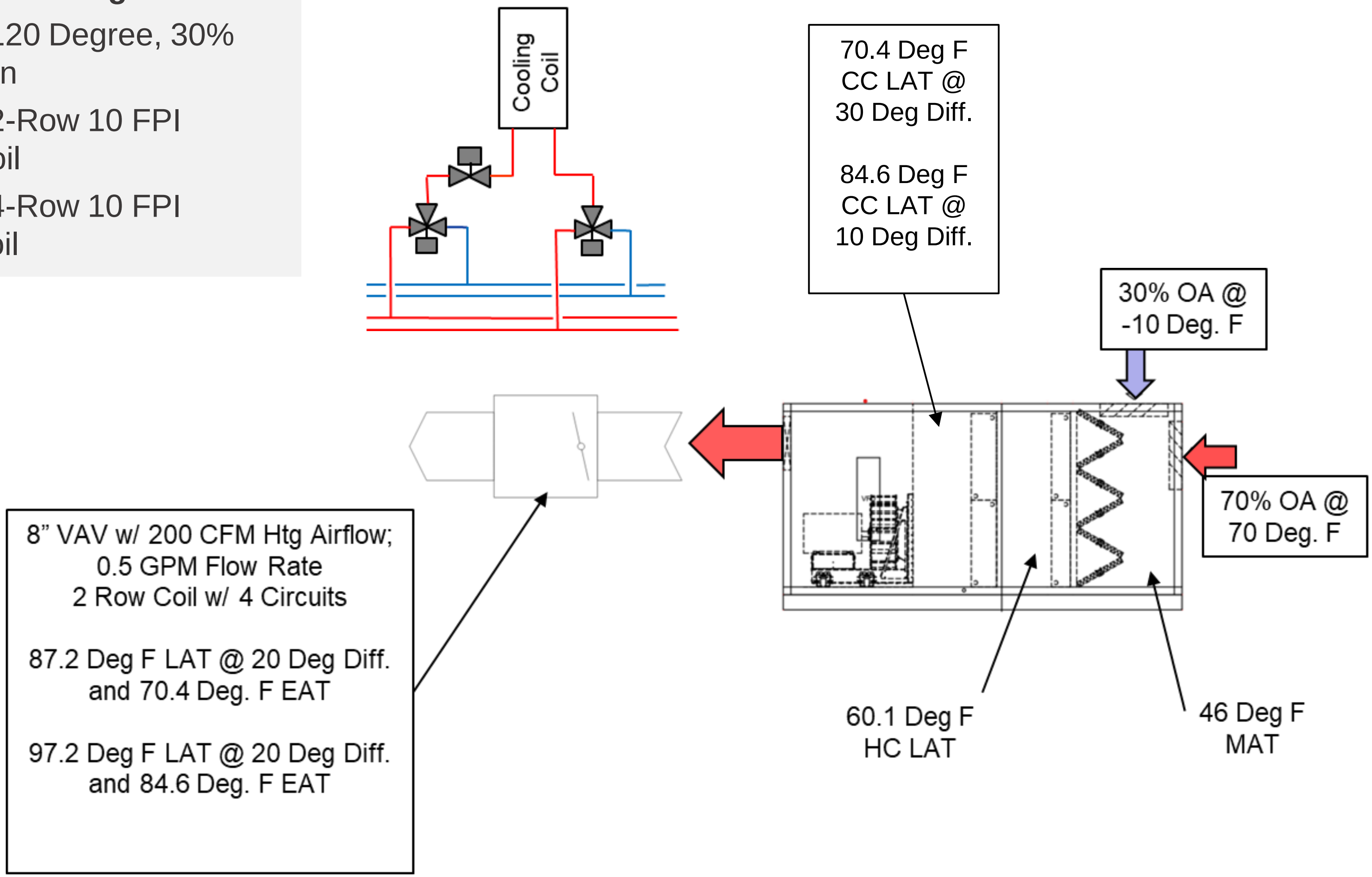
AIRSOURCE HEAT PUMP CONSIDERATIONS

- Max. and Min. Heating and Cooling Loads
- Fluid temperatures
- Flow Rates
- System Volume
- Equipment Turn Down
- Defrost
  - Source of Heat
  - Time to Defrost
  - Condensate Disposal
- Change Over Temperature

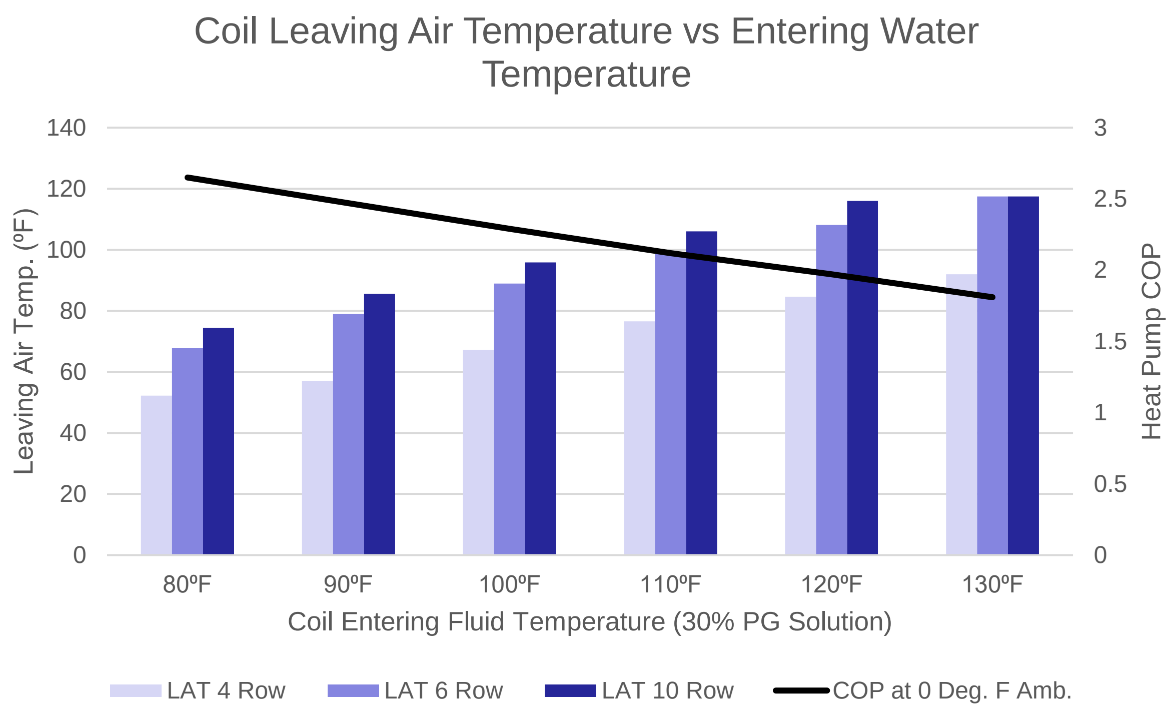
Low Temperature Fluid for Heating

Heating with 120 Degree Water

- Assumes 120 Degree, 30% PG Solution
- Assumes 2-Row 10 FPI Heating Coil
- Assumes 4-Row 10 FPI Cooling Coil



Chilled Water Coil for Heating

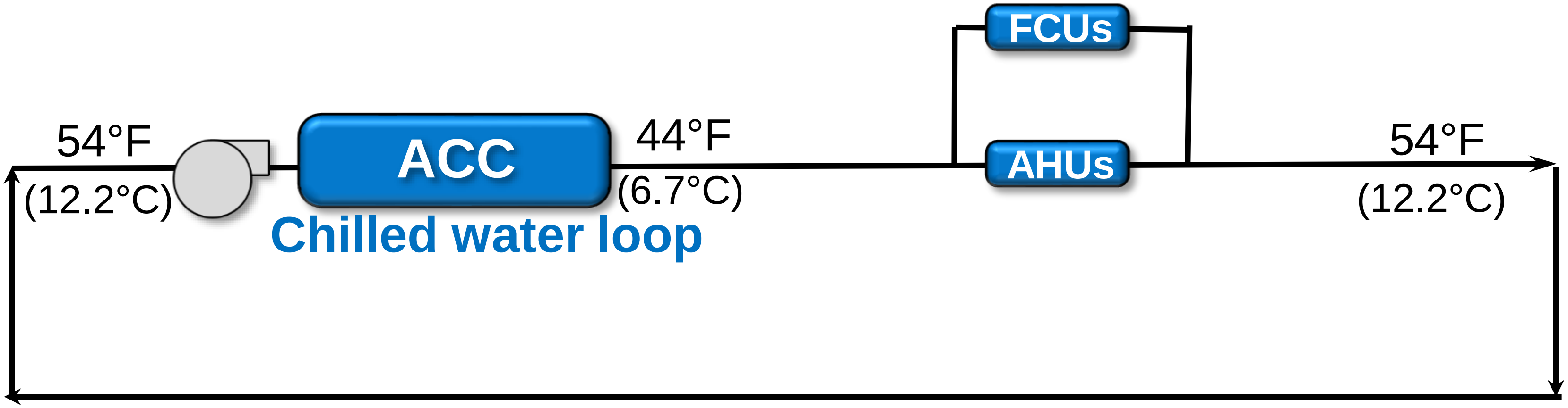


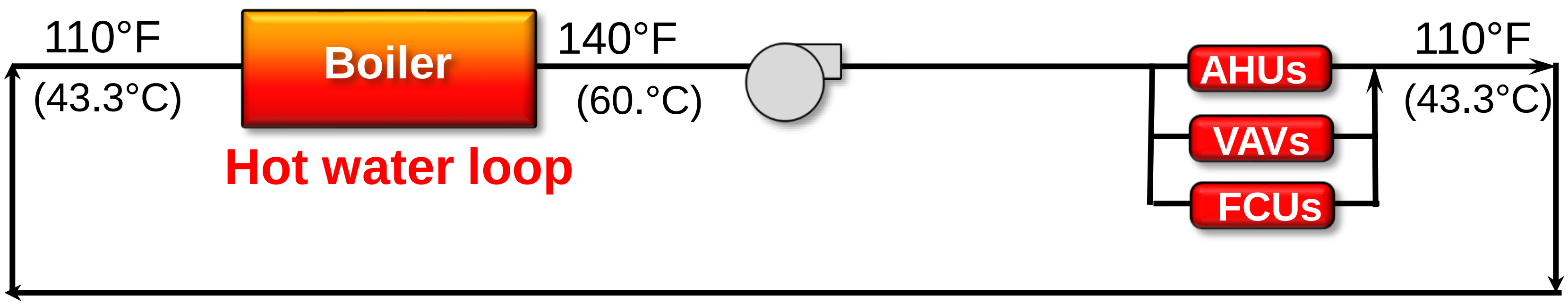
Chilled Water Coils Can be Utilized for Heating

- Lower grade heat can be used to deliver heat and achieve a leaving air temperature for heating
- Air source heat pump can still be 2-3X more efficient than boilers
  - Coils: Assumes 40ºF EAT, 10 FPI coil with 0.008" fins, 10 Deg. F Temperature Differential
  - Heat Pump: Assumes 0 Deg Ambient at SL

Piping Schematics

Typical Building: Air Cooled Chiller with Boiler

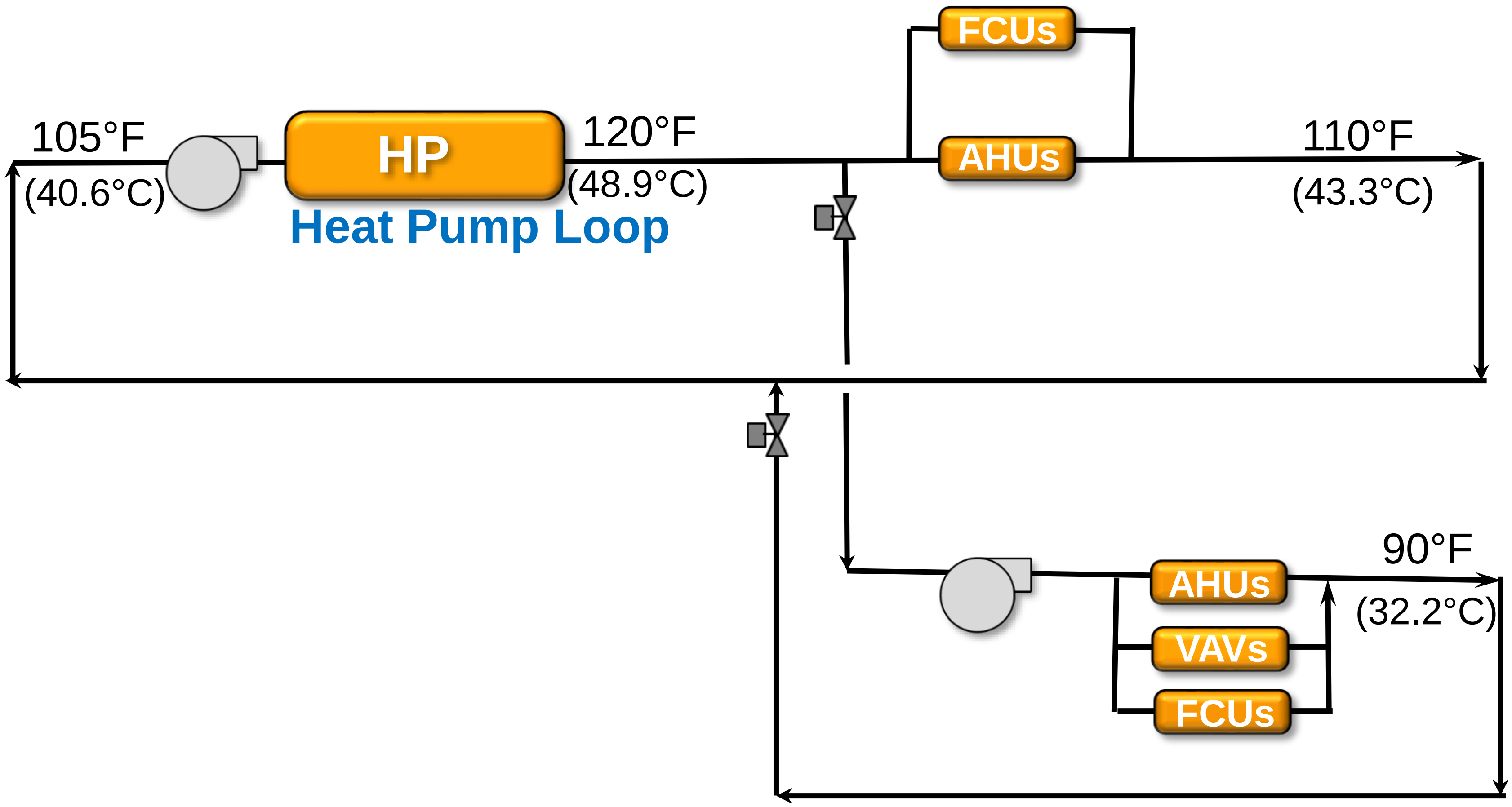




50°F
(10°C)
42°F
(5.6°C)

Piping Schematics

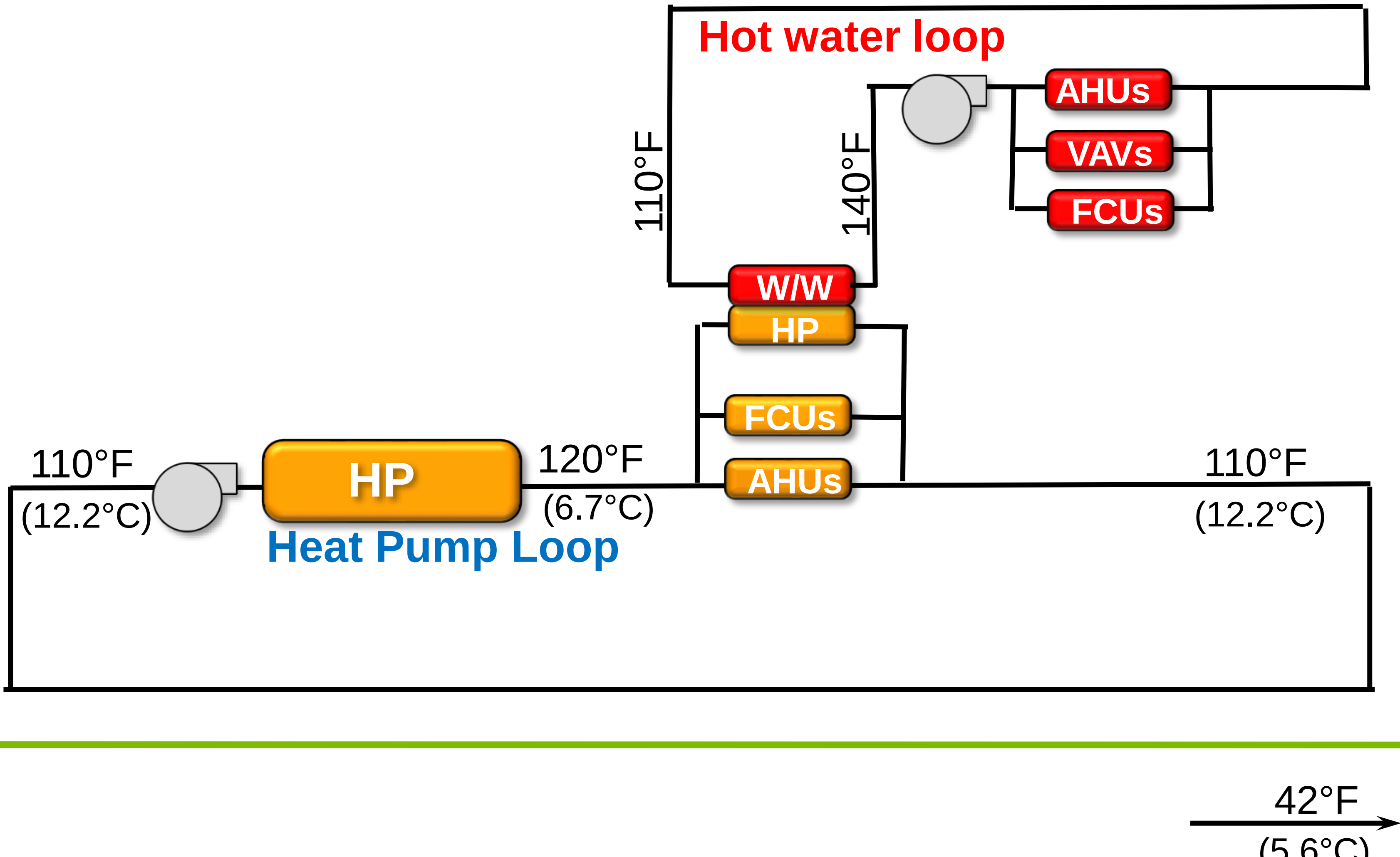
Typical Building: Air Source Heat Pump



42°F
(5.6°C)

Piping Schematics

Typical Building: Air Source Heat Pump with Water to Water Heat Pump



Application considerations

Keys to Success:

1) Remember that every application is different. Understanding what the facility's heat loads are (required temperatures and MBH) and when they occur is paramount

2) Remember that properly applied heating solutions save energy and the environment in almost every situation (new construction & retrofit)

3) Fastest return on investments are seen when utility rates are high and there is a consistent need for simultaneous heating and cooling

4) For buildings that require hot water at <180^{o}F (82.2^{o}C) use a heat pump

Remember:

- Many economic and environmental advantages with heat recovery and heat pump chillers

- Simultaneous heating and cooling applications offer the greatest paybacks

- Every potential application should in individually investigated