ASHRAE VIRTUAL WINTER CONFERENCE

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Systems and Equipment Seminar

What Makes a Compressor a Heat Pump Compressor?

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Turbo Compressors and Low-GWP Refrigerants in Large Commercial Heat Pump Systems

Danfoss

ENGINEERING TOMORROW

Learning Objectives

- Understand what makes water-water heat pumps utilizing turbo compressor technology a viable alternative
- Understand how dual cooling/heating 'symbiosis' application opportunities utilizing this technology influence viability vs single factor
- Understand how staged approach with compressors optimized to the operating temperatures and refrigerant influence viability and payback
- Understand the limitations with the technology operating temperatures, range and how they can be addressed

Acknowledgements

Leping Zhang – Senior System Technology Manager, Danfoss

Outline/Agenda

1. Why is the market focused on heat pump applications?
2. What is critical for a heat pump vs cooling-only compressor?
3. Challenges specific to an oil-free magnetic bearing heat pump compressor
4. How low-GWP refrigerants factor into this
5. Resulting capabilities/limitations
6. Where does the resulting capability lead you in application terms?
7. What is critical for those applications and an example

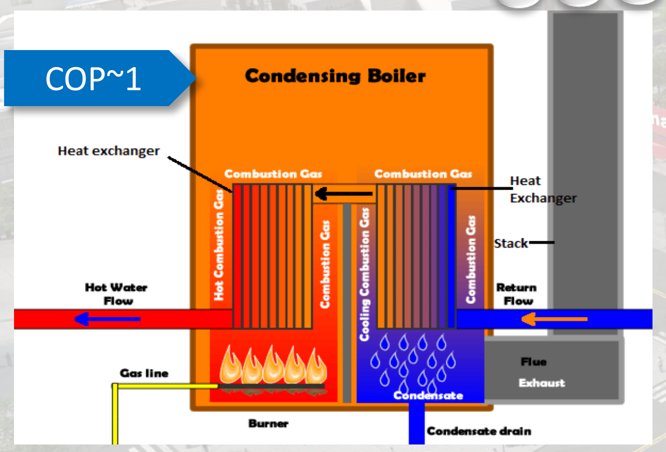
Why is the market focused on heat pump applications?

Fossil fuels

- Inefficient
- Drive CO_2 & other gas emissions impacting environment

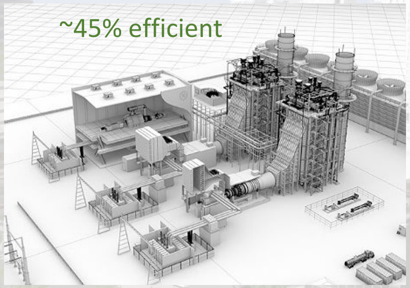
CO_2 SO_2 NOx

COP~1



Heat pumps

~45% efficient



Transmission & Distribution

-10%

COP~3.5

- More efficient
- Efficiency increases (especially oil-free) at part-load

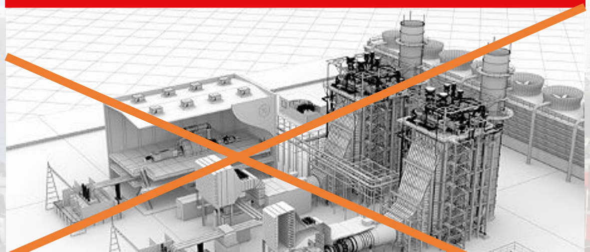
~35% operating cost reduction
~60% emissions reduction

Heat Pump
Part Load
Efficiency

Why is the market focused on heat pump applications?

Requires both reduction in **energy consumption** and **decarbonization** of energy consumed

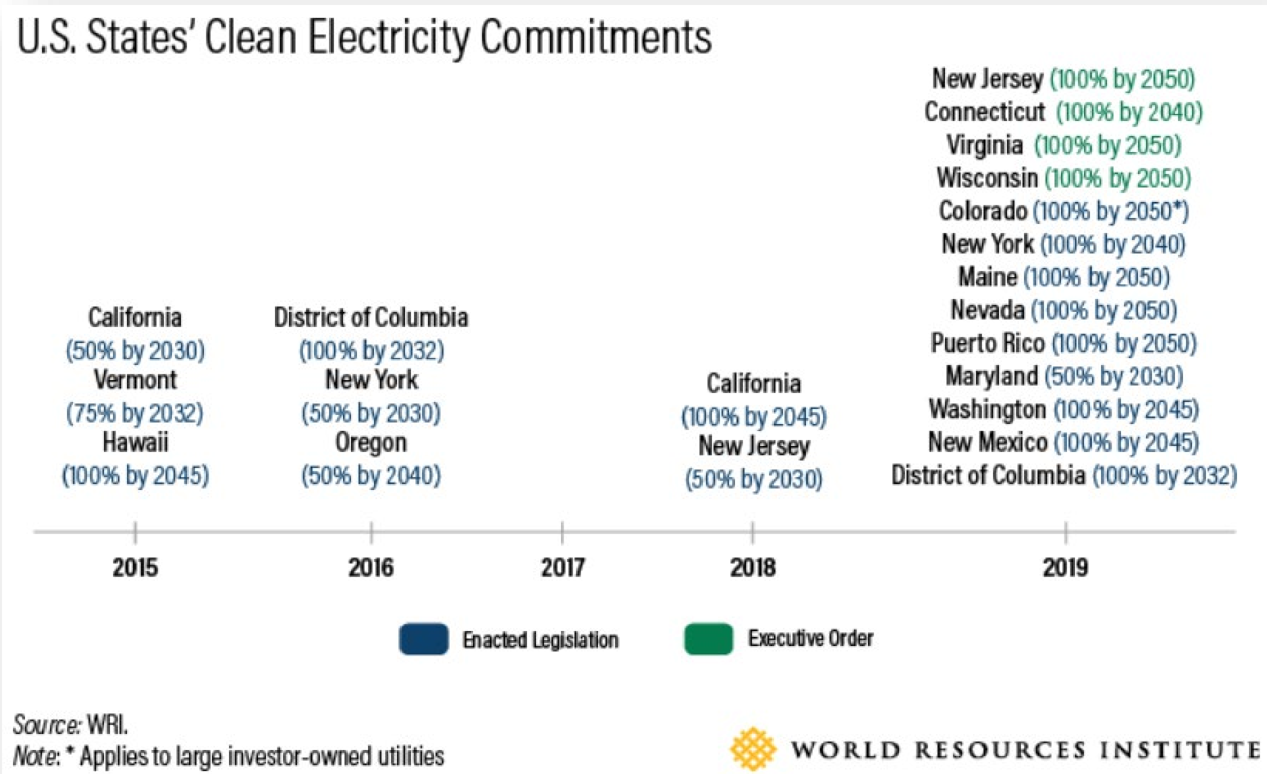
~45% efficient

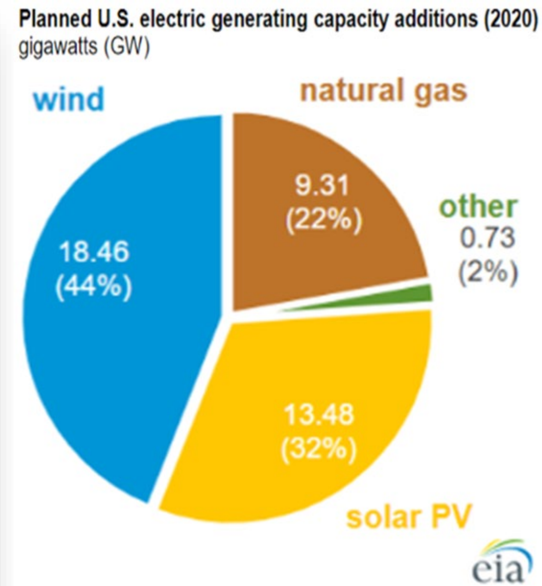


-10%

Completed through replacing fossil fuel generation with renewables

Why is the market focused on heat pump applications?

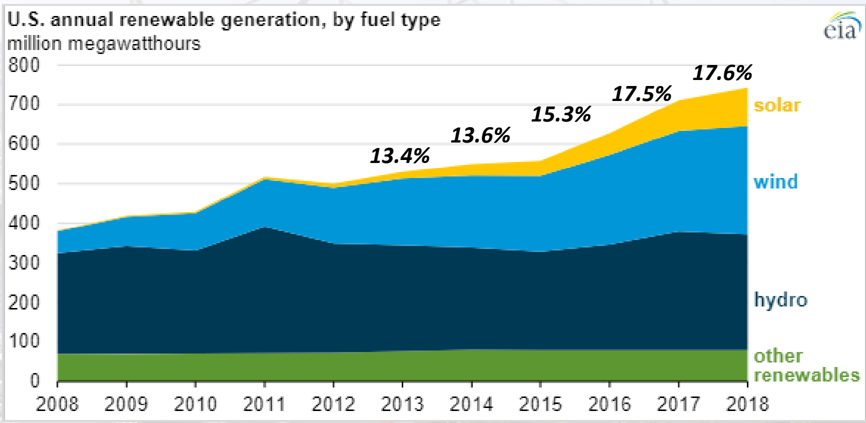


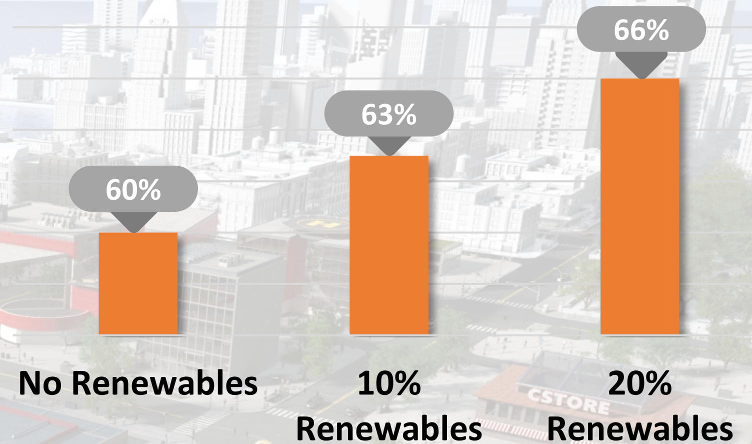


Renewables = 76% of 2020 new US capacity

11/20 IEA report – 90% of new global capacity

Why is the market focused on heat pump applications?





As grid integration of renewable energy grows, so does heat pump resulting **greenhouse gas emissions reductions**

Heat Pump CO_2 Emissions Reduction:
Renewables integration impact

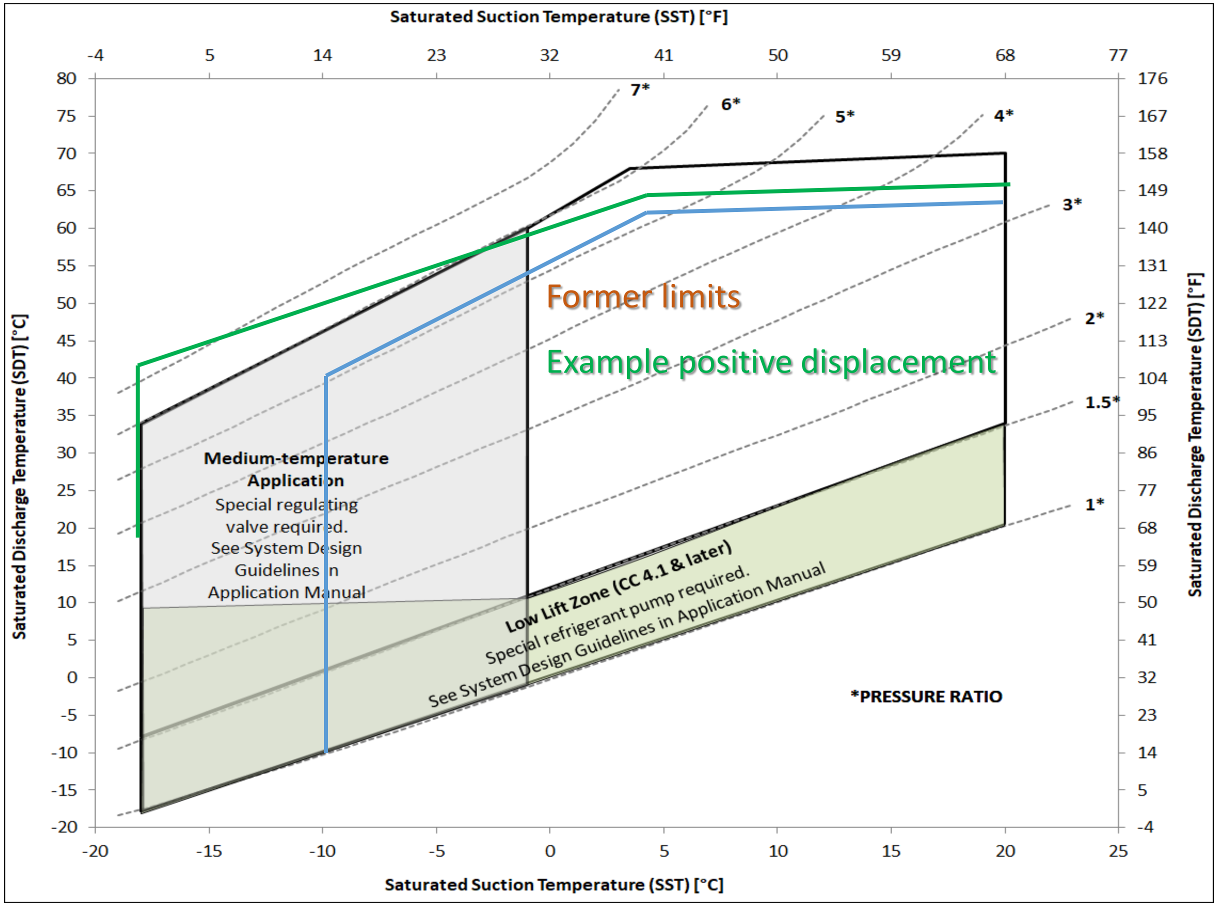
Based on oil-free AWHP applied in 'warm' climate

What is critical for a heat pump vs cooling-only compressor?

#1 – Higher pressure ratio capability –

- Specific to dynamic compression
- Ability to maintain stable operation
- Roughly +1 ratio with new generation vs previous cooling-focused

- More restrictive than amp-driven limits of positive displacement
- Lower 'slope' in drop with lower suction temperatures
- Critical for air-water applications

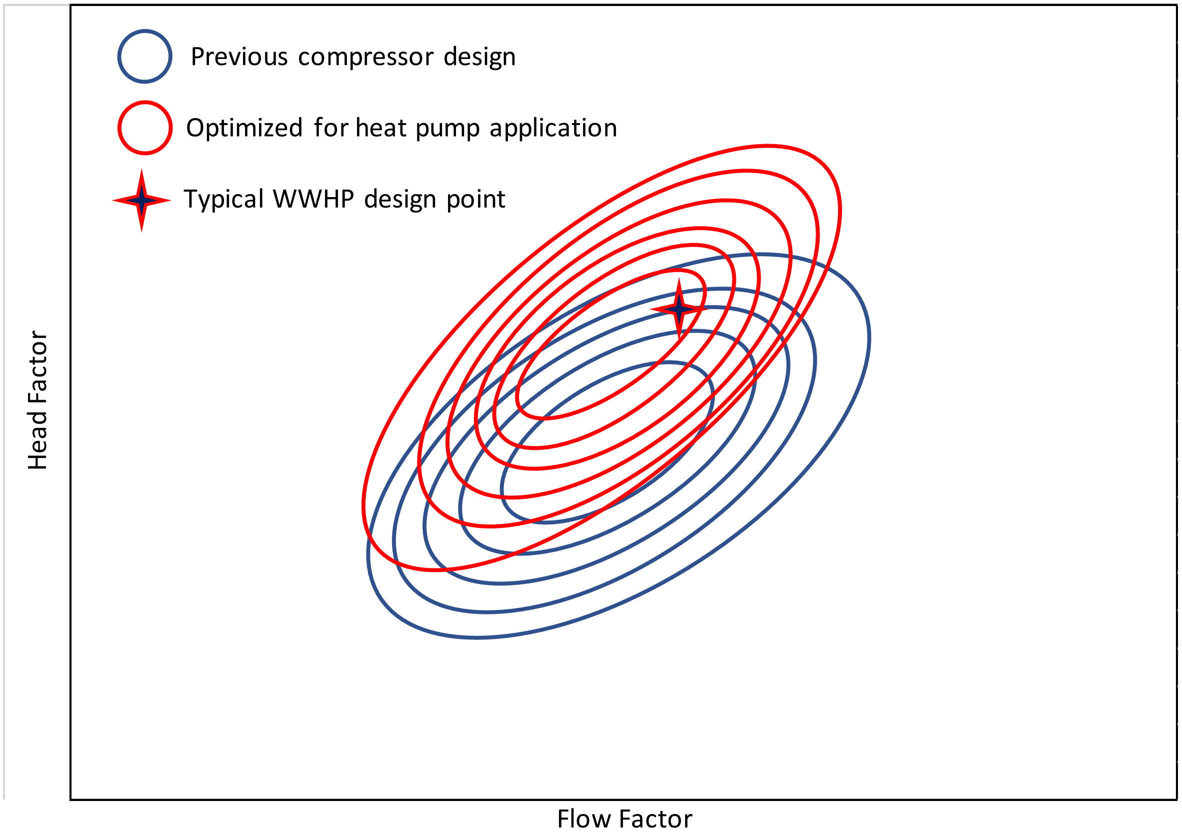


What is critical for a heat pump vs cooling-only compressor?

#2 – Optimized aerodynamic design to higher pressure ratio operation –

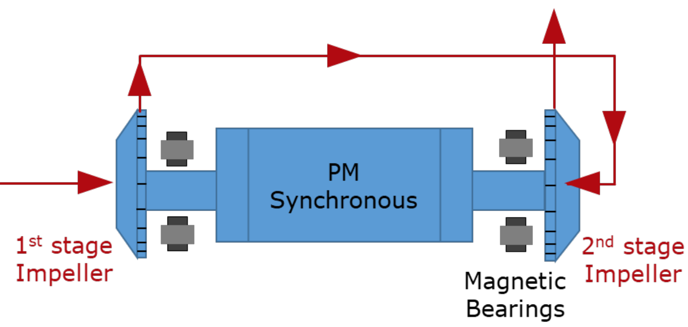
- All dynamic compression optimized to specific targets
- Efficiency islands indicate corresponding optimization
- Closer to center = higher compressor efficiency

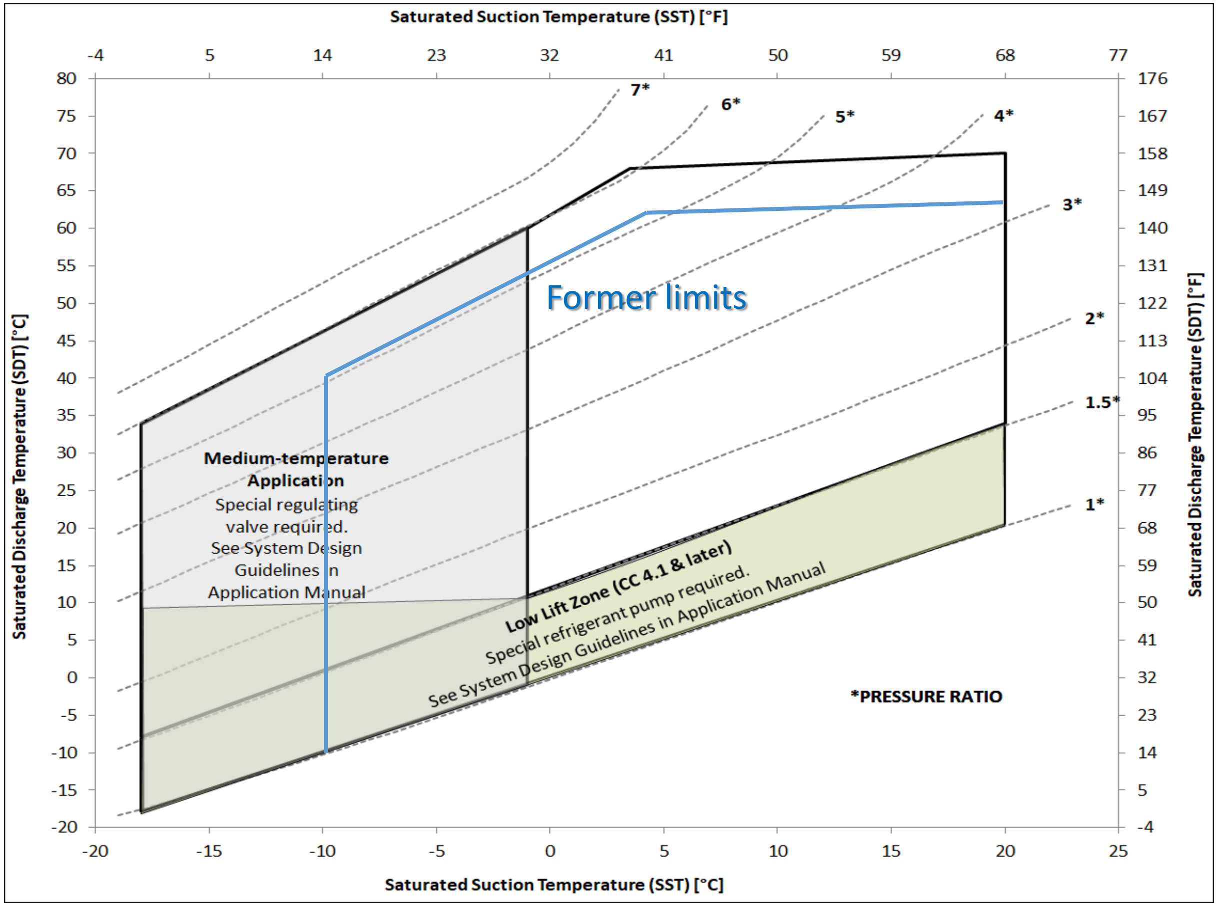
- Point shown is typical water-water heat pump design point
- Within the maximum efficiency point of new compressor design
- Possible with previous compressor but at lower efficiency



Challenges specific to an oil-free magnetic bearing heat pump compressor

- Axial (back-and-forth) forces larger variable with higher differential pressure
- Significantly enabled by opposite-end 2-stage compressor design

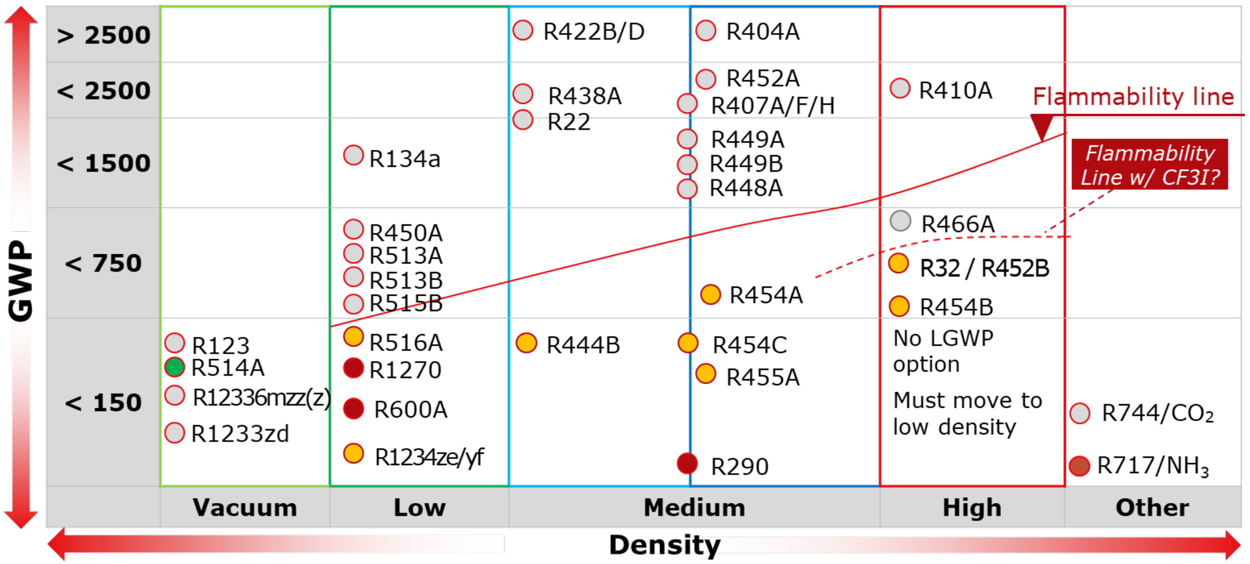


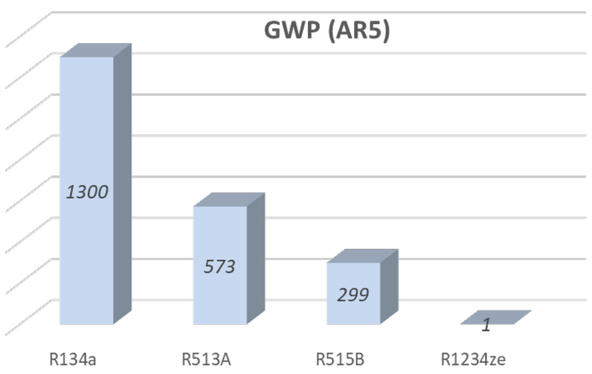


How low-GWP refrigerants factor into this

1. Dynamic compression optimal for high volume of large molecule low-pressure refrigerant
2. Lower pressure/density refrigerants enable lower-GWP, maximized efficiency with corresponding minimized flammability
3. Lower pressure refrigerant = Higher pressure ratio for equivalent differential temperature

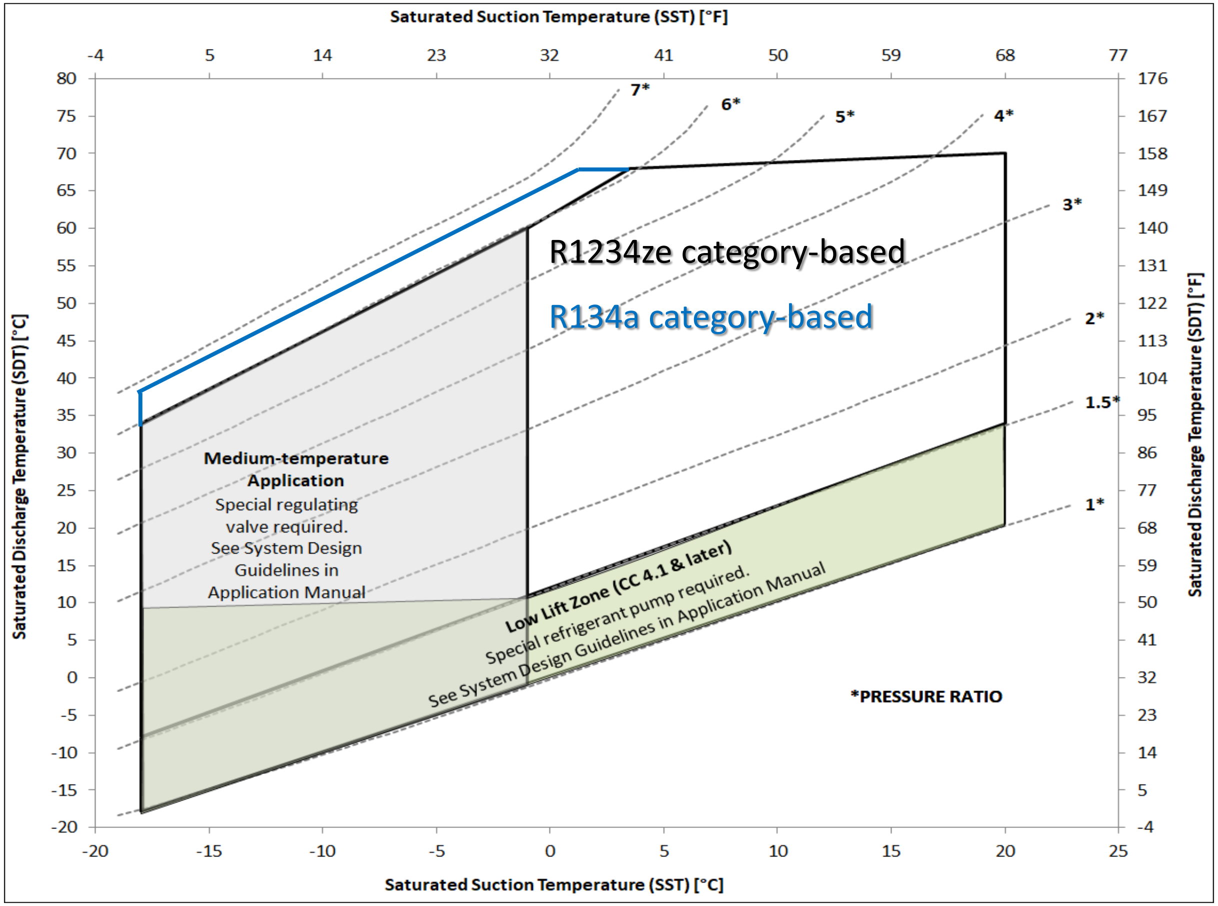
➢ The balance – Minimized pressure/flammability/GWP refrigerant with maximized differential temperature capability





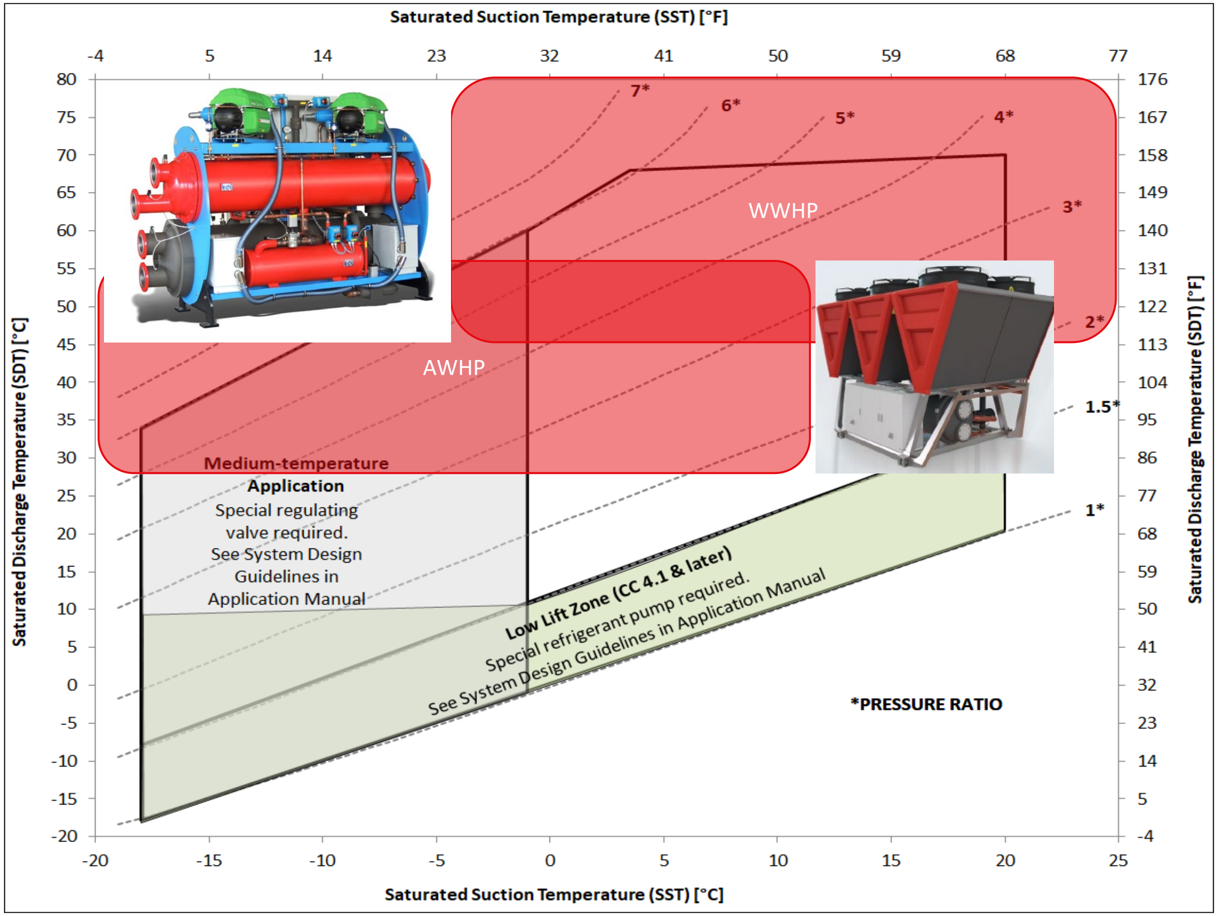
How low-GWP refrigerants factor into this

- Higher pressure / boiling point refrigerant = greater temperature pressure differential at same pressure ratio
- Example with R1234ze vs R134a – Both in same "low" pressure category from previous slide
- ~26% lower pressure/capacity R1234ze
- +5k differential temperature capability with R134a at same pressure ratio



Resulting capabilities/limitations

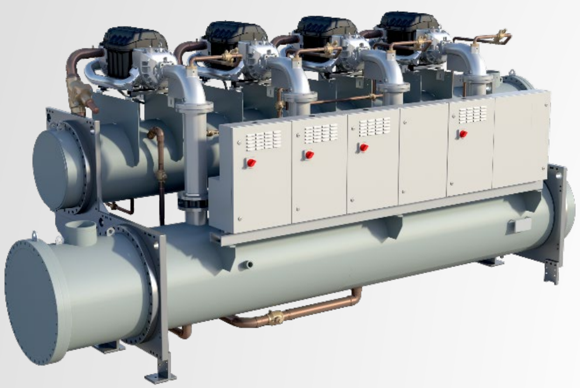
- Water-water heat pumps primarily operate in upper-right portion of map
- Air-water heat pumps in mid-left portion

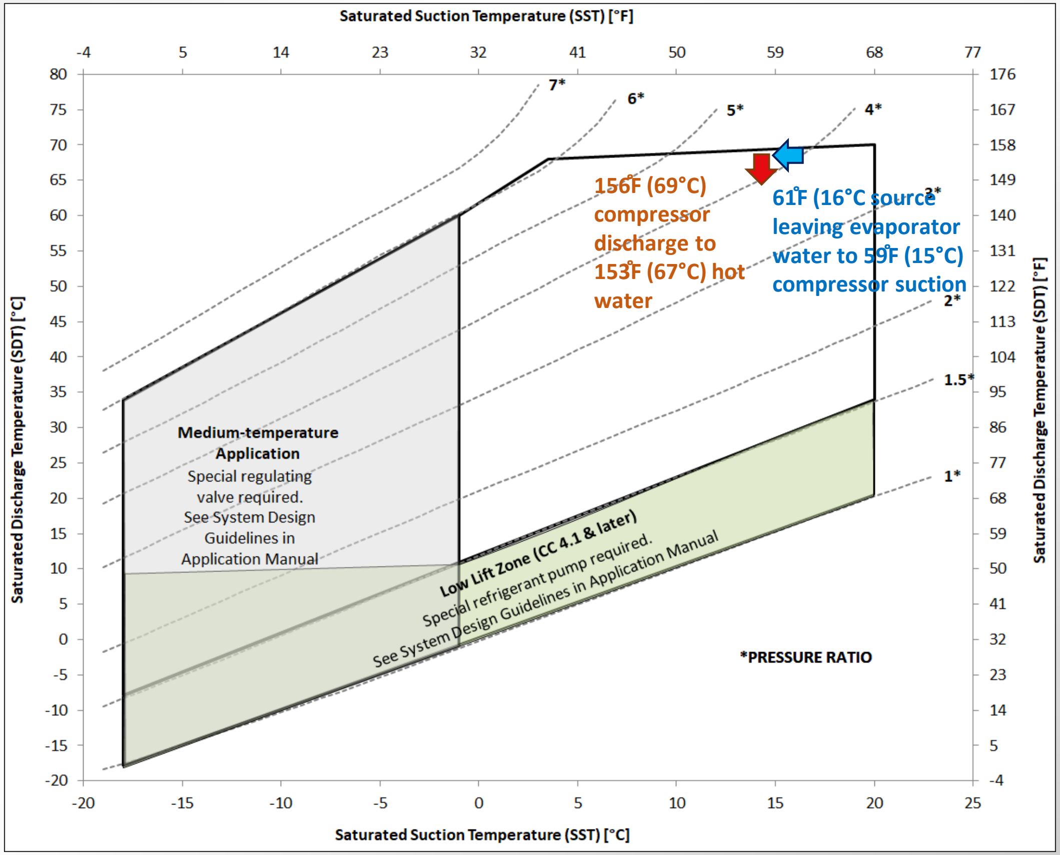


Resulting capabilities/limitations

Water-water heat pumps

- Example with 61°F (16°C) heat recovery source water, providing 153°F (67°C) hot water
- 2K condenser & 1K flooded evaporator approach
- Able to meet majority of target application requirements

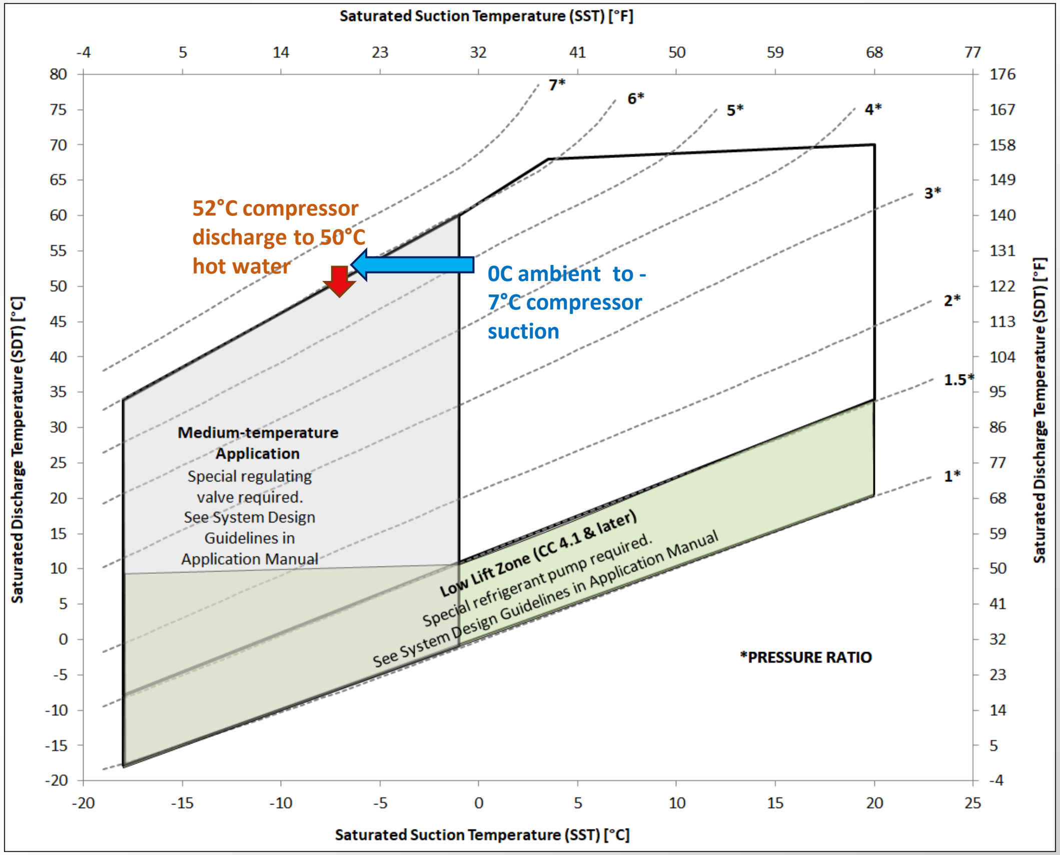




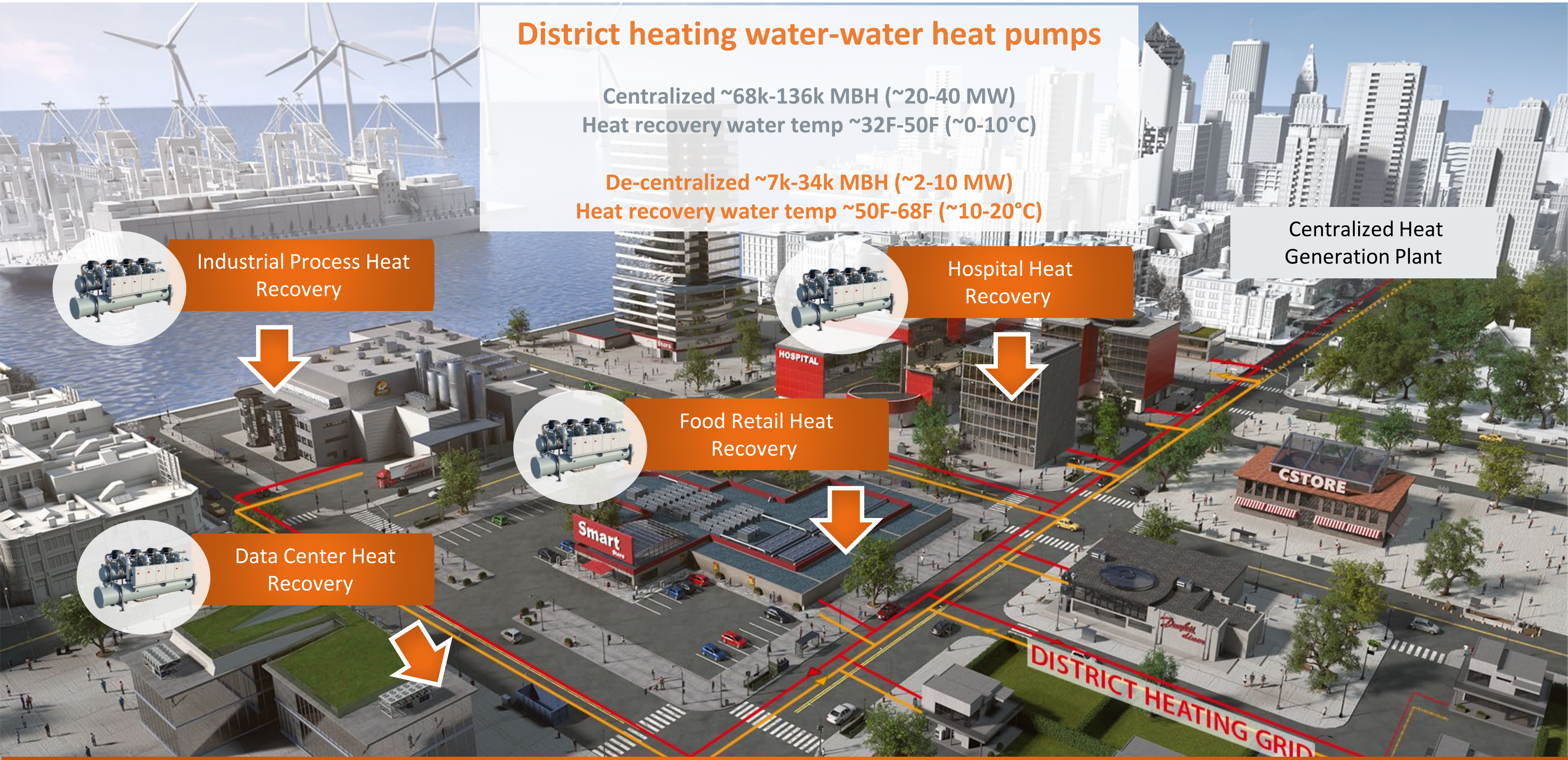
Resulting capabilities/limitations

Air-water heat pumps

- Example with 32°F (0°C) ambient air heat source, providing 122°F (50°C) hot water
- 7K air-refrigerant evaporator approach (+6K vs water-water)
- Limited to primarily newer buildings and mild climates



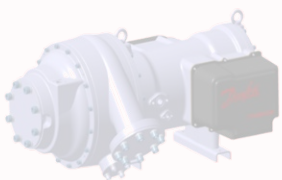
Where does the resulting capability lead you in application terms?



The higher the recovered temperature, the more efficient the Heat Pump

What is Critical for Those Applications?

- Lift – Temperature difference between Saturated Suction (SST) and Saturated Discharge (SDT)
- Three main groups with application overlap
- Water-water heat pump optimized solution – Mix of Medium and High



Standard

<u>Applications</u>:
Water-cooled chiller
Evap-cooled chiller

<u>Compressors</u>:
TT400, TT700
TG390, TG520
VTT1200
VTX1600

Up to ~47 or 62C

~32k design (~57F)

~42k max (~76F)

Down to ~4C

Medium

<u>Applications</u>:
Air-cooled chiller
Water-cooled chiller
Evap-cooled chiller
W-W heat pump
High-temp process

<u>Compressors</u>:
TT300, TT350
TG230, TG310, TG490

Up to ~63C

~42k design (~76F)

~57k max (~103F)

Down to -10C

High

<u>Applications</u>:
Air-cooled chiller
W-W heat pump
A-W heat pump
Med-temp process
Thermal storage

<u>Compressors</u>:
TTH375
TGH285

Up to ~69C

~55k design (~99F)

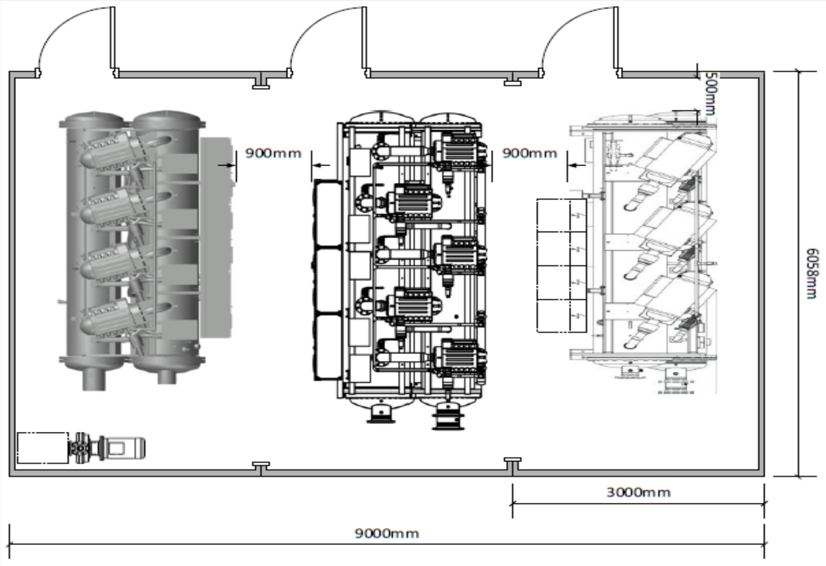
~65k max (~117F)

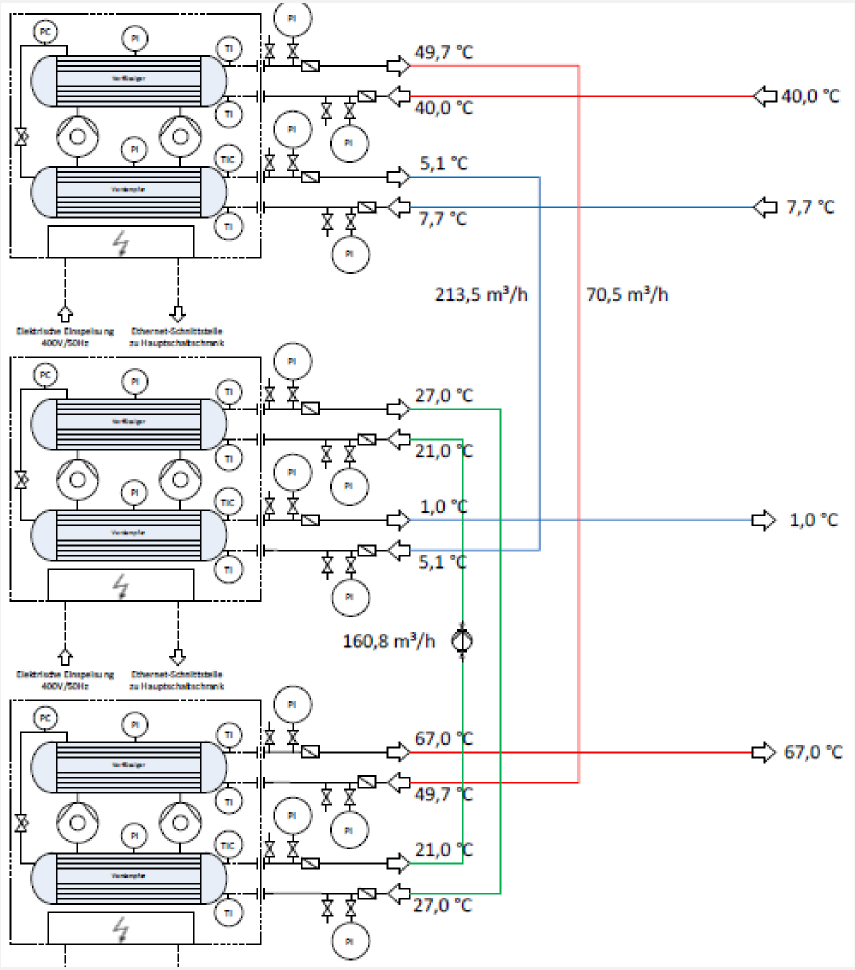
Down to ~-18C

Process Heat Recovery Example

Optimal System Design

- **1.6 MW process cooling / 2.2 MW district heating**
- Compact containerized solution with low maintenance, perfect for distributed heat recovery retrofits
- Worst case design conditions

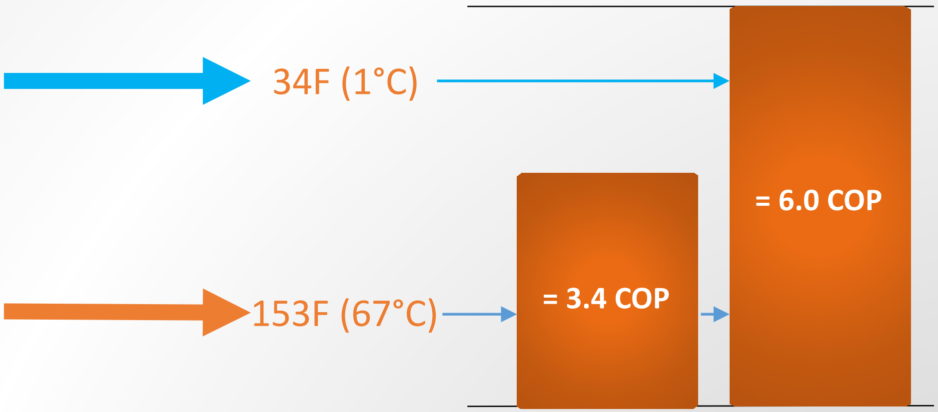




Process Heat Recovery Example

Performance

- Distributed application benefit:
  1. Chiller cooling
  2. Heat pump heating
- Change from cooling or heating to "moving heat"
- Efficiency improves with source and supply 'relief'



TER = (Heating + Cooling Capacity) / Power Input ➔ **TER =** $\frac{\text{1,572kW Cooling + 2,201kW Heating}}{\text{629kW power draw}}$ **= 6.0 COP**

Conclusion

1. Growth of heat pumps to replace fossil fuel-source heating is driven by efficiency and decarbonization
2. The potential increases as more renewables are integrated in the power grid
3. Dynamic compression and oil-free technology has expanded capability to meet the heat pump challenges
4. Optimization of the technology to the operating conditions and low-GWP refrigerants is a critical balance
5. This expanded capability has limitations and leads to main focus on water-water heat recovery applications
6. Symbiosis combined heating/cooling applications provide the greatest opportunity for heat pump maximized efficiency and shortest payback

Questions?

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