THE PATH TO DECARBONIZATION FOR COMMERCIAL HVAC SYSTEMS

Presented By: Jeff Seewald

March 20, 2024

Agenda

Topics

- Introduction
- Decarbonization
- Efficiency
- Refrigerants
- Electrification
- Resources
- Q&A

Key Takeaways

- Three levers to decarbonize of HVAC systems:
  - Efficiency
  - Refrigerants
  - Electrification
- Solutions available to you today include:
  - Application of IAQP for ventilation
  - Energy/heat recovery
  - Heat pumps, including cascade and geothermal systems
- Key design considerations when applying air source heat pumps for heating, especially in low ambient conditions – below an equipment-specific threshold:
  - Capacity decreases with outdoor air temperature
  - Hot water supply temperature decreases with outdoor air temperature
- Refrigerant selection is based on compressor and lift, and strikes a balance between direct and indirect emissions
- System and equipment flexibility is critical for mechanical and electrical adaptability, especially in existing buildings

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About The Presenter

Jeffrey Seewald, PE, CEM

HVAC Systems Business Development Manager

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- 30 years of experience
  - HVAC equipment and systems
  - Building automation and controls
  - Energy efficiency
- Technology and product development
- Technical and strategic consulting
- Project development and contracting for energy efficiency/performance and infrastructure renewal
- Areas of expertise and interest include energy efficiency, high-performance and zero energy buildings, central plants, energy/heat recovery, heat pumps, controls and IAQ

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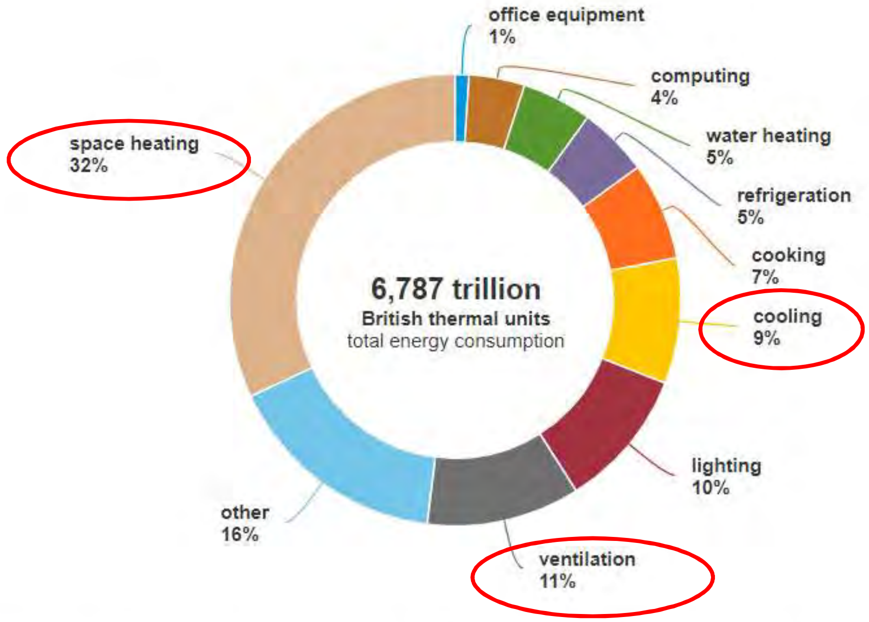
Decarbonization

Challenge of Decarbonization

Major fuels consumption by end use in U.S. commercial buildings, 2018

share of total

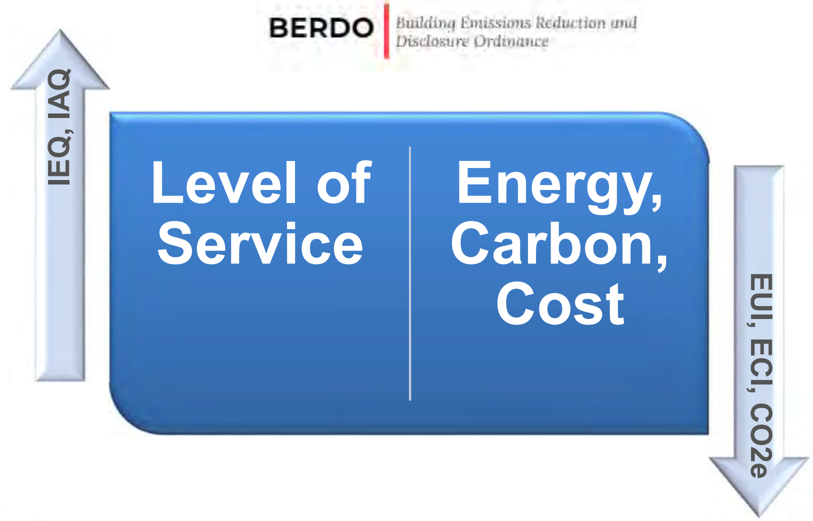


eia Data source: U.S. Energy Information Administration, 2018 Commercial Buildings Energy Consumption Survey, December 2022

Massachusetts Stretch Energy Code

CITY of BOSTON

BERDO | Building Emissions Reduction and Disclosure Ordinance



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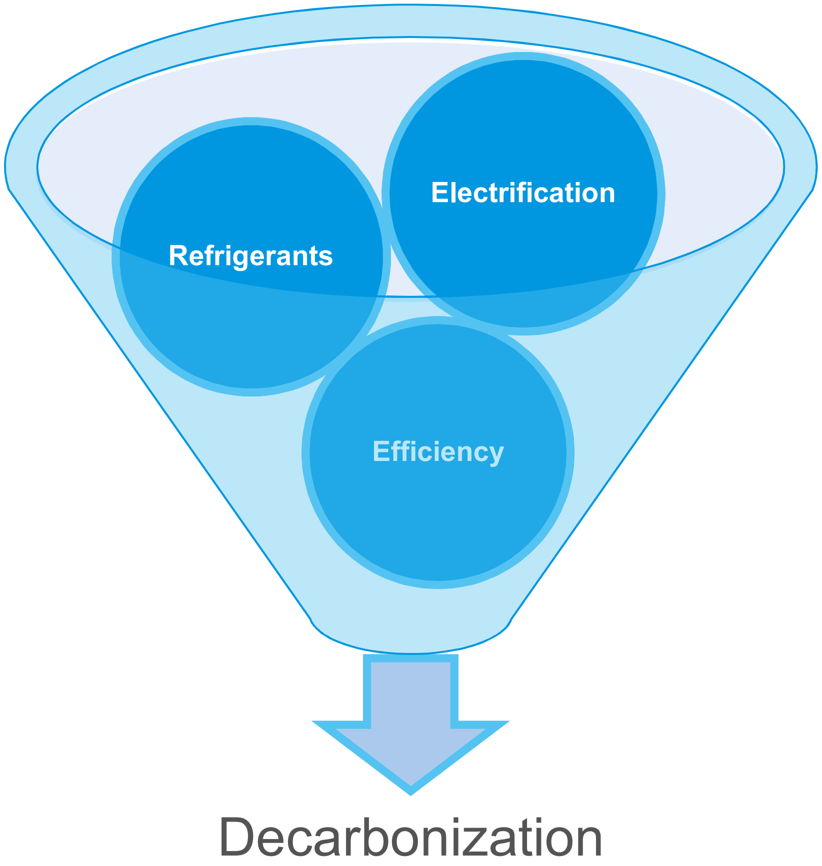
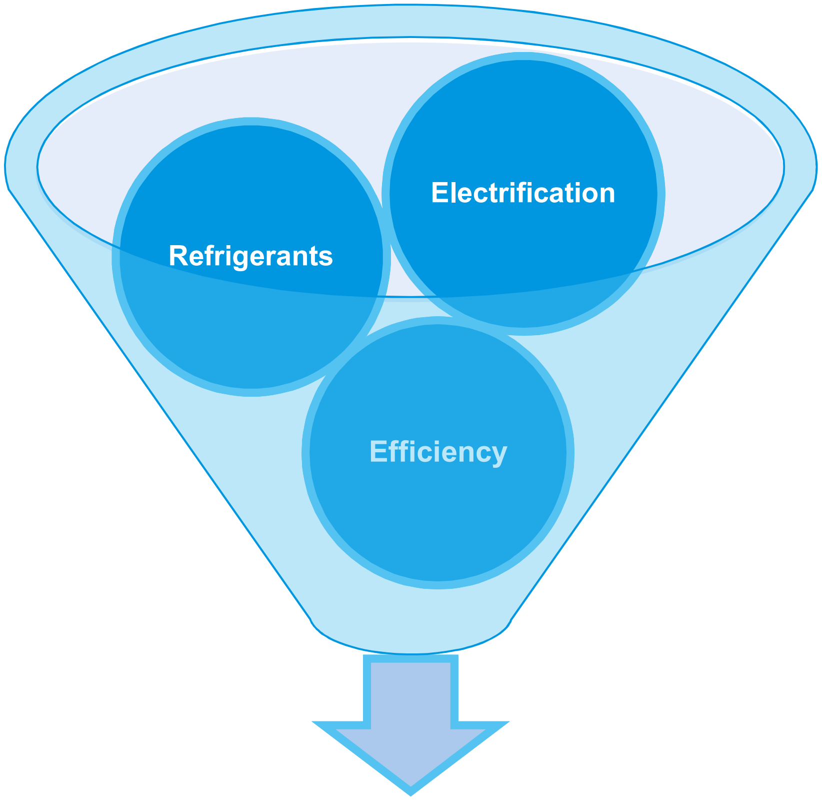
Decarbonization in HVAC



Decarbonization in HVAC

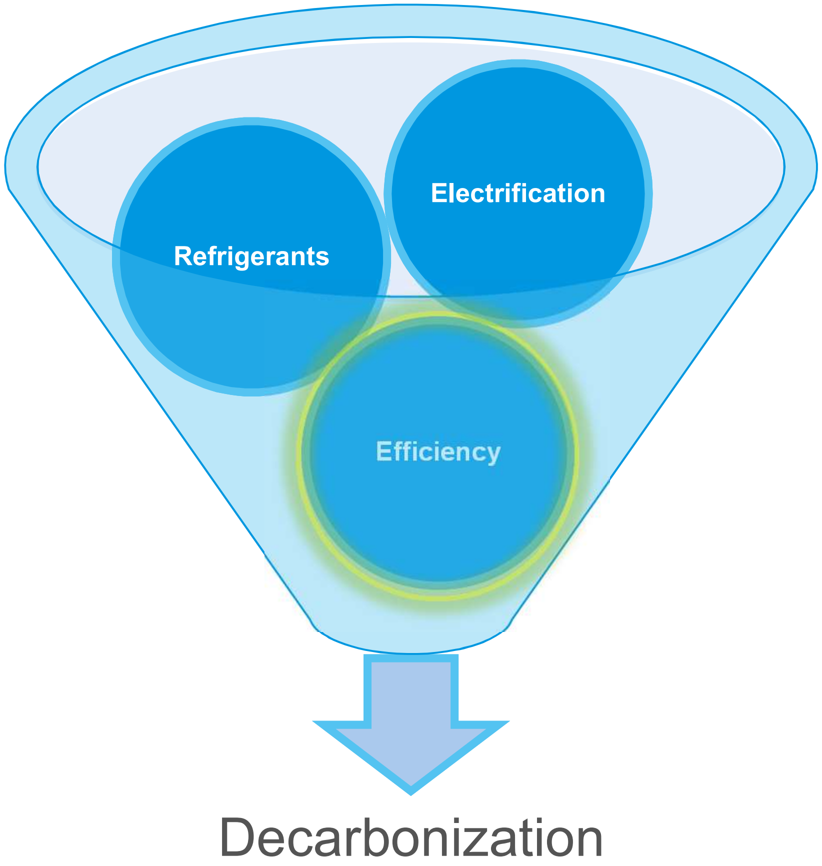


Decarbonization

Decarbonization in HVAC

Efficiency

- Greatest impact while the electricity grid is in transition
- Reduced (but not zero) impact as grid converts to renewable energy (e.g. embedded carbon in power gen equipment)



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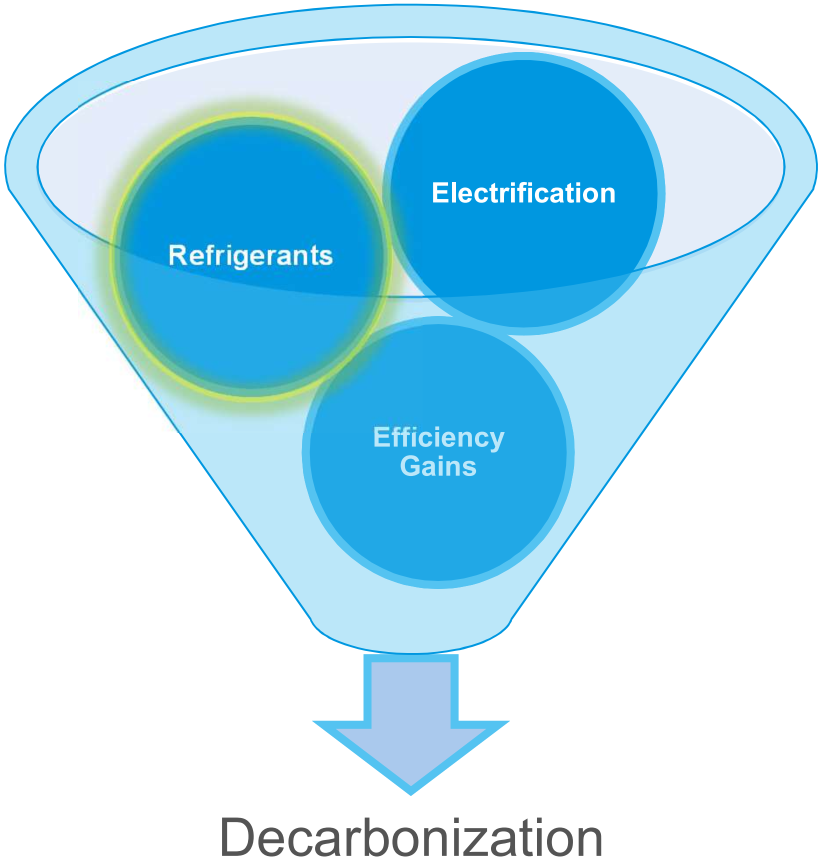
Decarbonization in HVAC

Refrigerants

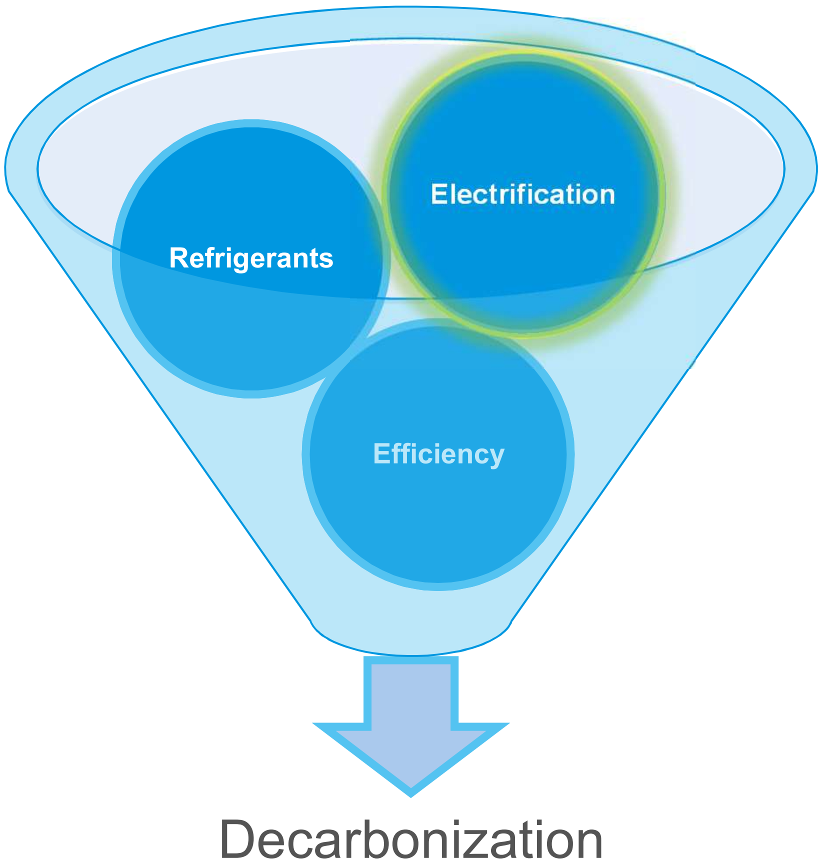
- Can have much higher global warming potential per pound than CO_2
- Direct effect: greenhouse effect of the gas
- Indirect effect: change in efficiency changes power usage over equipment lifecycle
- Life Cycle Climate Performance (LCCP): combines direct and indirect effect into one metric



Decarbonization in HVAC

Electrification

- Convert fossil fuel equipment/processes to electric
- Dependent on clean power grid



Efficiency

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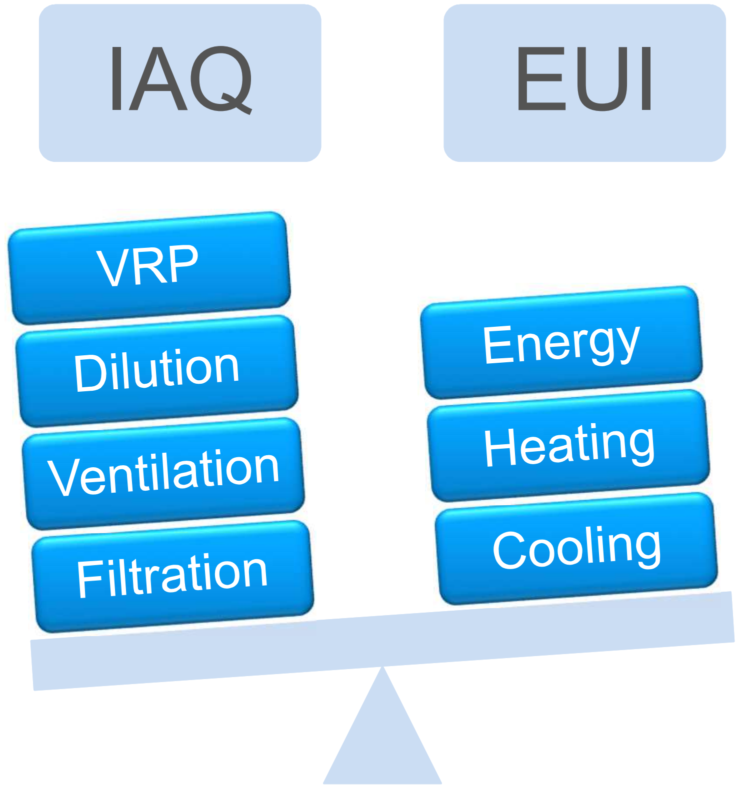
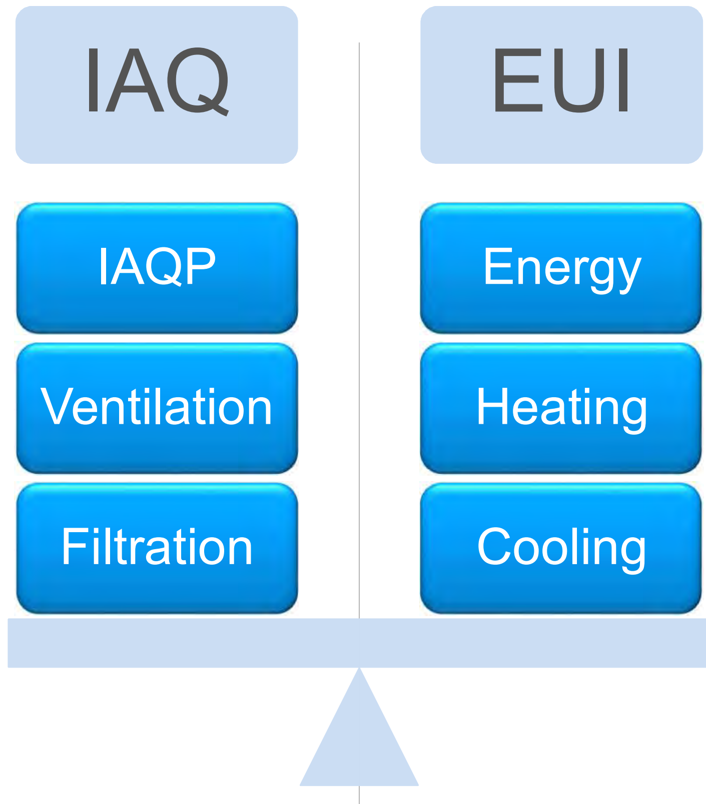
IAQ vs EUI: A Balancing Act



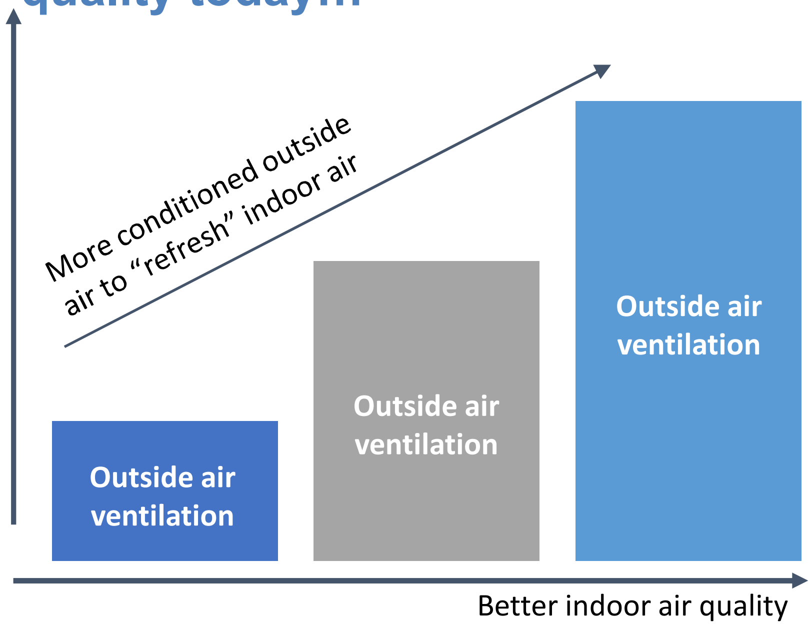
IAQ vs EUI: A Balancing Act



**Achieve a Better Balance
Between IAQ and Energy Performance**

IAQP: More Outside Air = More Carbon Emissions and Cost

How buildings ensure good indoor air quality today…



…results in higher emissions & more cost

- Larger and more expensive HVAC systems
- Higher energy use and carbon emissions
- Increased operating costs
- What if the outside air is polluted?

Relying on only outside air ventilation to deliver good indoor air quality is energy intensive and costly in many climates

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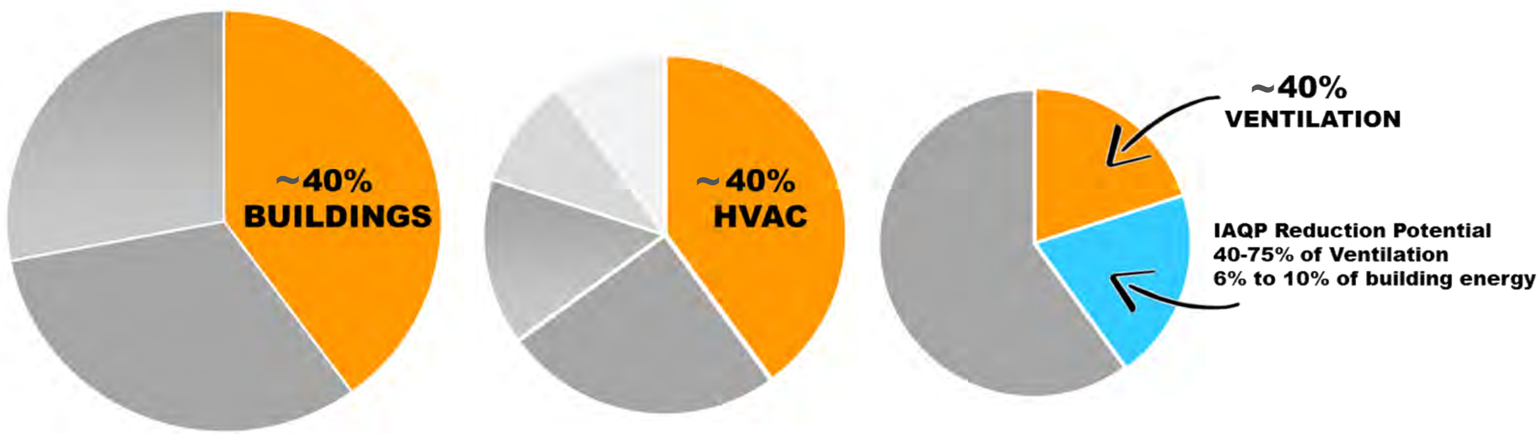
What Is The Impact of IAQP On Decarbonization?

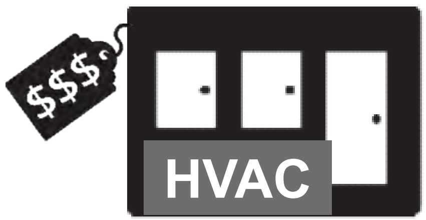
The **40-40-40** Approximation

Ventilation energy reduction is potentially a good opportunity for decarbonization



Scenario 1: Apply IAQP in a New Building

Save money on new HVAC equipment	Reduce HVAC EUI & energy costs by 40%	Lower Carbon Emissions & Improve IAQ	Earn points for green building rating systems



CapEx ↓ **OpEx** ↓ **IAQ** ↑ **LEED & WELL** ↑

IAQP + SVT

Reduce the OA code requirement by 40% - 80%!

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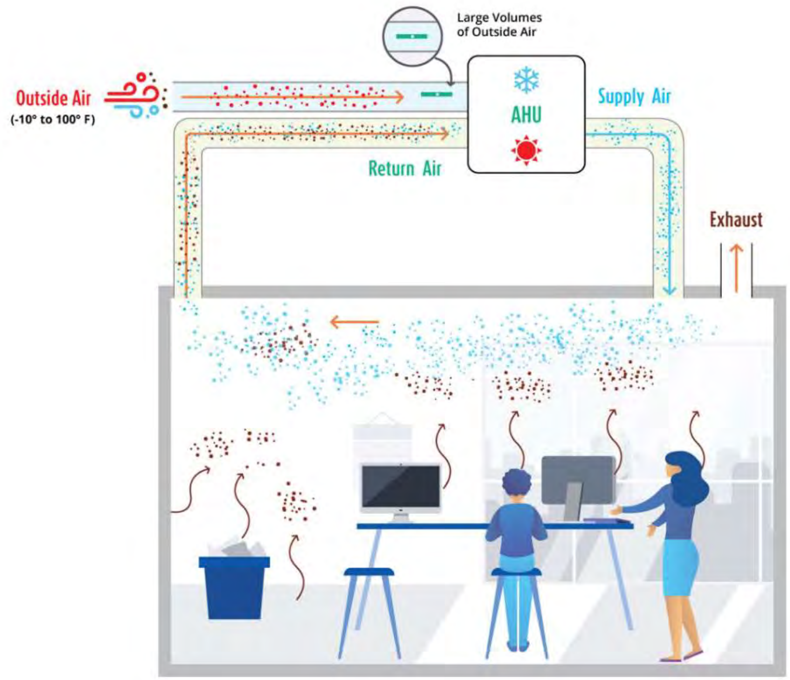
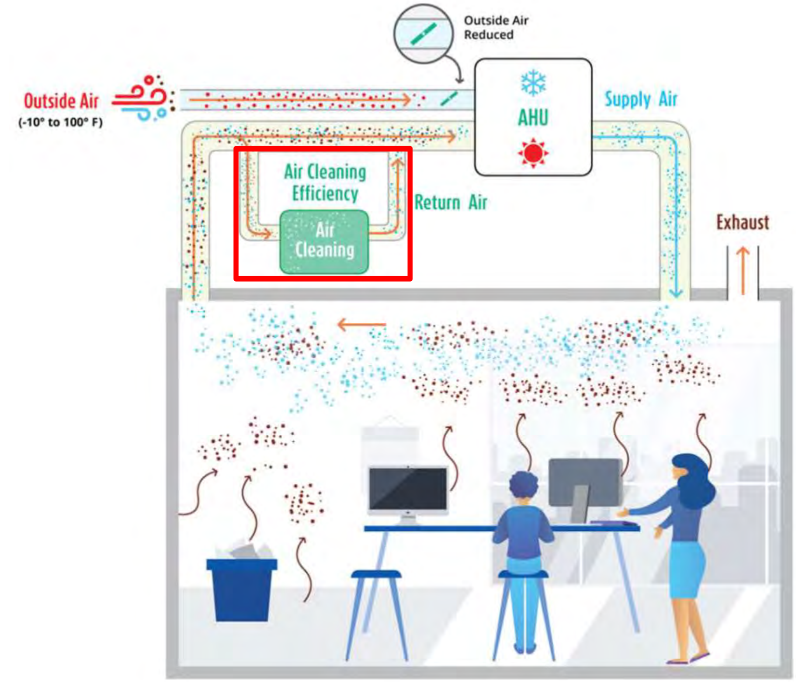
Scenario 2: Apply IAQP in an Existing Building

Category	Opportunity (Retrofit Difficulty →)	
Envelope	• Insulation • Sealing	• Windows and doors
Electrical / Lighting	• Lighting • Variable speed drives	• Solar (on site generation)
Mechanical / HVAC	• Ventilation optimization	• Equipment replacement • System replacement
BAS / controls	• Re/retro-commissioning or re-tuning	• System replacement

Ventilation Rate Procedure v.s. Indoor Air Quality Procedure





VRP = CFM per Area (sqft) + CFM per Design Occupancy (people)

IAQP = (Emissions Rate – Cleaning Effectiveness) / Concentration Limit

"The IAQP may allow for a more cost-effective solution to providing good air quality…"
- Standard 62.1-2019 User's Manual, Pg. 100

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SVT in Daikin RTUs & AHUs

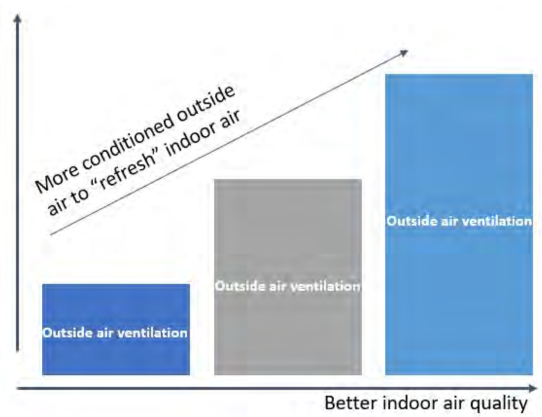
SVT Module

- Integrated in:
  - Vision/Skyline AHUs
  - Rebel Applied RTUs
- Removes CO_2
- Periodically regenerates sorbent media

IAQP + HP = Win/Win

Leverage IAQP to:

- Reduce ventilation and max load
- Downsize HP
- Manage first cost
- Reduce energy usage



Leverage Rooftop HP or Applied VRV HP to:

- Electrify heating
- Dual fuel or 100% electric
- Handle the ventilation
- House the IAQP air-cleaning solution

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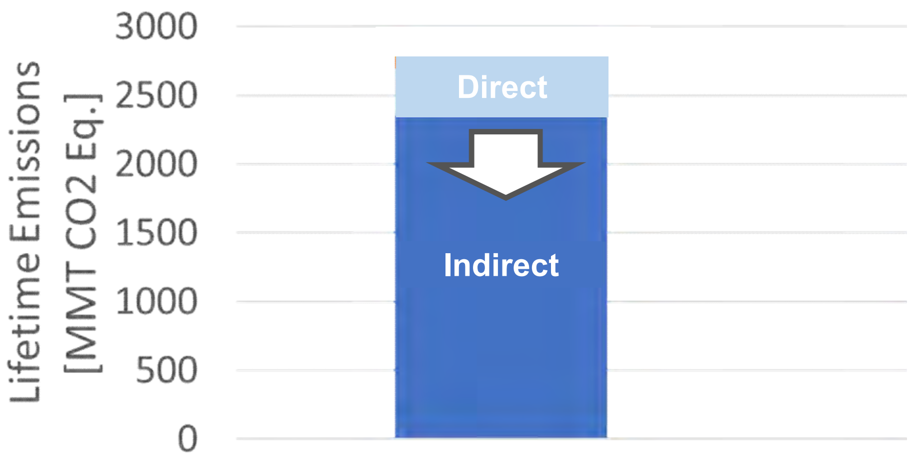
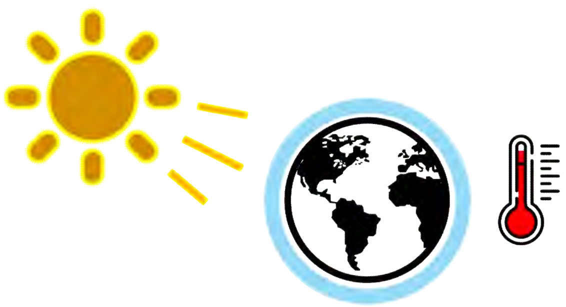
Refrigerants

CO_2 eq. Emissions Mostly from Electricity Consumption





As the electric grid becomes more renewable, direct emissions will become a larger percentage of the total, but today are a very small impact compared to equipment efficiency and corresponding energy use.

(animation not to scale)

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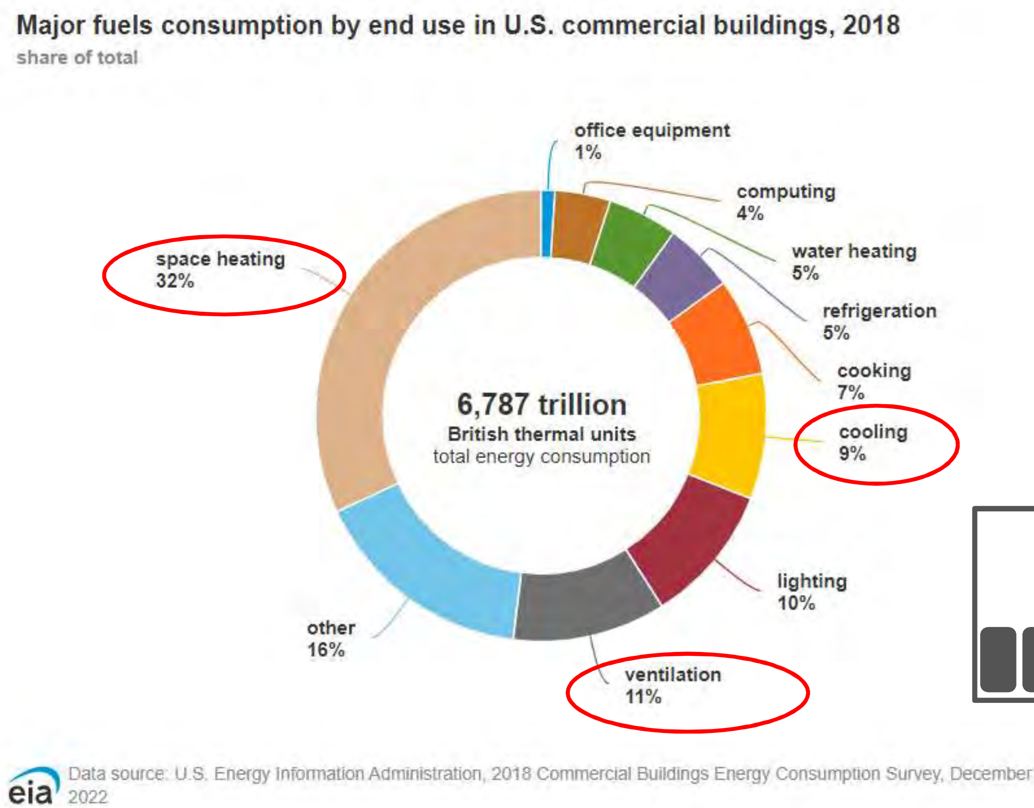
Refrigerants By Compressor Technology

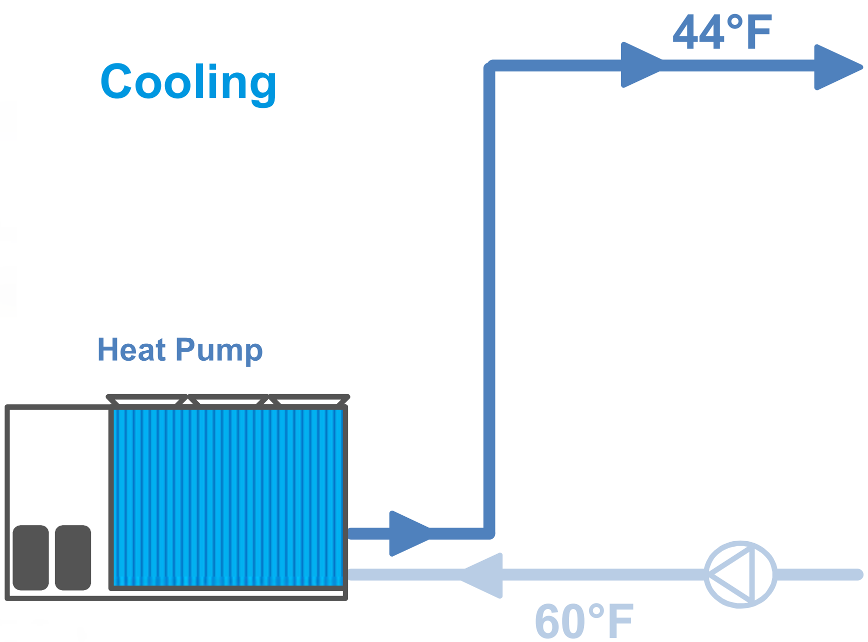
Compressor	Refrigerant	Low GWP Alternative	
Scroll	R410A GWP = 2088	R32 GWP <700	R454B GWP <500
Screw	R134a GWP = 1300	R513A GWP < 600	R1234ze GWP < 10
Centrifugal	R134a GWP = 1300	R1233zd GWP < 10	R1234ze GWP < 10

Pressure

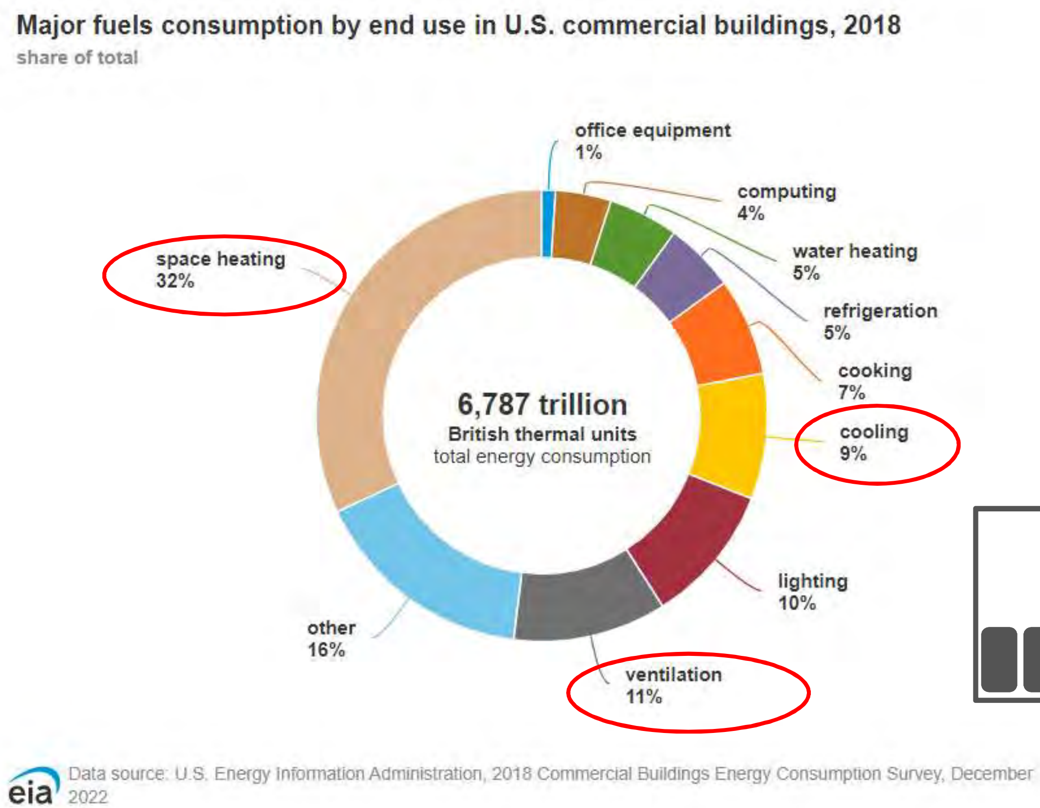
Electrification

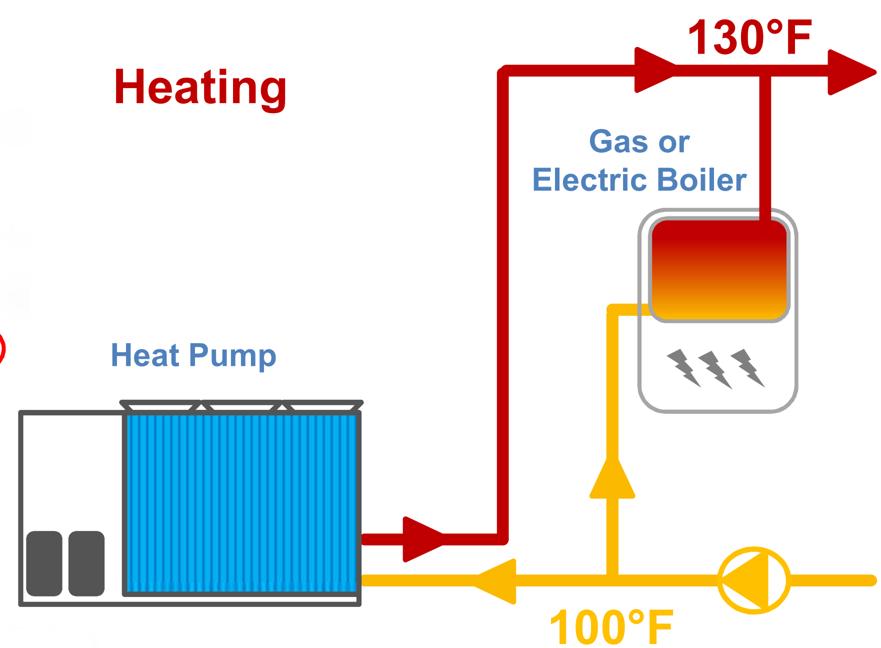
Challenge of Decarbonization



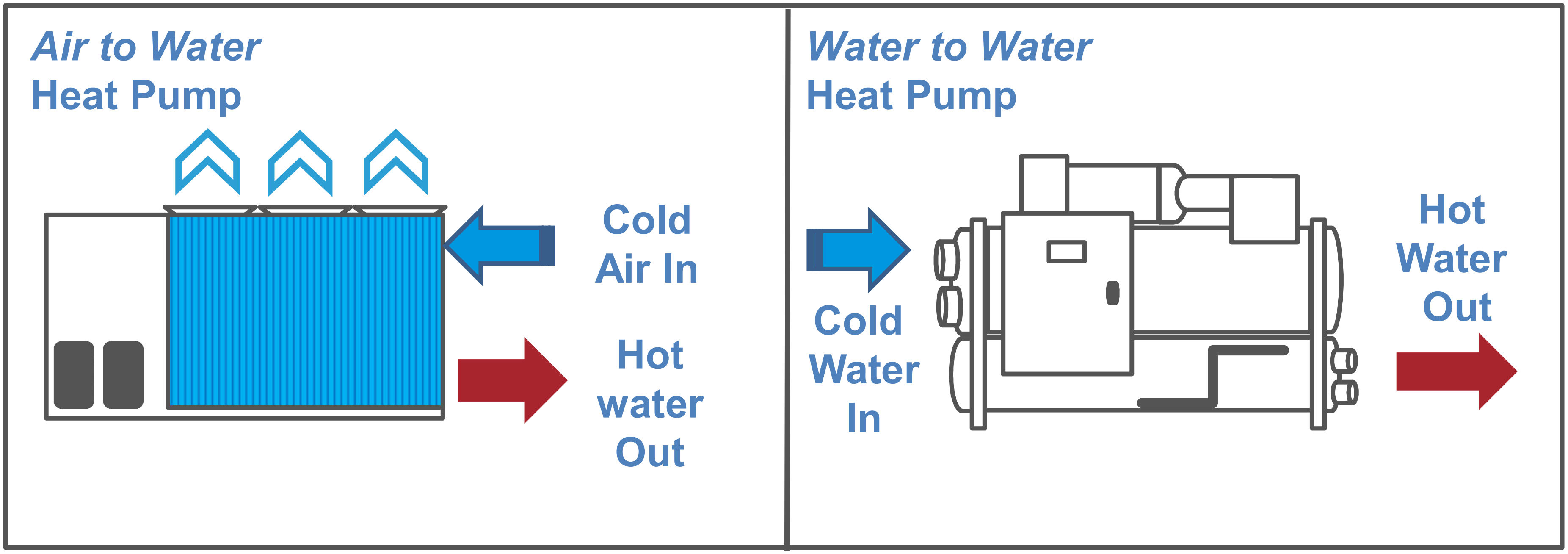


Challenge of Decarbonization

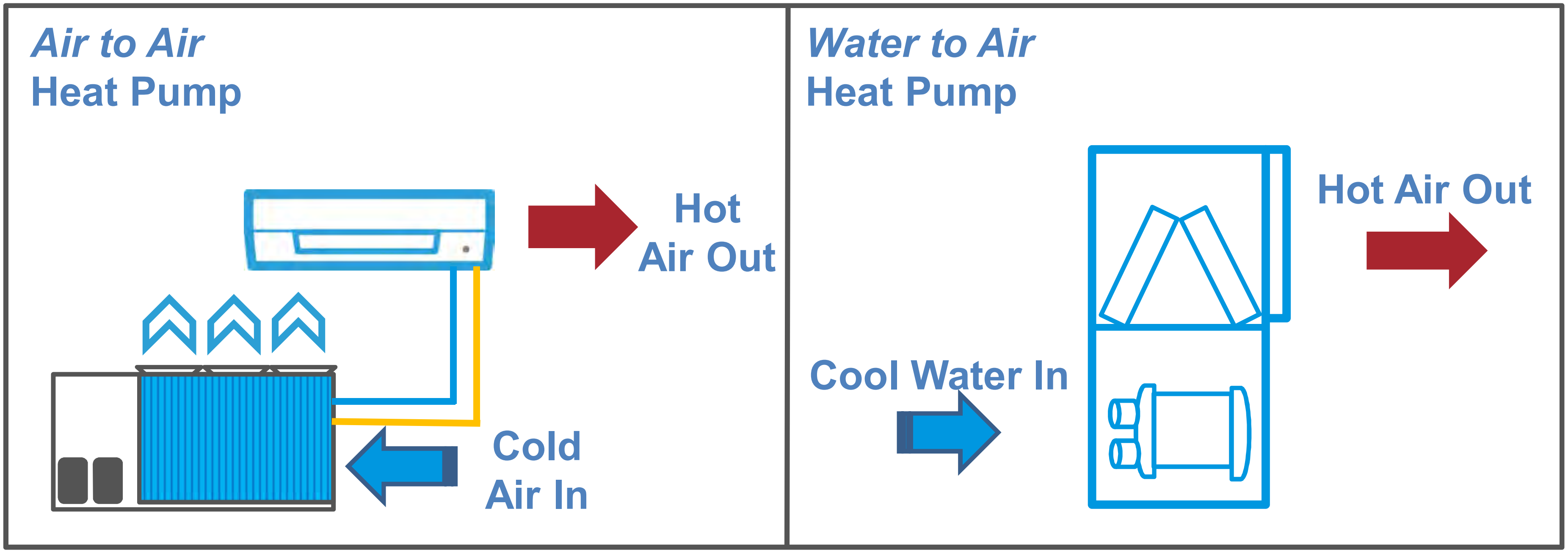




Types of Heat Pumps



Heat Pumps Continued…



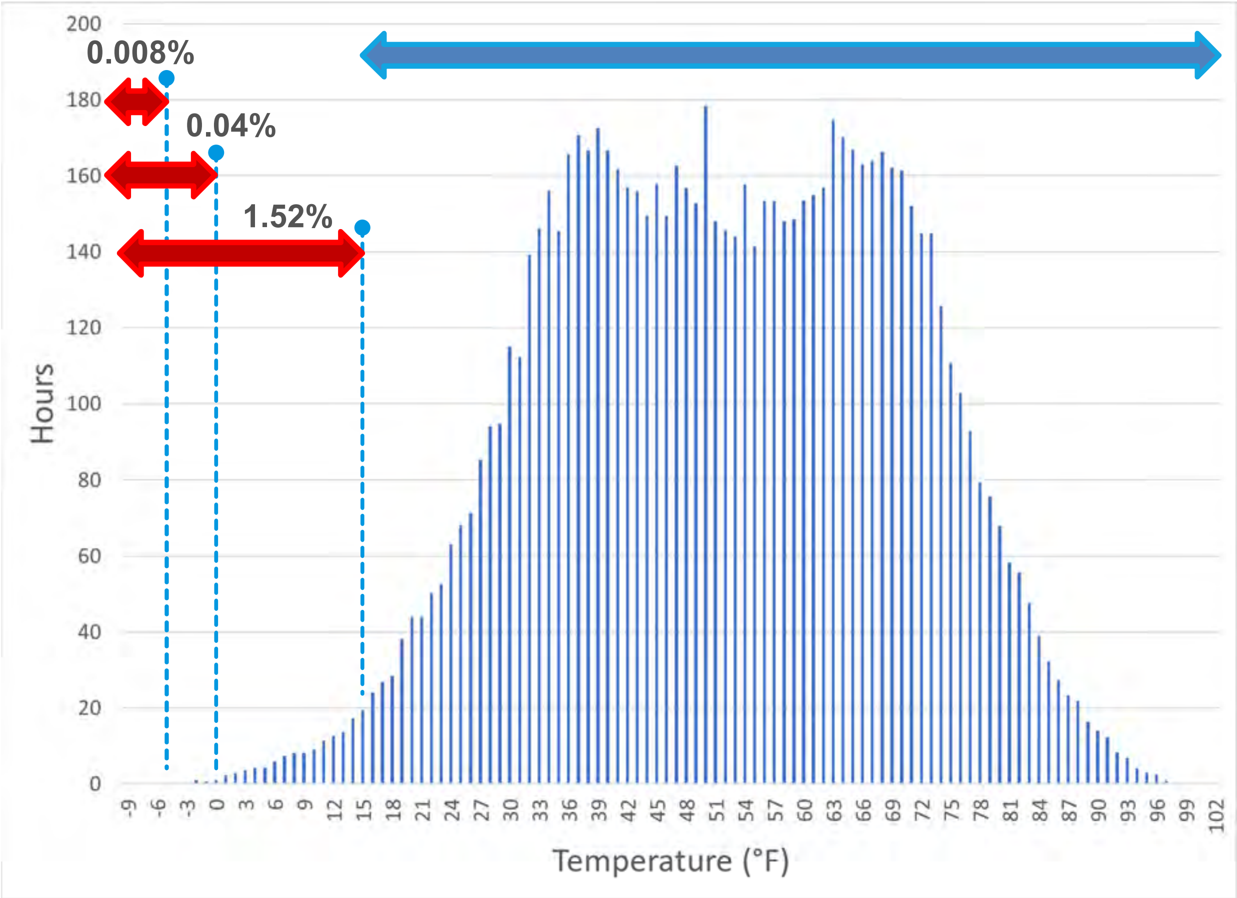
Design Conditions

Weather Data

- Very few run hours at temperatures below 15°F
- How do you design the system?
  - 100% electric heat pump, substantially larger to accommodate less than 2% of the hours?

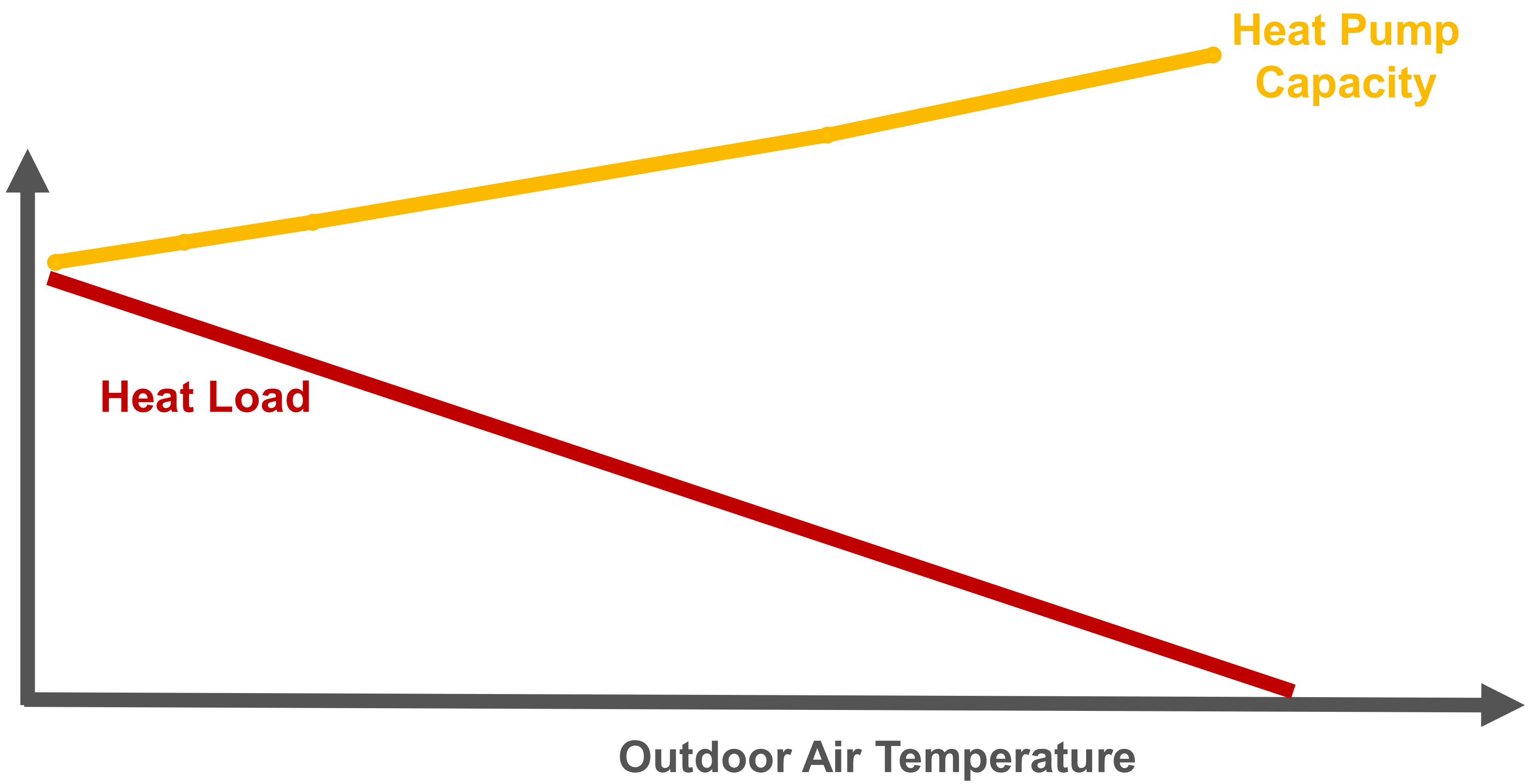
  - Or,
    - Hybrid heat pump system with supplemental heat?

"Don't let perfect be the enemy of good!"

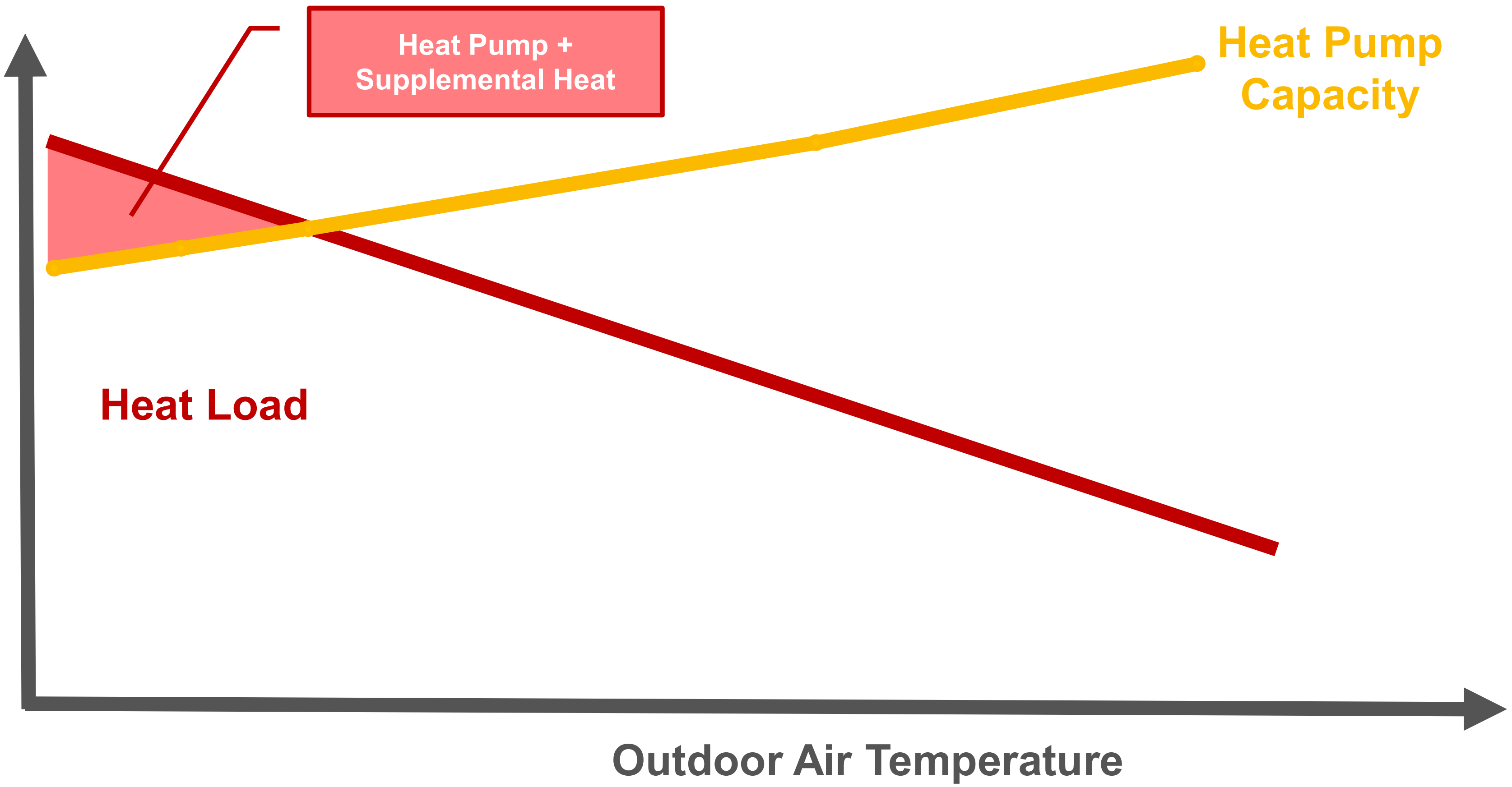


Source: ASHRAE Weather Data Viewer, for Boston Logan

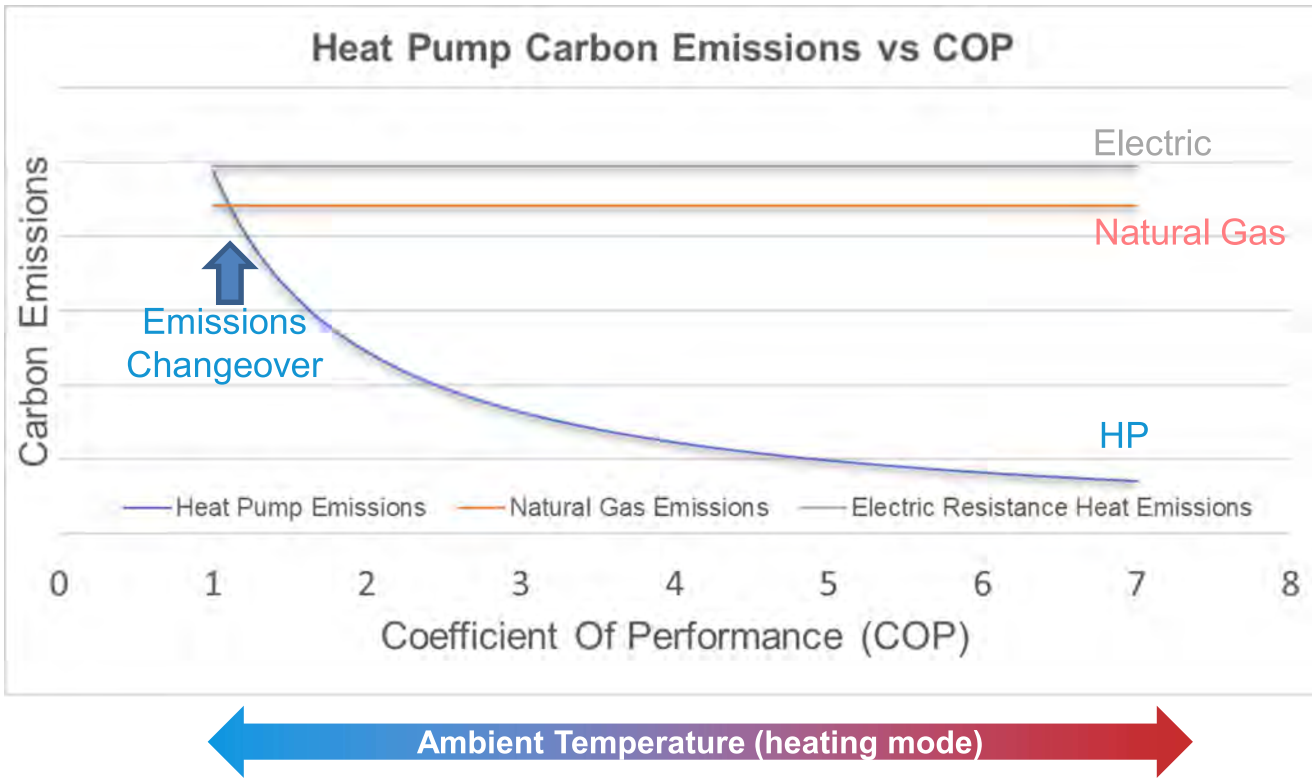
Air Source Heat Pumps



Air Source Heat Pumps



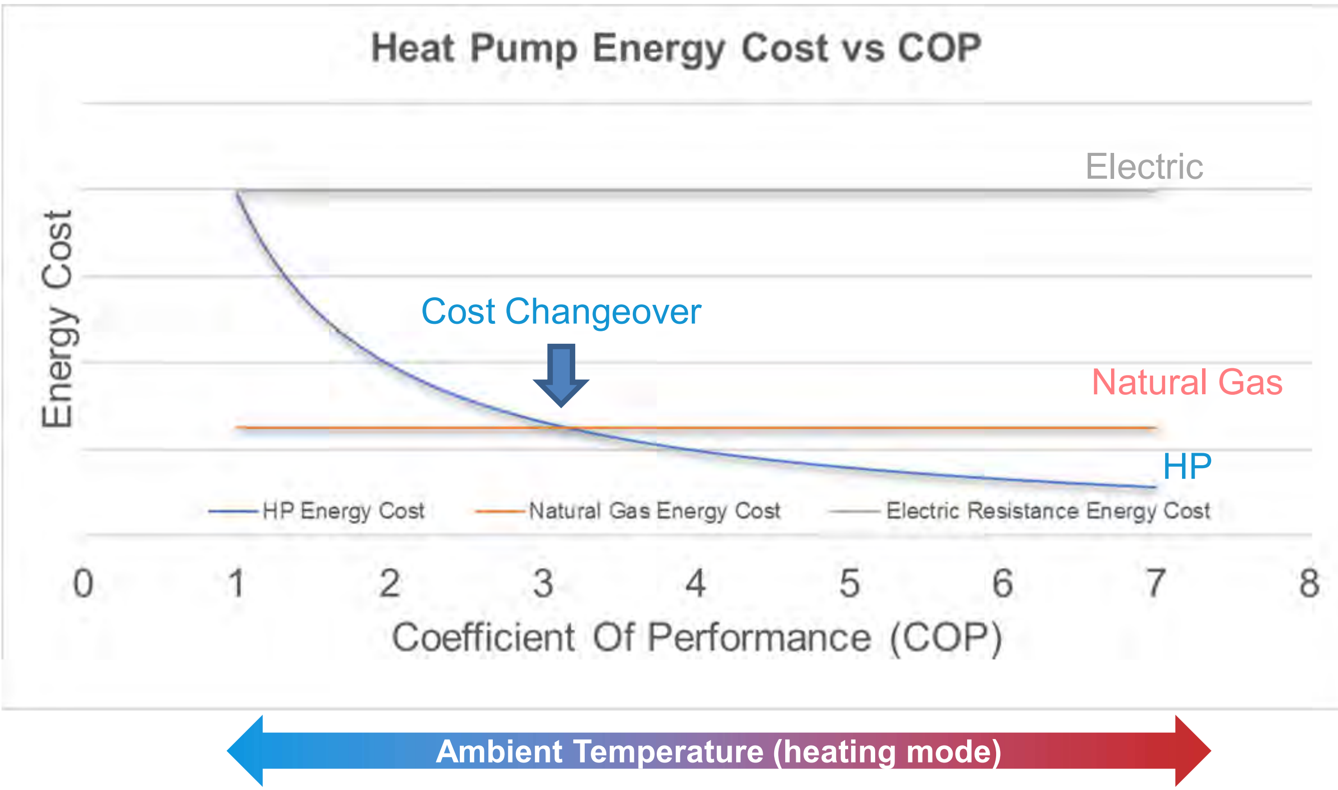
Air Source Heat Pumps and Emissions



Assumptions

Natural Gas Efficiency:	85%
Electric Resistance Efficiency:	99%
Grid Emissions Factor: (gram/kWh)	245
Natural Gas Emissions (lbs/therm)	12.1

Air Source Heat Pumps and Operating Cost



Assumptions

Natural Gas Efficiency:	85%
Electric Resistance Efficiency:	99%
Electricity Cost: ($/kWh)	$0.197
Natural Gas Cost: ($/therm)	$1.55

Rooftop Units

Rebel Heat Pump with Inverter Compressor

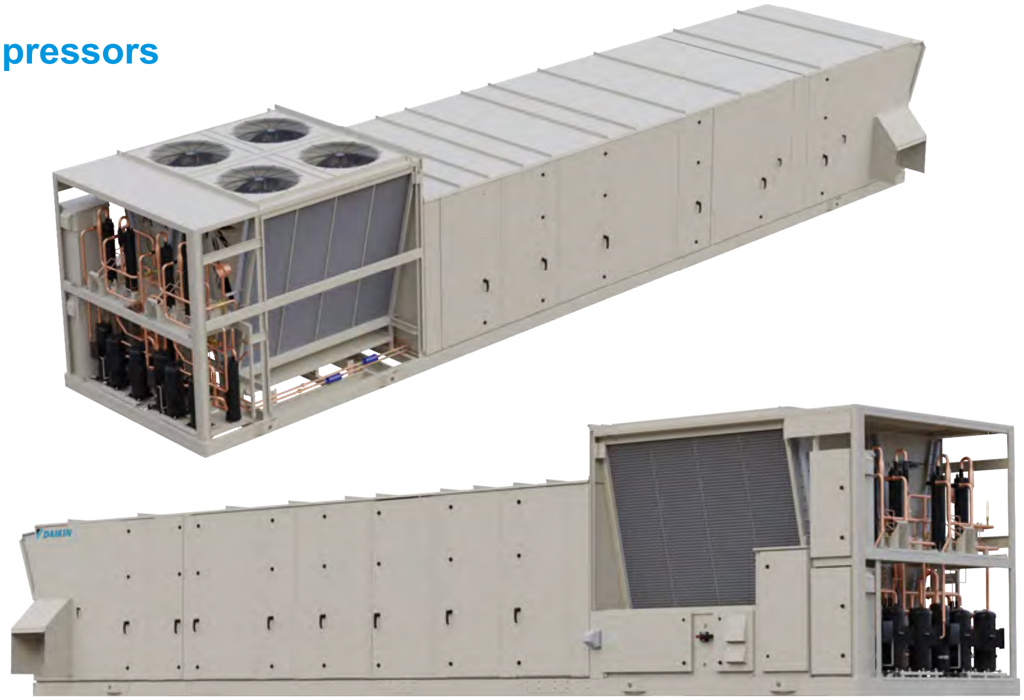
- Capacity: 3 to 31 tons
- Refrigerant: R-32
- Efficiency:
  - COP 3.4 @ 47°F
  - COP 2.1 @ 17°F
- Supplemental Heat:
  - Gas
  - Hot water
  - Electric

3 to 31 tons

Rooftop Units

Rebel Applied Heat Pump with Inverter Compressors

- Capacity: 30 to 75 tons
- Refrigerant: R-32
- Efficiency:
  - COP 3.6 @ 47°F
  - COP 2.4 @ 17°F
- Supplemental Heat:
  - Gas
  - Hot water
  - Electric



30 to 75 tons

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Rooftop Units

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Existing Unit

Rooftop w/ Gas Heat

	Existing Unit
MCA	130A – 1/0 AWG
MOP	150

New ASHP Rooftop Unit

	Scenario 1: Std Heat Pump	Scenario 2: Inverter Heat Pump	Scenario 3: Inverter HP Dual-point Electrical
MCA	280 amps – 300 MCM	233 amps – 4/0 AWG	C1: 130A 1/0 AWG C2: 100A 3 AWG
MOP	300 amps	250 amps	C1 150A / C2 = 125A
Install Requirements	New 280A Feed (+6 wire sizes)	New 233A Feed (+3 wire sizes)	Use existing 130A Feed, New 100A Feed
Relative Electrical Install Cost	High	Medium	Low

Existing Unit

Rooftop w/ Gas Heat

	Existing Unit
MCA	130A – 1/0 AWG
MOP	150

New ASHP Rooftop Unit

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Air Source Heat Pumps - DOAS Solutions

ASHP Rooftop:

High Capacity

- Larger single unit sizes available
- Inverter capacity boost

OA Preheat Technology

- Expands ambient range

All-in-One Solution

- No field refrigerant piping

Applied VRV (VRV + AHU)

Wide Ambient Range

- VRV units with low ambient capability
- OA temp for AHU coil still a factor

Modular, Decentralized Design

Multiple AHUs per Condensing Section

- Scalable and cost-effective

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Air Source Heat Pumps – Applied VRV

- **Indoor / outdoor unit ratio**
  - Increase indoor to outdoor unit ratio to maximize value
  - Many indoor units on one outdoor system
  - Flexibility to meet design needs
- **Double Wall & Higher Static Pressure Construction Is Key for DOAS**
  - Important to specify
  - Avoid sweating
- **Additional Capabilities**
  - Hot gas reheat
  - Static pressure control

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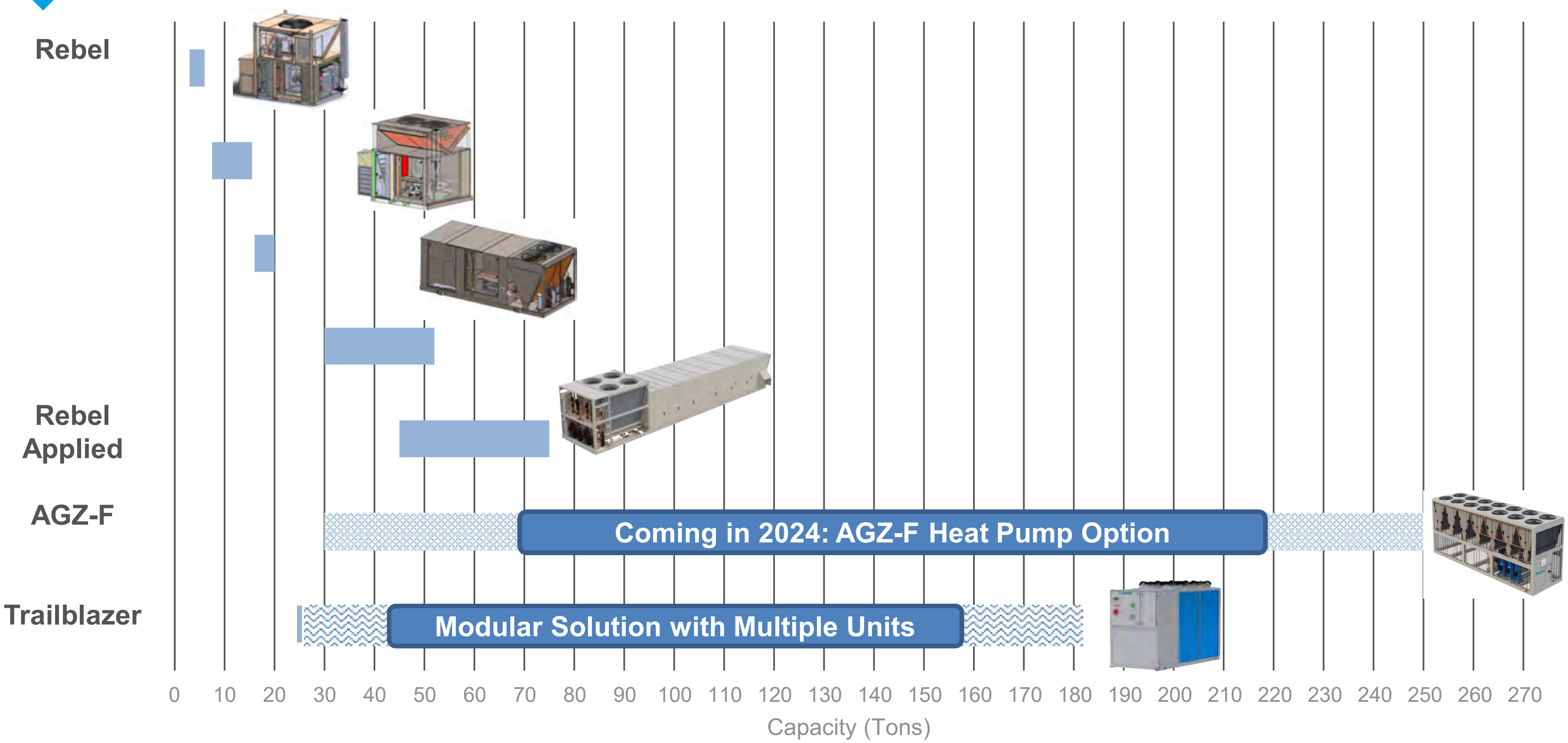
2024 Air Source Heat Pump Line-Up



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Air Source Heat Pumps

AGZ-F Heat Pump Option

- Capacity: 30 to 220 tons
- Refrigerant: R-32
- Efficiency:
  - Standard
  - High Efficiency
- Variable Speed Condenser Fans
- Low Ambient Option to -4°F
- Sound Reduction Option

Coming in 2024…

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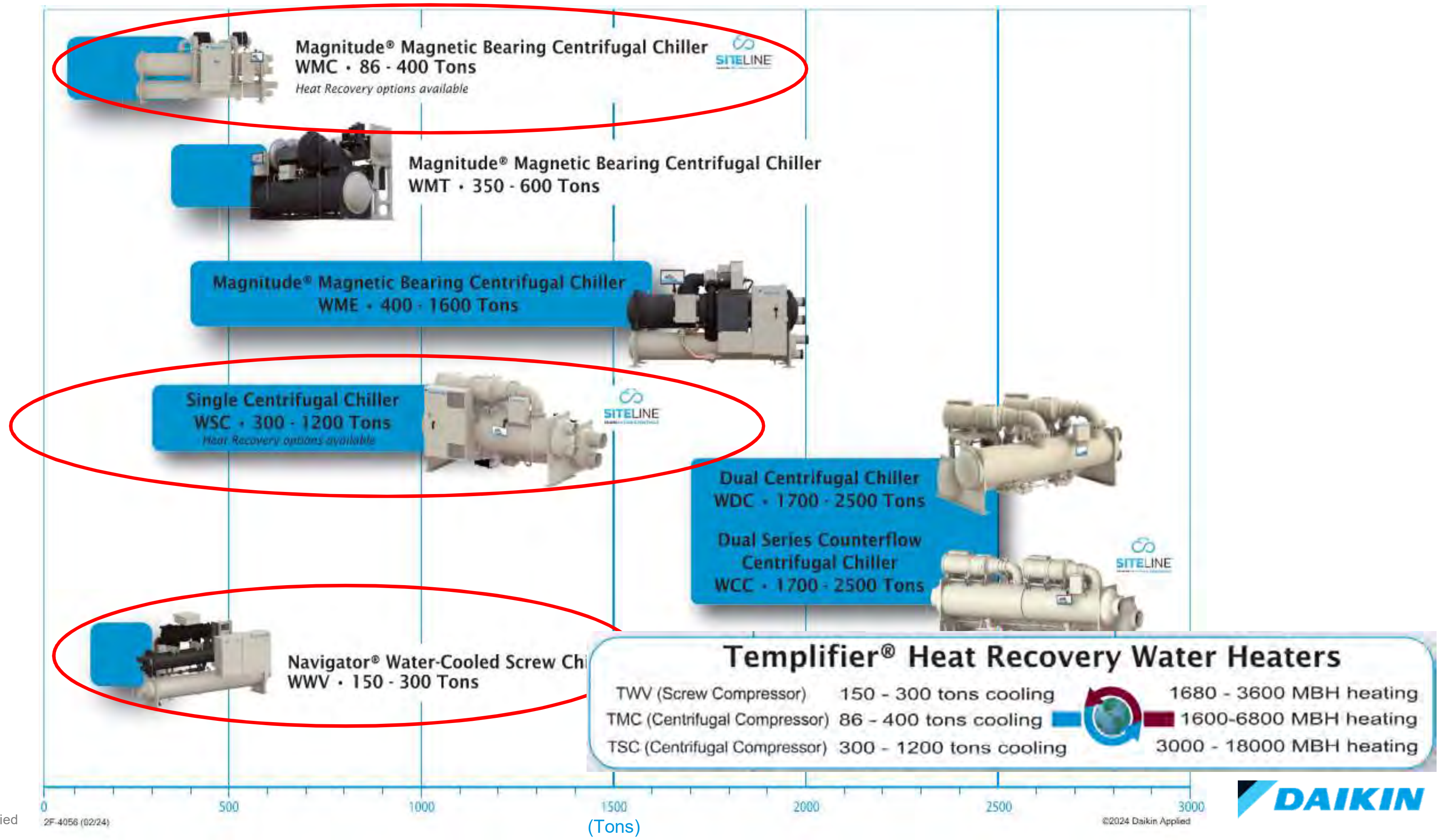
Chillers / Heaters



Chillers / Heaters

Navigator TWV - Templifier® Water Heater

- Capacity:
  - 150 to 300 tons
  - 1,200 to 4,300 MBH
- Refrigerant: R-513A
- Condenser water temperature up to 140°F
  - Up to 130°F @ 25°F evaporator leaving temperature

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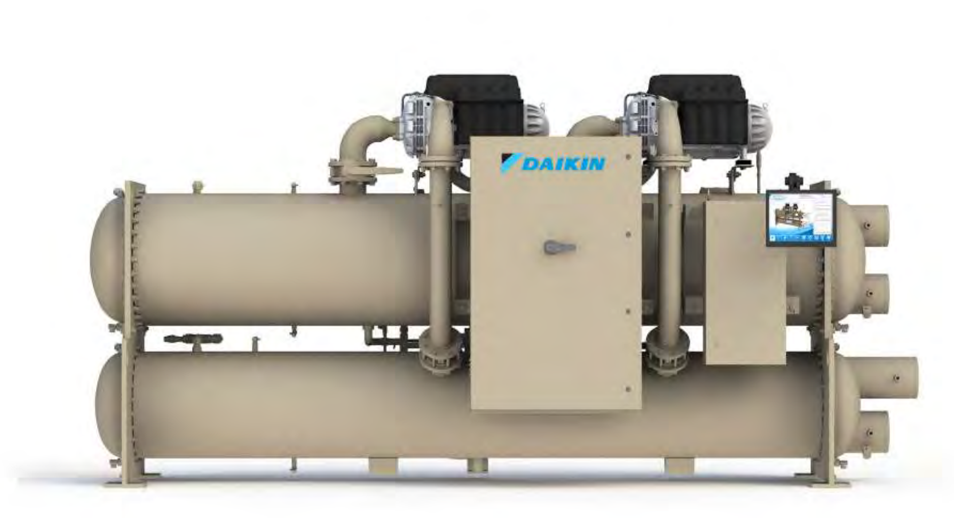
Chillers / Heaters

Templifier® Centrifugal Water Heater

- Capacity:
  - 86 to 400 tons
  - 1,600 to 6,800 MBH
- Refrigerant: R-513A
- Condenser water temperature up to 140°F



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Chillers / Heaters

Templifier® Centrifugal Water Heater

- Capacity:
  - 300 to 1,200 tons
  - 3,000 to 18,000 MBH
- Refrigerant: R-513A

- Note: In ASHRAE 90.1-2019, condenser heat recovery is required for acute care inpatient hospitals…
  - That operate on a 24-hour basis
  - Where the design cooling capacity > 300T
  - Where simultaneous heating and cooling occurs above 60°F

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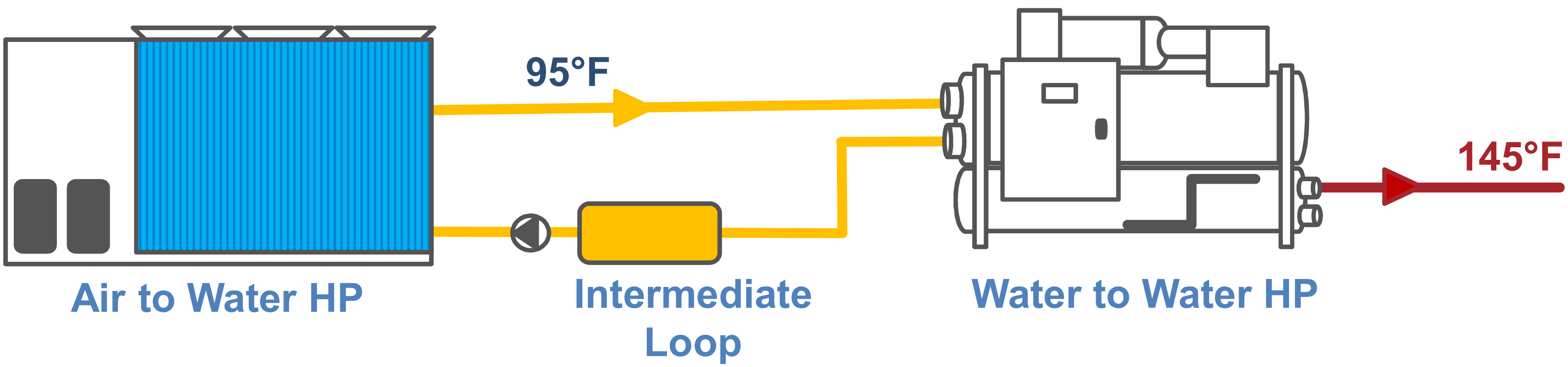
Combined Air and Water Source Heat Pump Systems

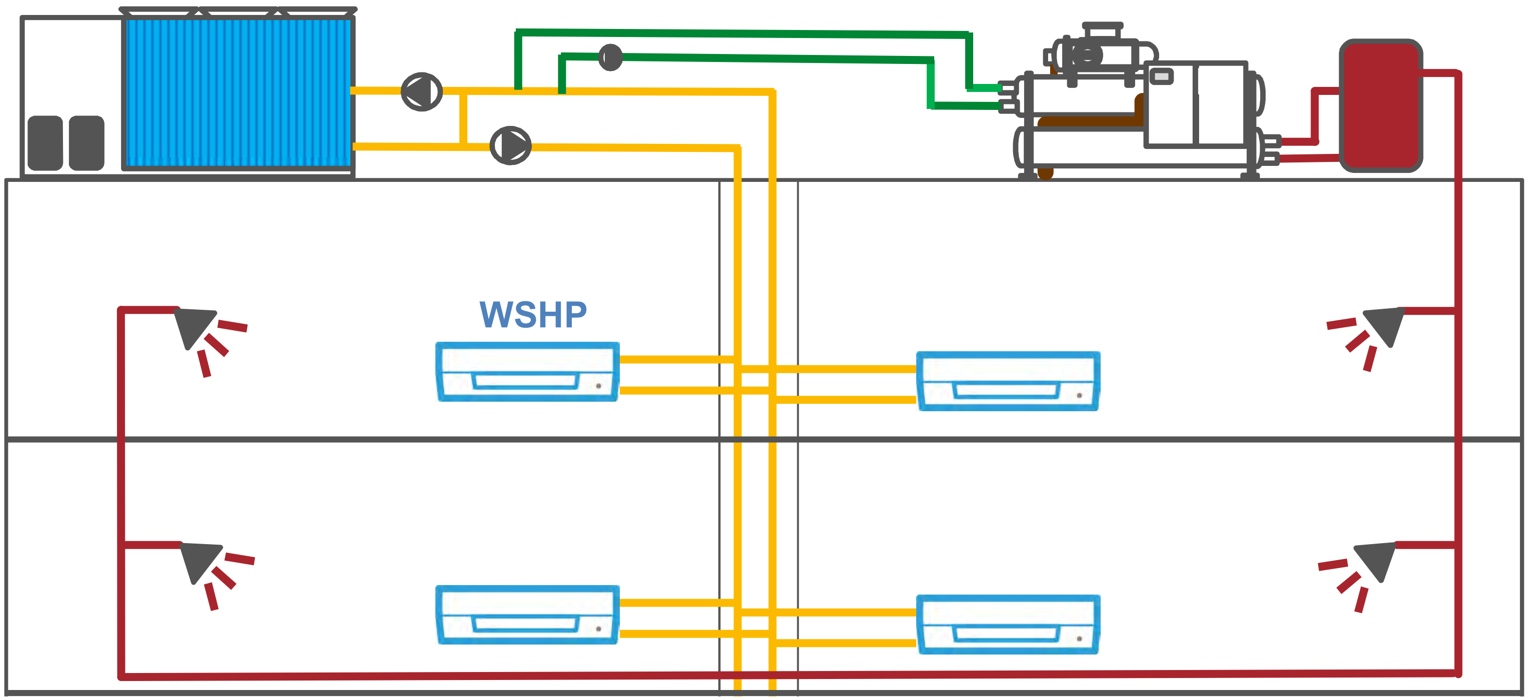
Cascade Systems

- Share the lift across heat pumps
- Improve air-to-water heat pump low ambient performance
- Share and store energy in the building for comfort or domestic hot water needs



Combined Air and Water Source Heat Pump Systems

Fully Electric Centralized Solution For Comfort And DHW Combined

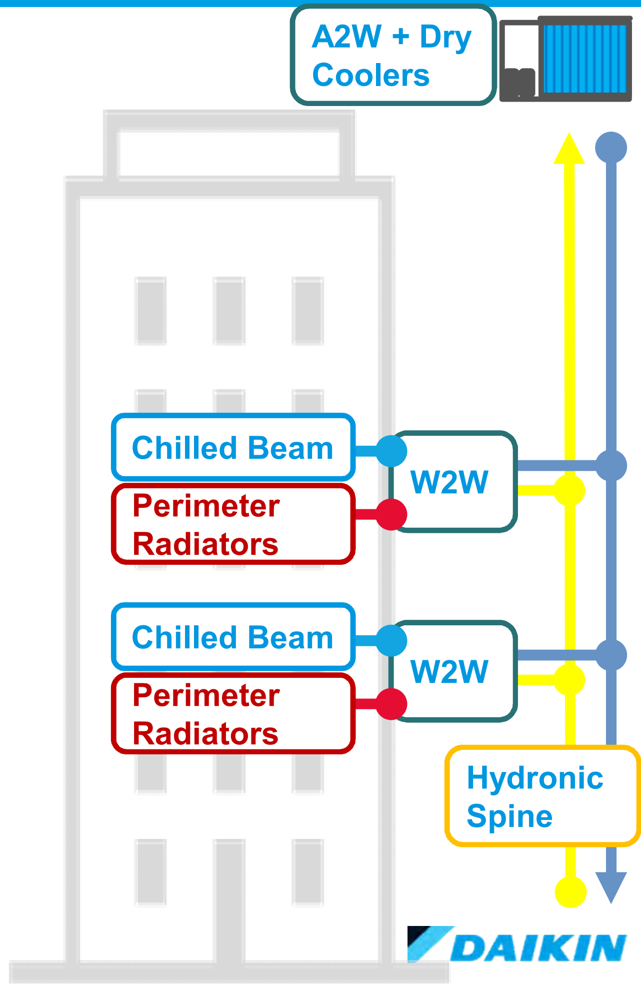


345 Hudson Building

- **Deep energy retrofit to address building energy use and emissions**
  - Address building insulation and envelope
  - Cascade HP system
    - A2W HP + Dry Cooler: Serve as heat adder/remover with hydronic spine for entire building – share energy between floors
    - Floor by floor W2W HPs serving perimeter radiators for heating and chilled beams for cooling
    - Separate DOAS system to address latent load

- **Expected Outcomes:**
  - By 2032, 50% energy use reduction
  - 85% carbon emissions reduction
  - Peak heating and cooling loads reduced by 92% and 63%, respectively

Read more here: https://be-exchange.org/case_study/high-rise-low-carbon-partner-profile-345-hudson/



Combined Air and Water Source Heat Pump Systems

Mega-Q

- Hold for slide that references Mega-Q (presentation from day before)

Geothermal Heat Pump Systems

- Avoids air source heat pump challenges
- District systems
  - Share heat between buildings
  - Combine with data centers for heating
- Incentives
  - Utilities
  - DOE - Geothermal district heating/cooling systems

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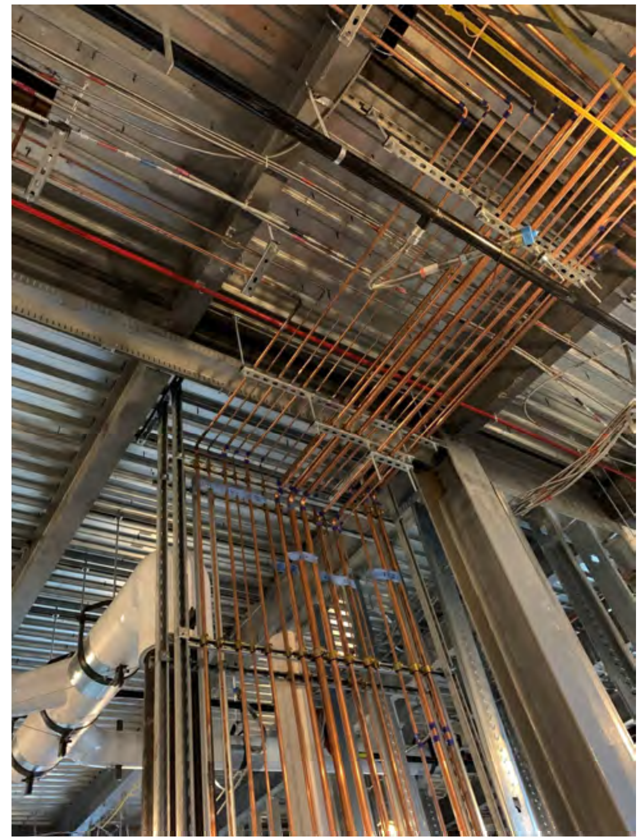
New Office Building



Office Retrofit

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Questions & Key Takeaways

Key Takeaways

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  - Efficiency
  - Refrigerants
  - Electrification
- Solutions available to you today include:
  - Application of IAQP for ventilation
  - Energy/heat recovery
  - Heat pumps, including cascade and geothermal systems
- Key design considerations when applying air source heat pumps for heating, especially in low ambient conditions – below an equipment-specific threshold:
  - Capacity decreases with outdoor air temperature
  - Hot water supply temperature decreases with outdoor air temperature
- Refrigerant selection is based on compressor and lift, and strikes a balance between direct and indirect emissions
- System and equipment flexibility is critical for mechanical and electrical adaptability, especially in existing buildings

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THANK YOU FOR YOUR TIME AND ATTENTION

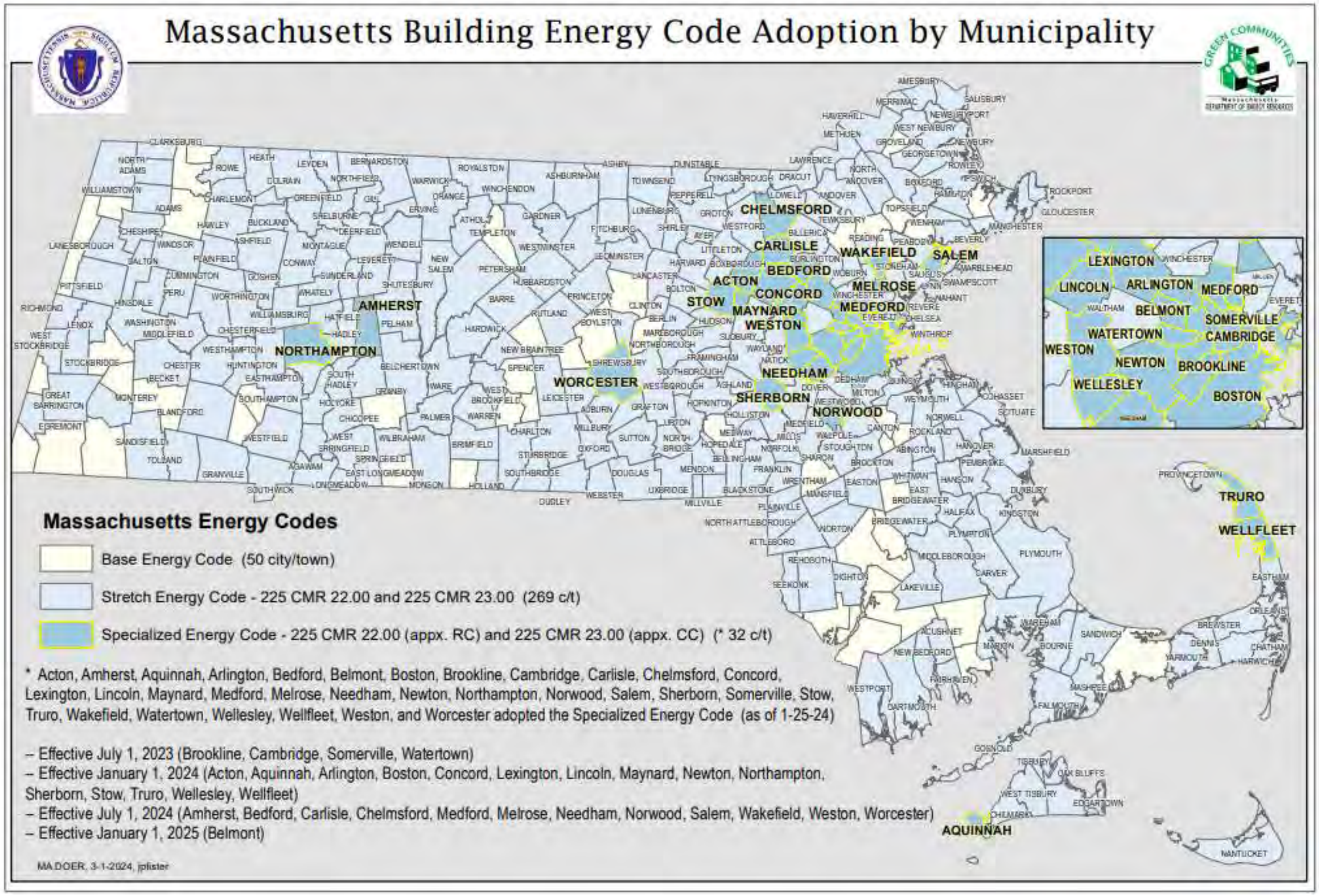
For more information, contact:

Jeff Seewald
jeffrey.seewald@daikinapplied.com

Reference

- The slides that follow are reserved for reference with supporting information and additional detail.

Massachusetts



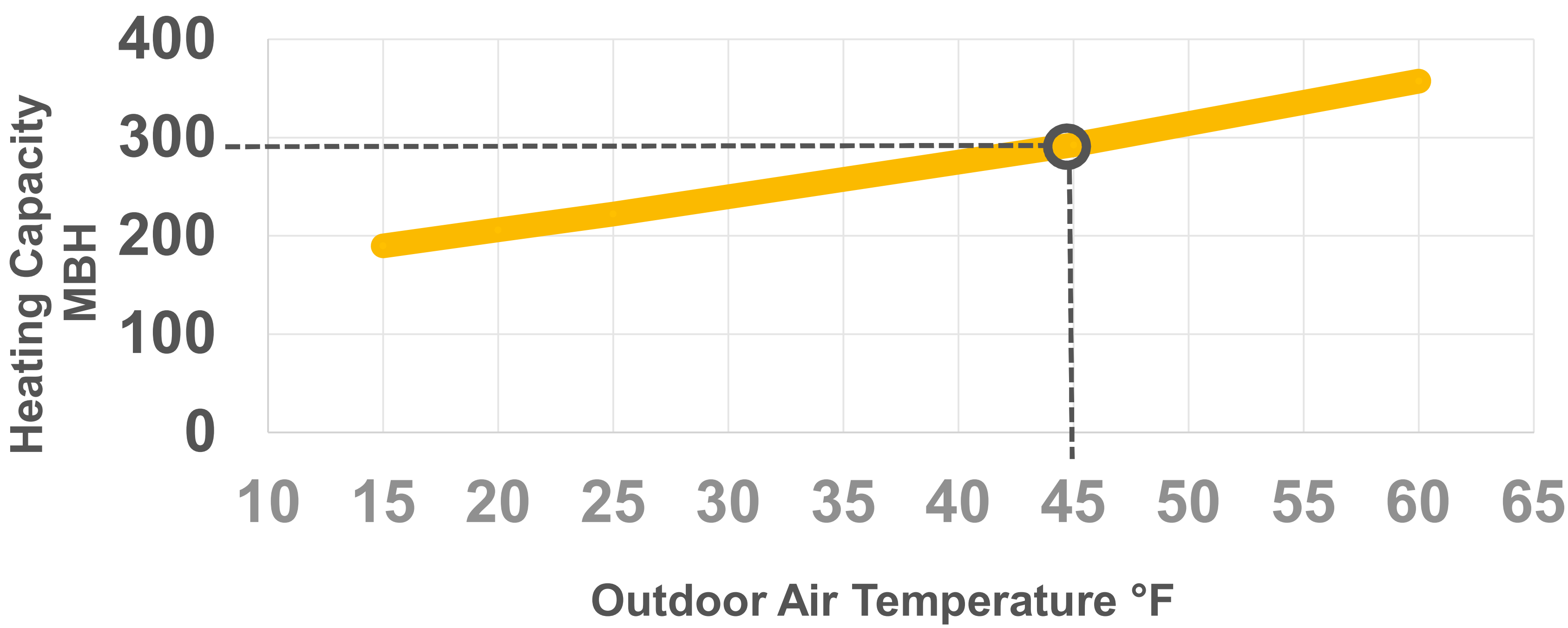
Boston

CITY of BOSTON

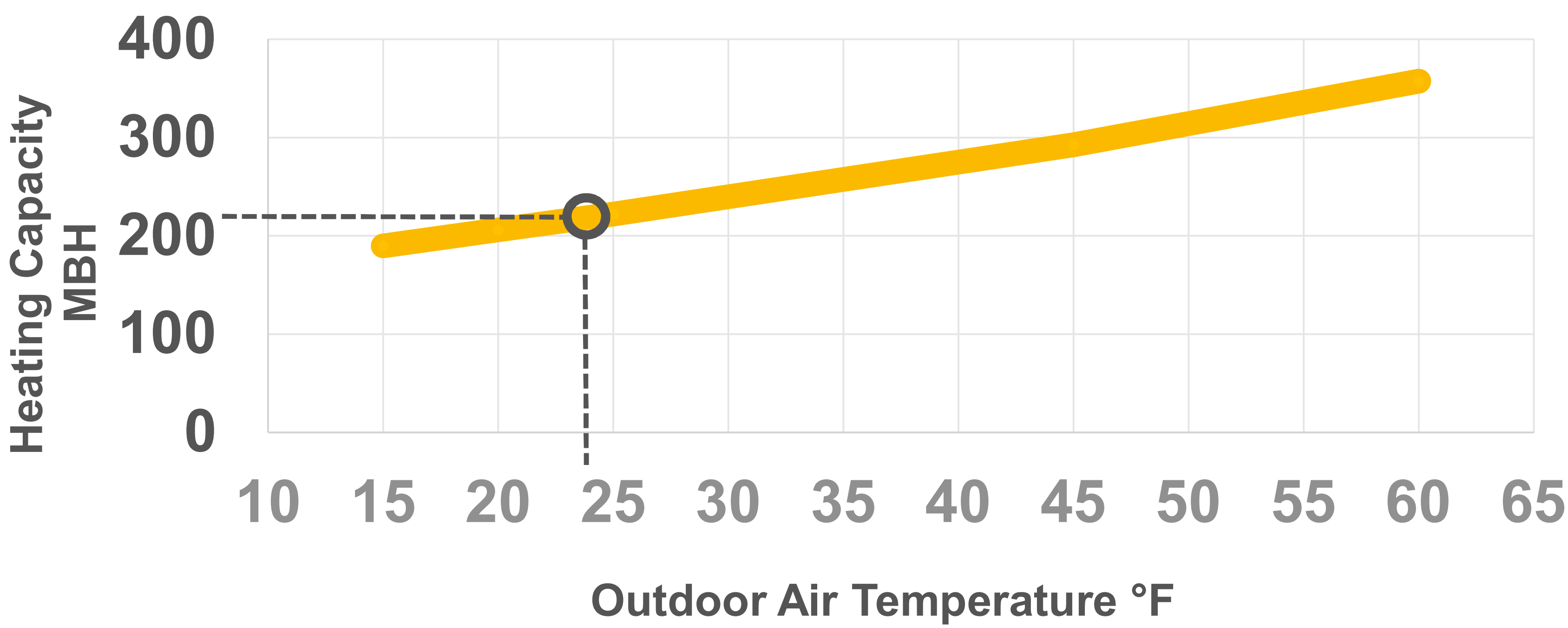
BERDO | Building Emissions Reduction and Disclosure Ordinance

- Report annual energy and water use
- Reduce greenhouse gas emissions over time
- Phased implementation approach
- Applies to:
    - Non-residential buildings 20,000 sq ft and larger
    - Residential buildings with 15 or more units
- In 2024, 5,884 buildings subject to BERDO reporting

Air To Water HP Capacity vs Ambient Temperature



Air To Water HP Capacity vs Ambient Temperature



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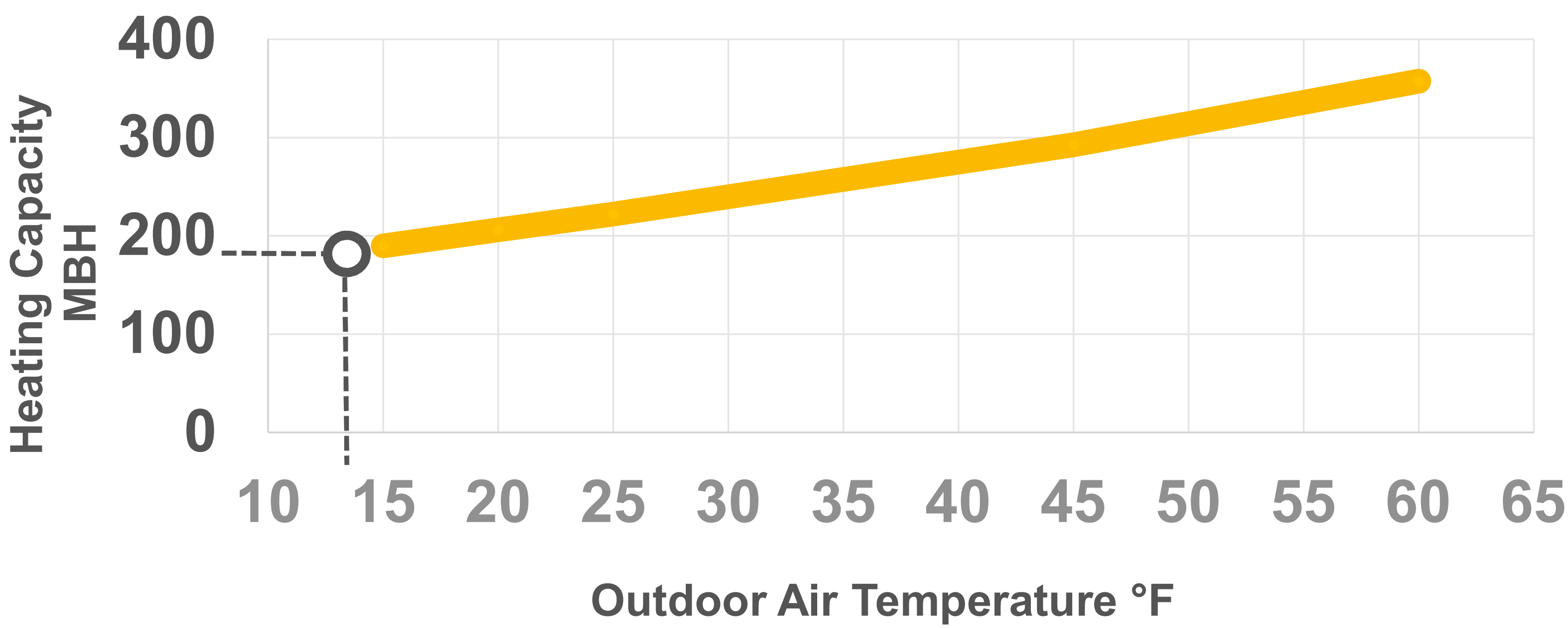
Air To Water HP Capacity vs Ambient Temperature



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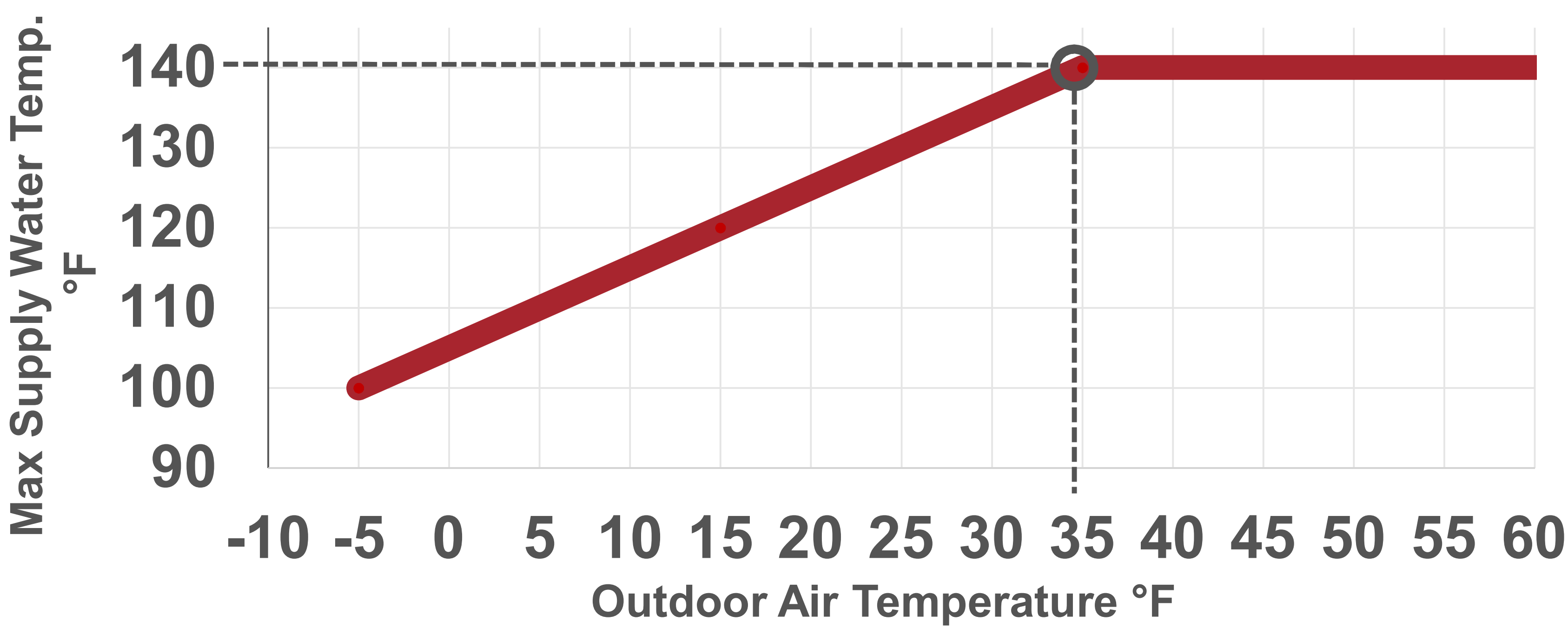
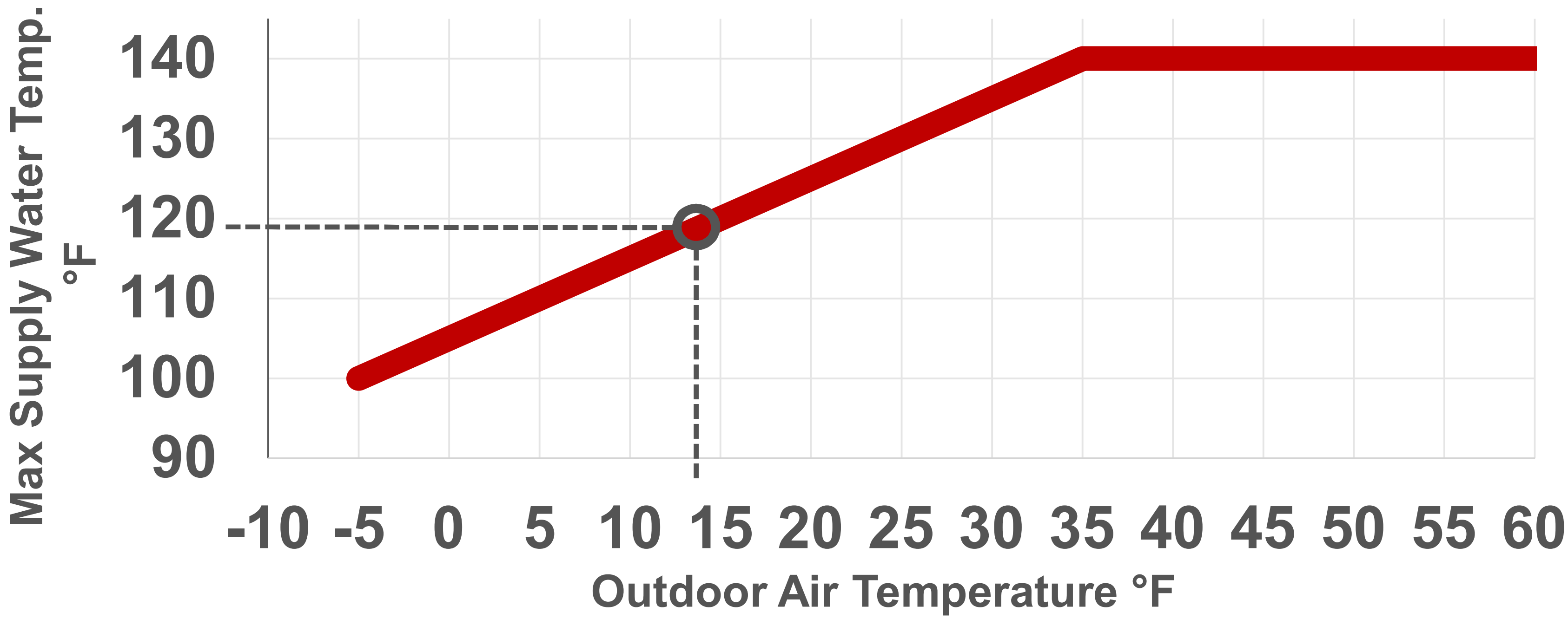
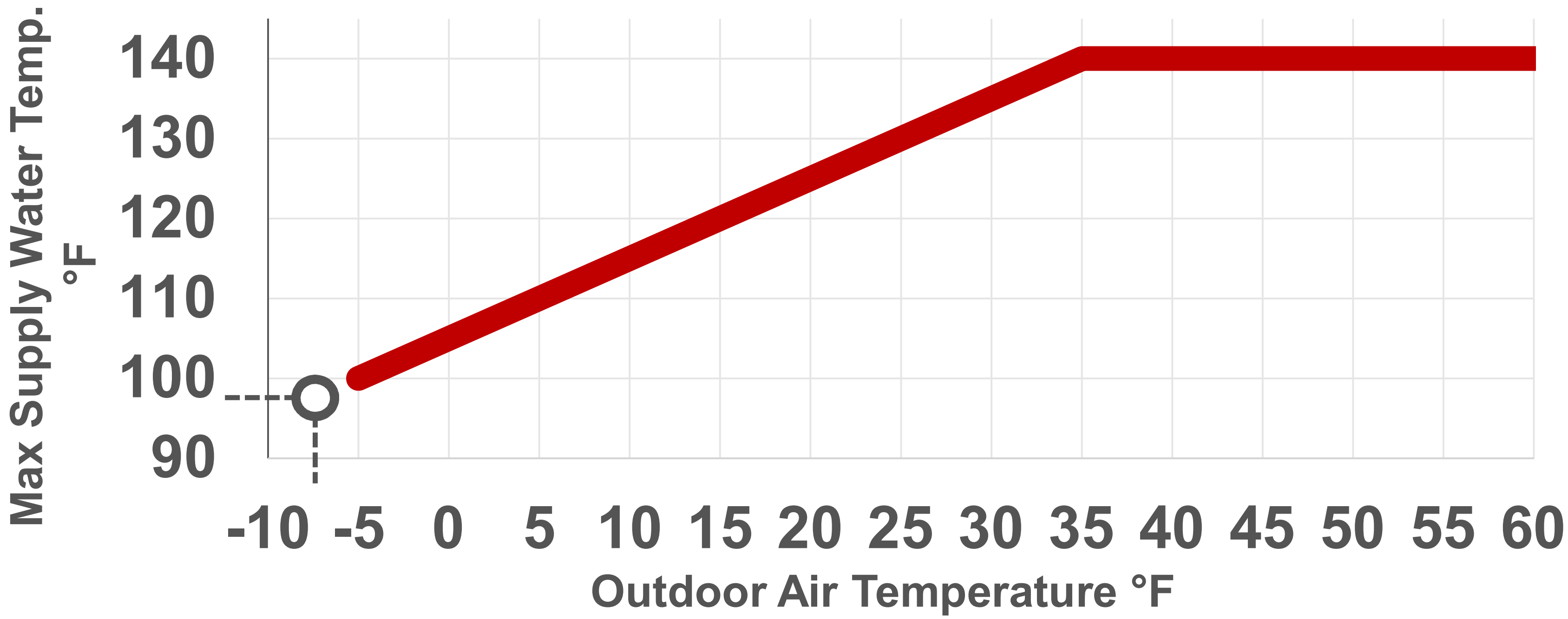
Supply Temperature vs Ambient Temperature



Supply Temperature vs Ambient Temperature



Supply Temperature vs Ambient Temperature



Q&A