De-Carbonizing the Campus: Planning, Tools & Technologies

CampusEnergy2023

February 27 – March 2, 2023

Gaylord Texan Resort & Convention Center | Grapevine, Texas

INTERNATIONAL DISTRICT ENERGY ASSOCIATION

High Capacity Transcritical CO2 Heat Pump for Human Comfort in Large Buildings

Jonathan Berney P.Eng, Emerson Canada

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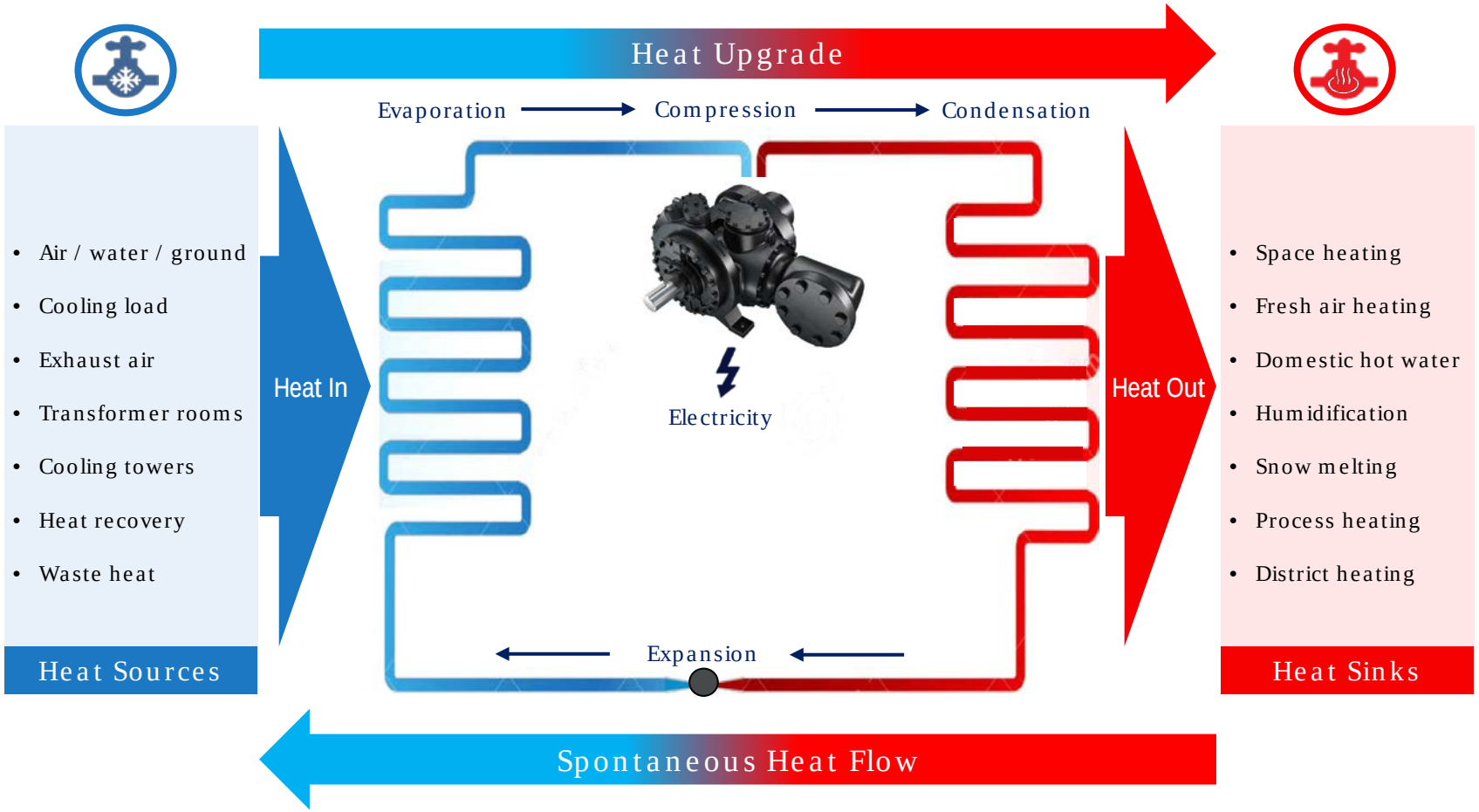
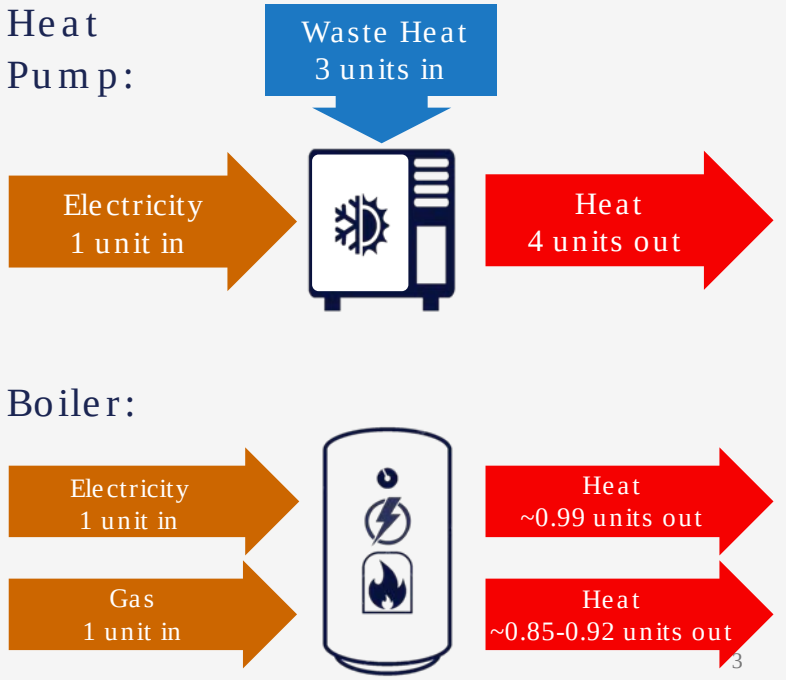
Heat Pump Fundamentals

Repurposing Available Waste Heat to Improve Operational Efficiency



Heating: Heat Pump vs. Boiler

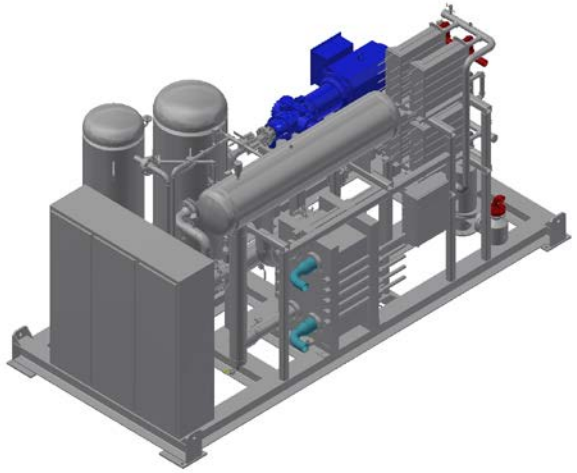


Next Generation Building HVACR Sustainability

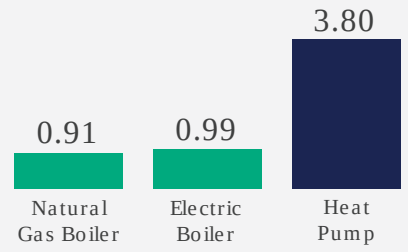
Eco-friendly heat pump solution designed to reduce greenhouse gas emissions and improve energy efficiency while offering load flexibility

Key Features

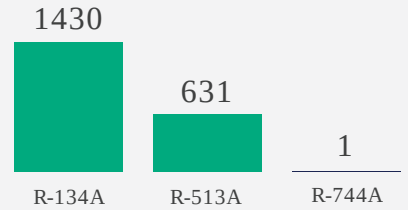
- High Efficiency Simultaneous Heating & Cooling
- Environmentally-Friendly (A1) Refrigerant
- Integrated Control System with Demand Response Functionality
- Single Screw Compression Technology
- Robust System Design for Maximum Durability
- Engineered Solution Built in North America



Heating Efficiency (COP)



Global Warming Potential



Applications Space Heating | Domestic Hot Water | Chilled Water

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Demonstration Project: Hydro Quebec

Shawinigan, Quebec, Canada

Heat Pump Showcased in Simulated Lab Environment

- Vilter customized heat pump system supplies hot/cold water for space heating/cooling and domestic hot water applications
- Solution performance and dynamic control system validated at real building conditions
- Installed System: Heating: 1,350 kW (4.6 MMbtu/h) | Cooling: 953 kW (3.2 MMbtu/h)
- 10,000+ hours of operation since system was commissioned in 2020

Canada's Largest Utility Interested in Demand-Side Grid Flexibility

- Electrification of buildings will increase peak demand on transmission system
- The transition from natural gas to electric boilers can increase peak demand by 140%
- Building space/water heating is a valuable source of grid flexibility when smart controlled heat pumps are integrated and combined with thermal storage

Sustainability Performance – 10,000 Hours of Operation

Greenhouse Gas Reduction:

- 99.6% less emissions than comparable boiler/chiller for savings of 2476 tonnes of CO_2

Electricity Consumption Savings:

- 61.7% lower energy spend than comparable boiler/chiller for savings of $628,884

EMERSON

Hydro Québec

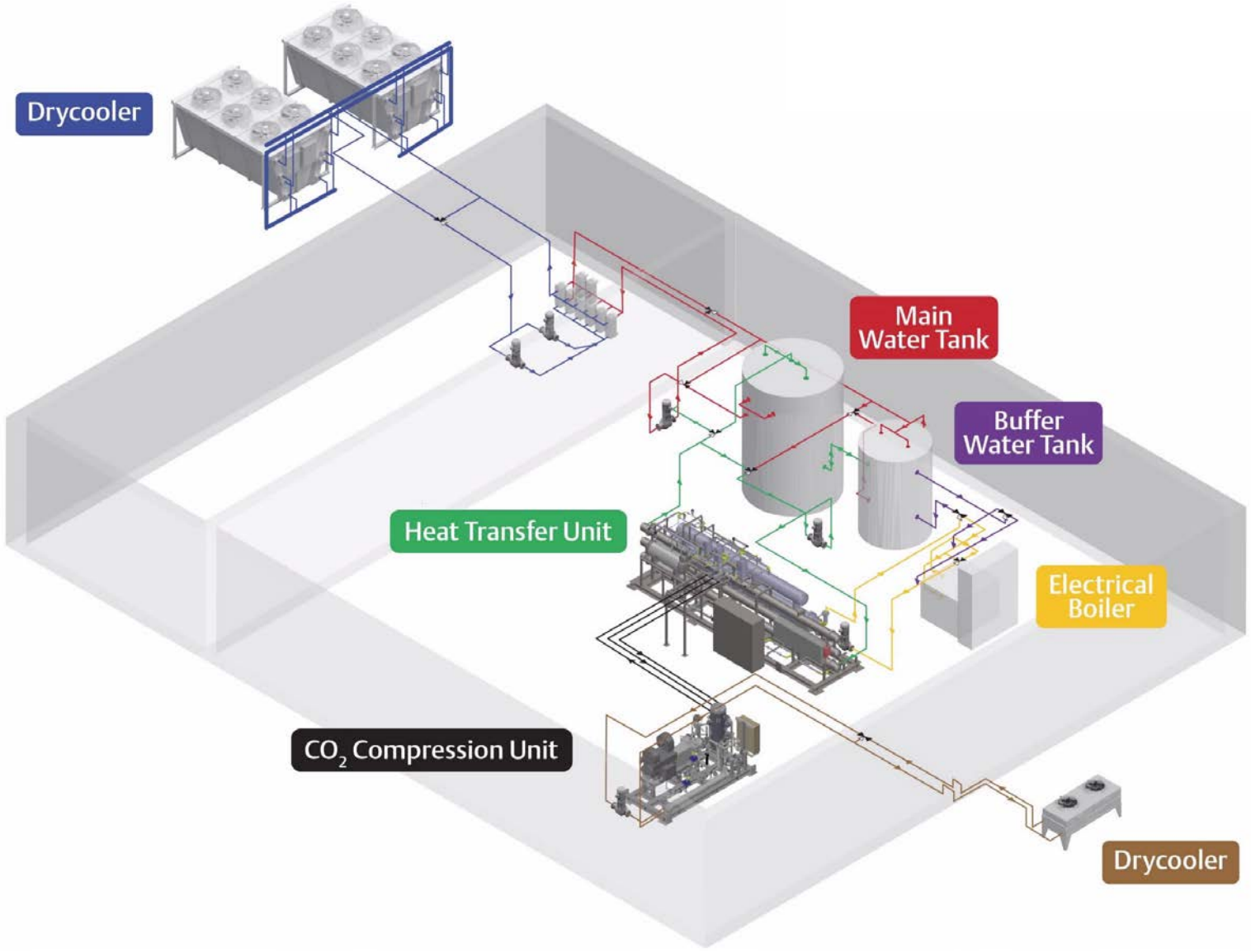
Hydro Quebec Energy Technologies Lab (LTE)

Technical Information

VHP System Overview	
System Configuration	Water to Water, Single Stage
Refrigerant	R744 (A1 Safety Class, GWP = 1, ODP = 0)
Controls	Emerson MAS CPL410 PLC (BACnet capability)
Compressor	Single Screw (VSS)
Maximum Operating Pressure	1,550 psig (106 bar)
Maximum Motor HP / Speed	865 HP (645 kW) / 4,300 RPM
Capacity Modulation	VFD
Certifications	UL & CSA with CRN
Typical Applications	Water heating, space heating/cooling, industrial processes
Unit Performance	
Heat Source Inlet Temperature	50°F to 70°F (10°C to 21°C)
Heat Sink Outlet Temperature	Up to 160°F (71°C)
Heat Sources	Lake/sea/river, ground, heat recovery, waste heat
Capacity Per Unit	Heating: Up to 1,700 kW (5.9 MMbtu/h) | Cooling: Up to 1,300 kW (4.3 MMbtu/h)
Efficiency (COP)	Up to 6.4 (combined heating and cooling)*

*Under normal heating conditions at 65°F heat source water and 140°F heat sink requirement. Efficiency may vary depending on the type of heat exchangers utilized.

HP Unit Tested at Real Conditions at Hydro Quebec Energy Technologies Laboratory (LTE)

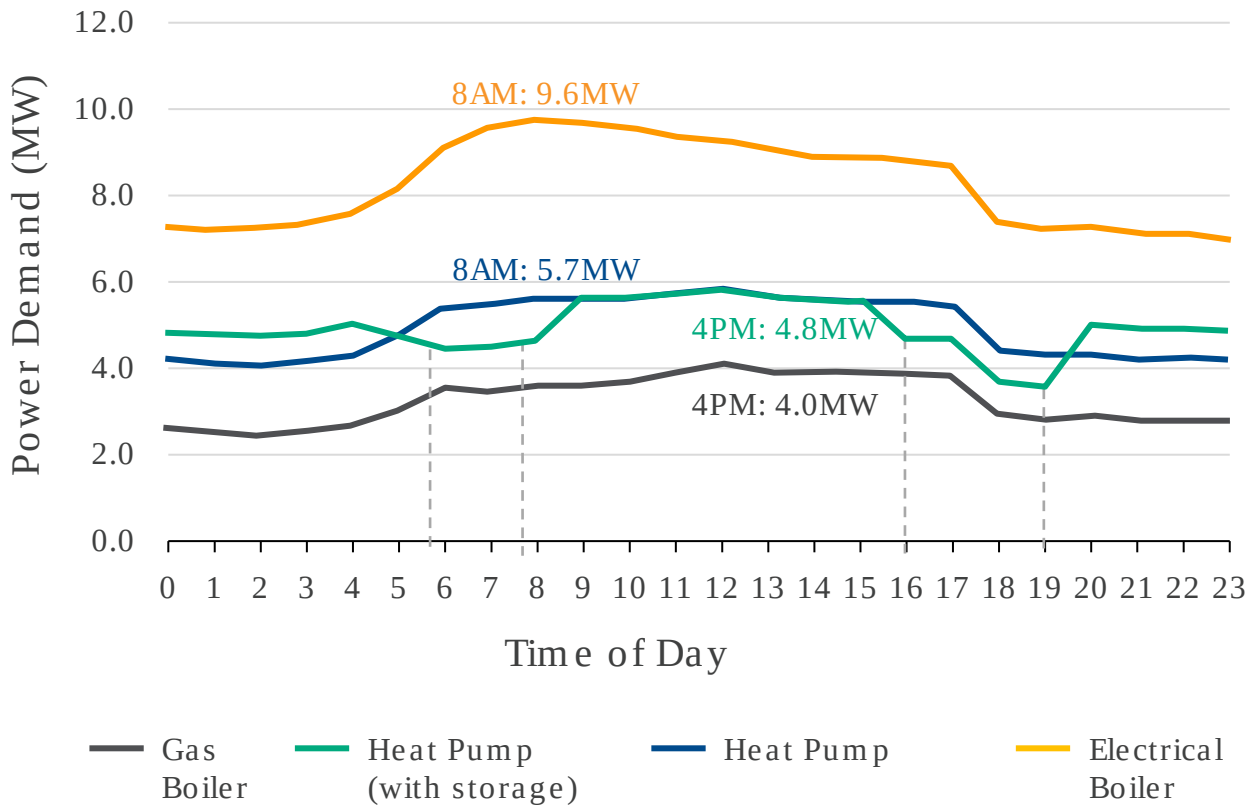


Live Testing Update from Shawinigan

- Simulated lab environment provides an opportunity to demonstrate and validate heat pump performance at real building conditions
- **11,000+** hours of operation

Utilities are Interested in Heat Pump Technology to Reduce the Impact of Space Heating Electrification on Power Demand

Power Demand (MW)
Large Commercial Building (Quebec, Canada)



PEAK DEMAND ENERGY MANAGEMENT

- Combining the heat pump with heat storage will reduce power demand during peak hours
  - Electrical boilers can increase peak loads by ~140%
- Heat storage helps to perform demand side management and allows the heat pump to run at its optimal (efficient) point of operation
- The use of a heat pump increases the power demand by a manageable percentage, much less than an electrical boiler

Interaction with Building Management System

Dynamic Control Platform Enables Participation in Demand Response Events

Dynamic L2 Control

Demand Response Participation & Coordination
Demand response scheduling & alignment with utility pricing

Heating & Cooling Load Forecasting
Estimation of thermal loads based on past & current data (artificial intelligence)

Reporting & Trends
Real time visualization and storage of historical data

Cloud (Web Platform)

DR & Weather Inputs for L2 Control Platform

Utility Smart Meters
Demand response & pricing signals

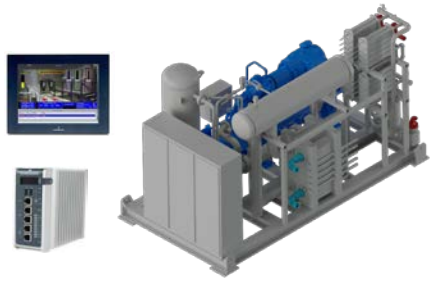
Weather Forecast
Local temperature conditions

External Data

Historical Building Data

Heat Pump with L1 Control

Packaged heat pump with industrial PLC control and local HMI



Heat Pump Data & Operation

Thermal energy production, state of charge

Energy Storage

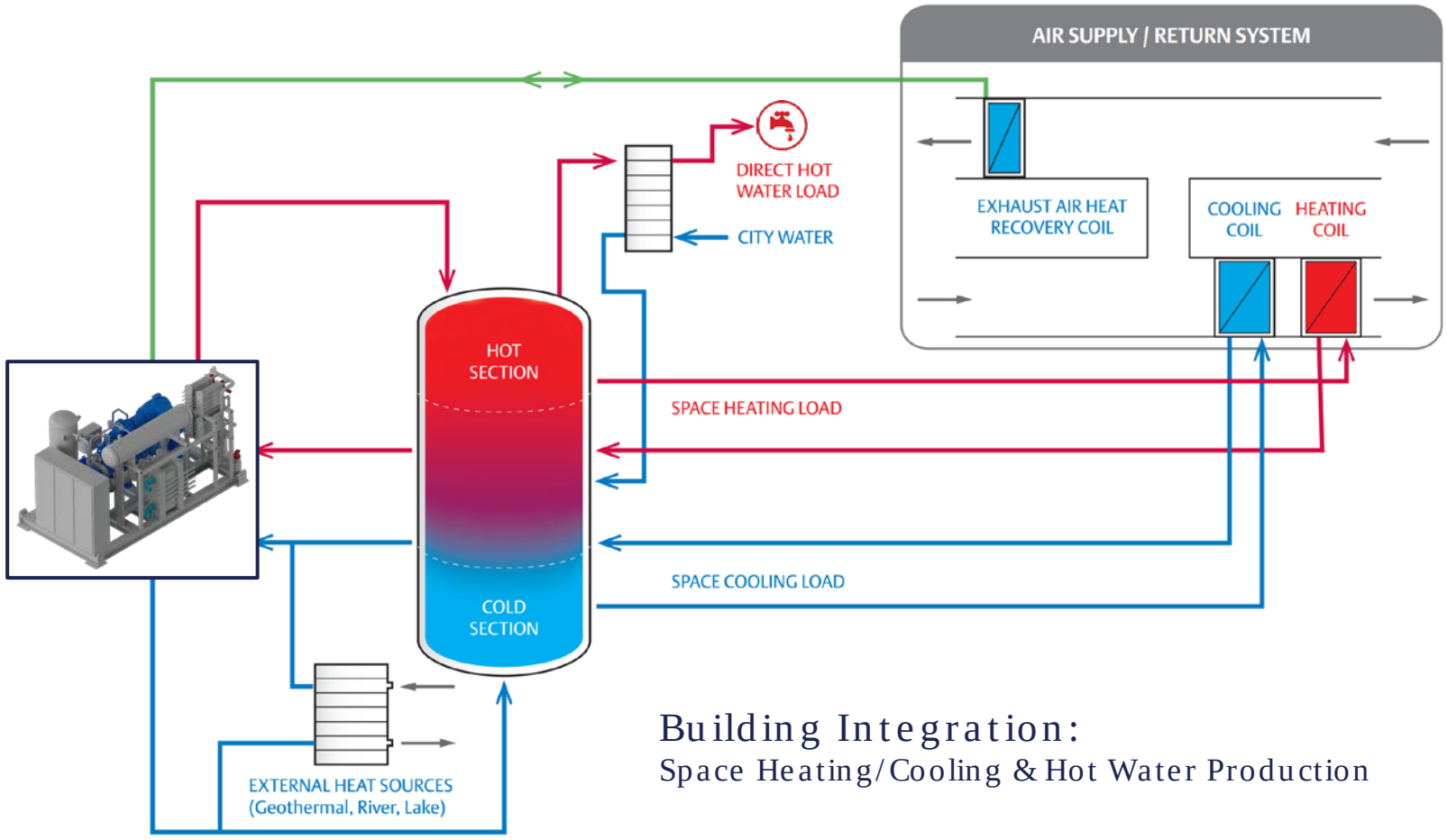
Thermal storage tank

Building Management System

Local to Building

High Efficiency Simultaneous Heating & Cooling

Designed for Building HVAC, District Energy & Industrial Processing Applications



Building Integration:

Space Heating/Cooling & Hot Water Production

Sustainable Thermal Design

Integrated Solution:

- Heat pump system upgrades heat from a heat source and transfers it to a stratified water storage tank for use in domestic hot water, space heating, and chilled water applications

Heat Sources:

- Air, water, ground (geothermal)
- Cooling load
- Exhaust air
- Transformer server rooms
- Cooling towers
- Heat recovery

Heat Sinks:

- Space heating
- Domestic hot water
- Humidification
- Snow melting
- Fresh air heating
- District heating

25 Year Comparison: GHG Emissions & Energy Consumption

Data Inputs

	Montreal, QC	Toronto, ON	New York, NY	San Jose, CA
Heating Capacity Required	1350 kW			
Cooling Capacity Required	950 kW			
Heat Pump Efficiency (COP)	6.4 combined (3.8 heating)			
Electric Boiler Efficiency (COP)	0.99			
Gas Boiler Efficiency (COP)	0.91			
Chiller Efficiency (COP)	4.2			
Electrical Energy Cost	$0.035 / kWh	$0.118 / kWh	$0.167 / kWh	$0.177 / kWh
Electrical Demand Cost	$13.43 / kW	$4.75 / kW		
Electricity CO2 Emissions	0.003 kg / kWh	0.031 kg / kWh	0.169 kg / kWh	0.210 kg / kWh
Natural Gas Cost	$0.048 / kWh	$0.039 / kWh	$0.058 / kWh	$0.058 / kWh
Natural Gas CO_2 Emissions	0.181 kg / kWh	0.181 kg / kWh	0.181 kg / kWh	0.181 kg / kWh

All figures in $CAD. USD/CAD exchange rate = 1.304

25 Year Comparison: GHG Emissions & Energy Consumption

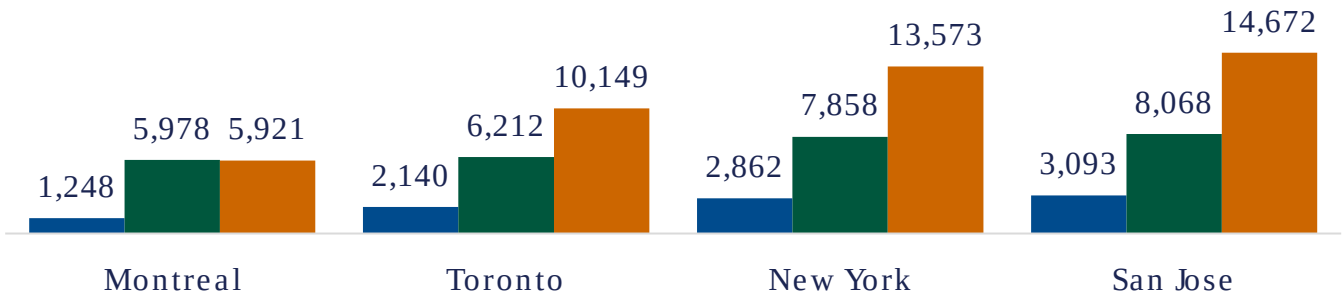
CO_2 Heat Pump vs. Alternative Heating & Cooling Technologies

Summary

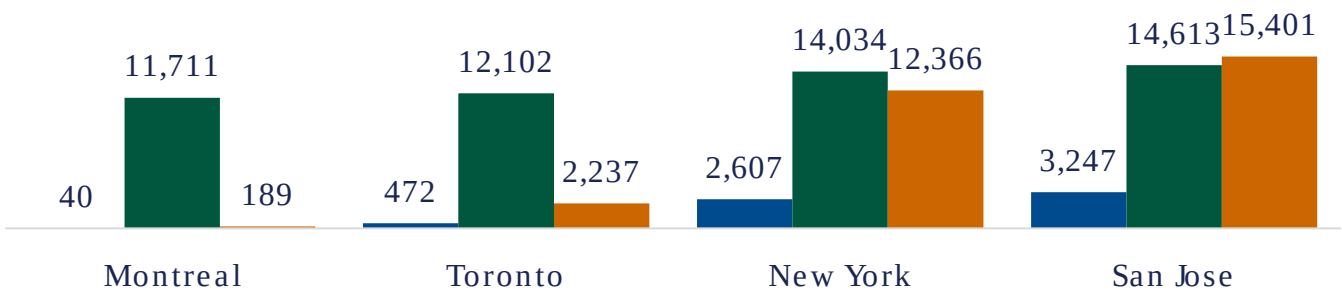
- 1,350 kW heating & 950 kW cooling
- CO_2 heat pump outperforms traditional boiler/chiller technology in every region:
  1. Energy Consumption
  2. Energy Cost
  3. GHG Emissions
- In Montreal (cleanest electricity region), the utilization of an electric boiler/chiller will cost an energy premium of $4.67M over 25 years ($186,920/yr)
- In San Jose, the utilization of an electric boiler/chiller will cost an energy premium of $11.57M over 25 years ($463,160/yr)

Energy Consumption
MWh

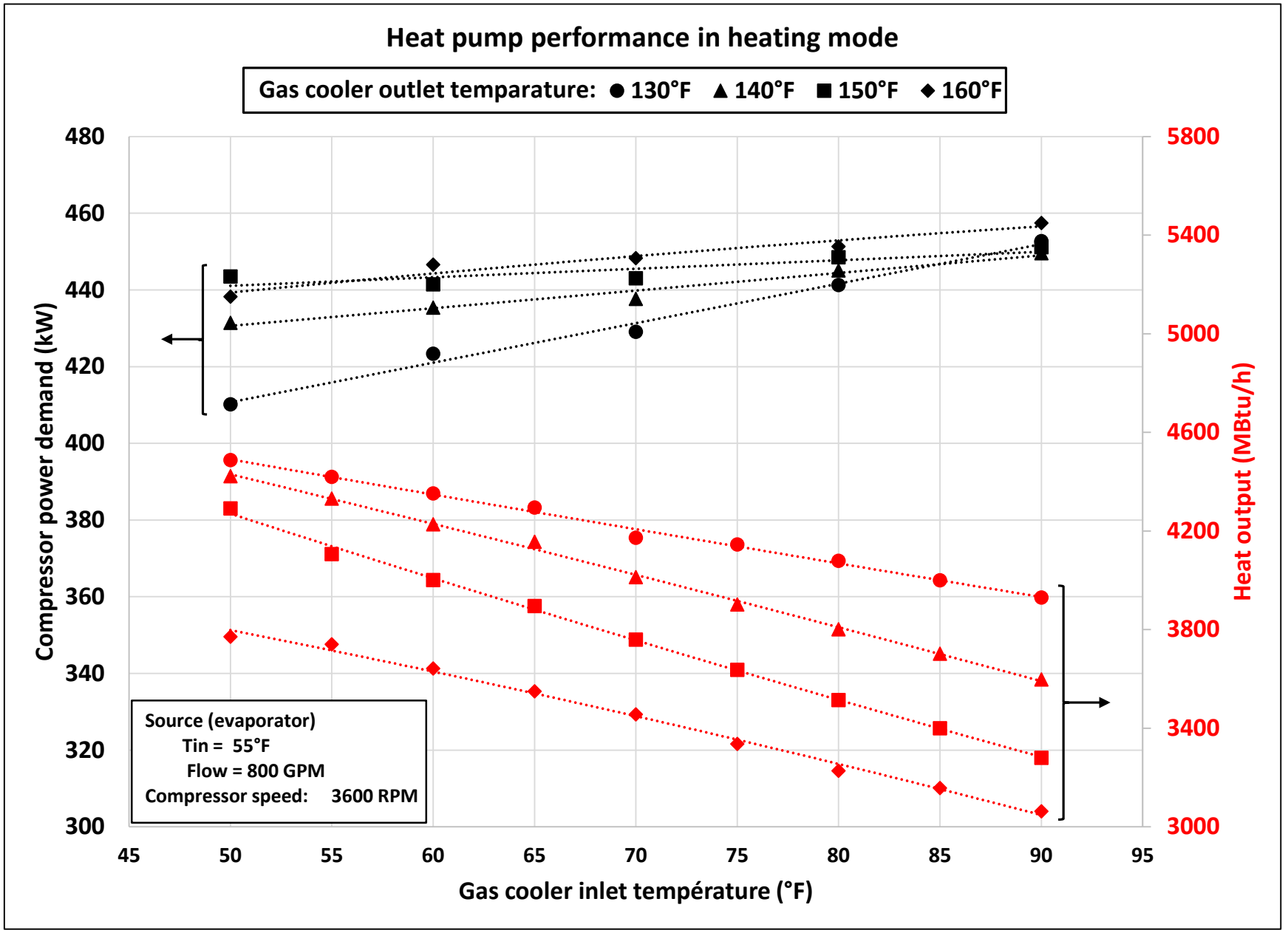
Energy Cost
$k (CAD)



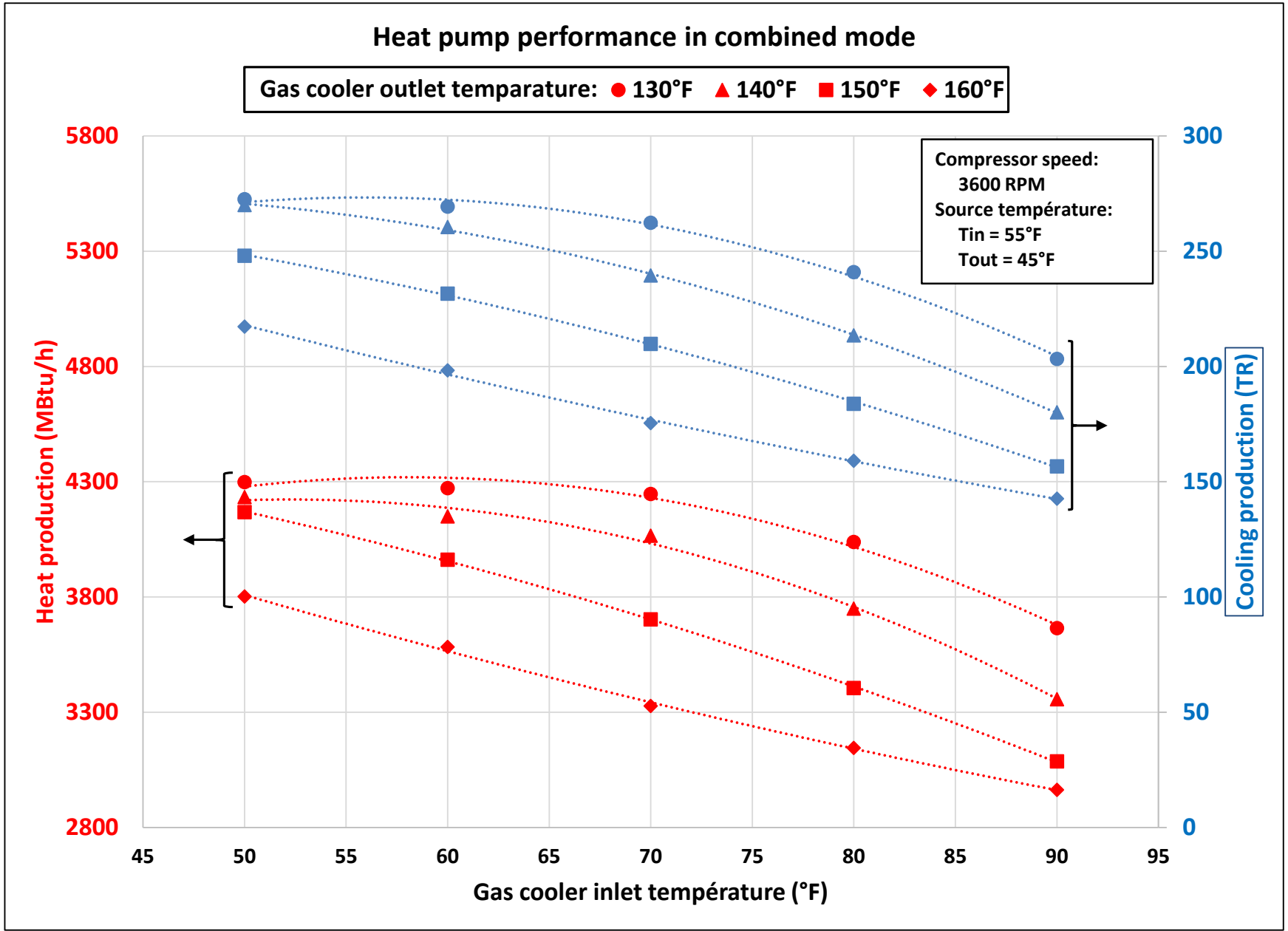
GHG Emissions
Tonnes of CO_2



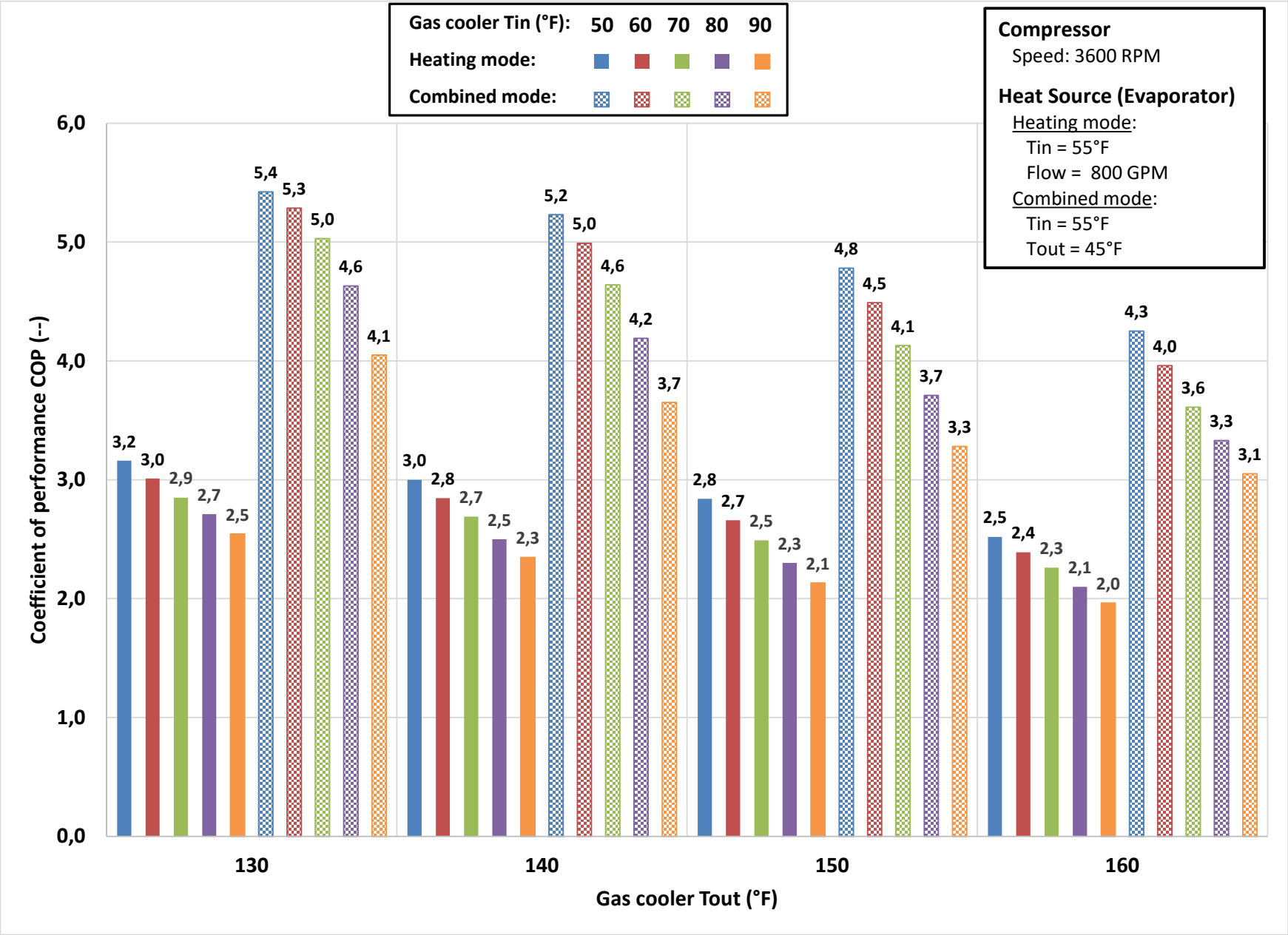
Heat Pump Performance



Heat Pump Performance



Heat Pump Performance



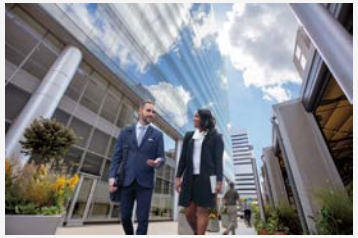
Greening Our Buildings & Industry Processes

CO_2 heat pump is an efficient, sustainable solution for use in new building projects and deep energy retrofit initiatives

Project Criteria

- Project Type: greenfield or deep energy retrofit
- Size of Heating: > 10,000 m^2 (107,000 ft^2)
- Suited for systems with base load temp of up to 180°F
- Performance is enhanced with simultaneous heating and cooling requirements
- Natural refrigerant solution with GWP = 1, ODP = 0 and no known TFA or chemical decomposition impact

Commercial Buildings



- Domestic hot water
- Space heating
- Fresh air heating
- Garage heating
- Chilled water

Food & Beverage Processing

- Preheat water
- Sanitization
- Bottle warming
- Ingredient water
- Pasteurizing
- Space heating
- Chilled water

Industrial Manufacturing

- Preheat water
- Sanitization
- Process heating
- Space heating
- Fresh air heating
- Chilled water

Other Industries

- Preheat water
- Process heating
- Vacuum pump cooling
- Fresh air heating
- Chilled water
- Space heating

Thank You!

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