NORTH AMERICAN Sustainable Refrigeration Council

NASRC
Sustainable Refrigeration Summit

Technology Focus: Total Cost of Ownership

Derek Gosselin – Director of Technical Product Support – Dover Food Retail
Andre Patenaude – Director Solution Strategy – Emerson Cold Chain

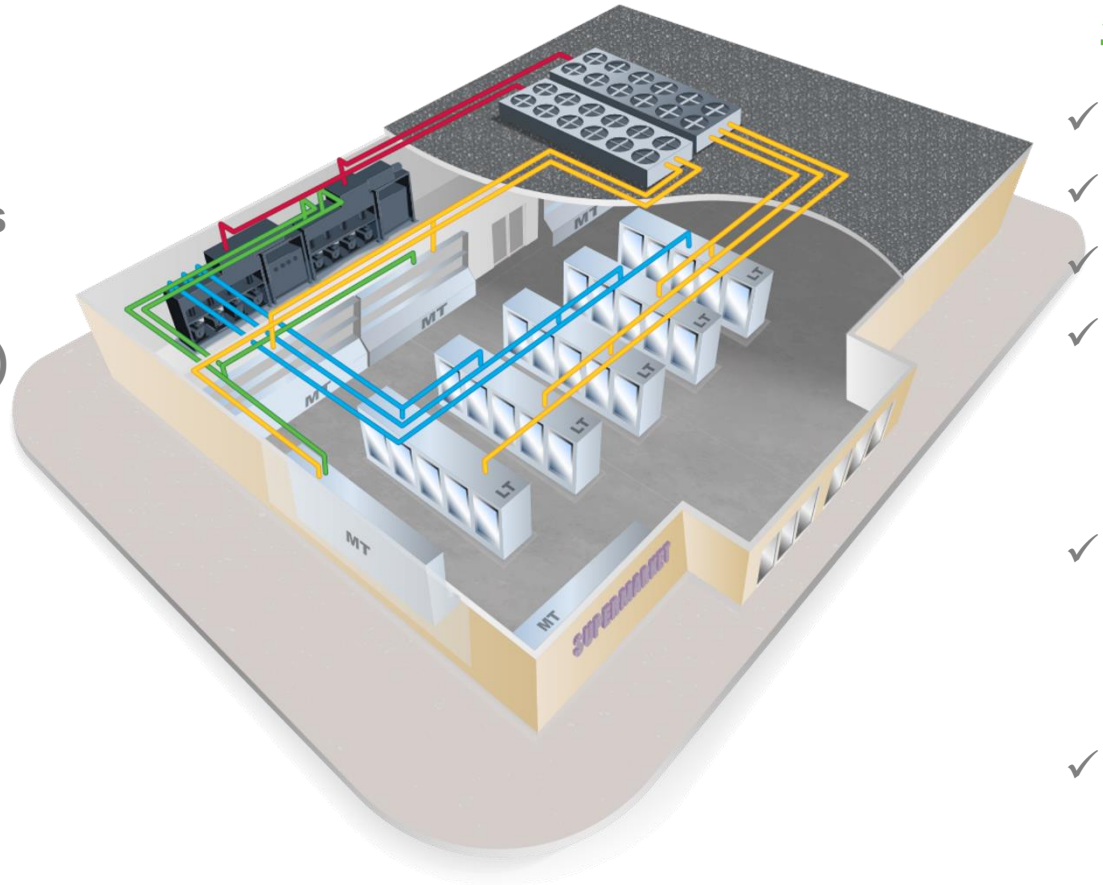
DOVER FOOD RETAIL

EMERSON

Total Cost of Ownership Study

Architecture Options

1. Centralized DX
2. Distributed Scroll Packs
3. Condensing Units
4. CO2 Booster (Adiabatic)
5. CO2 Booster
6. R290 Micro Distributed
7. Scroll Booster



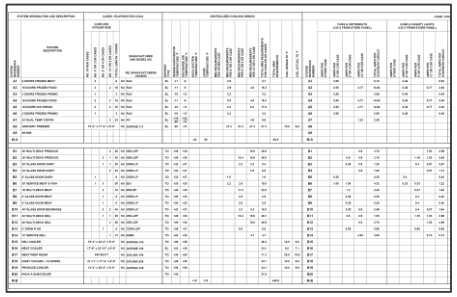
Specifications

- ✓ 25,000 ft^2 Store Size
- ✓ 450MBH MT (30 Cases + 5 Coolers)
- ✓ 91MBH LT (16 Cases + 1 Freezer)
- ✓ Schedules for each;
  - ✓ Refrigeration
  - ✓ Electrical
- ✓ Floor Plans for each;
  - ✓ Refrigeration
  - ✓ Electrical
- ✓ LCCP Analysis

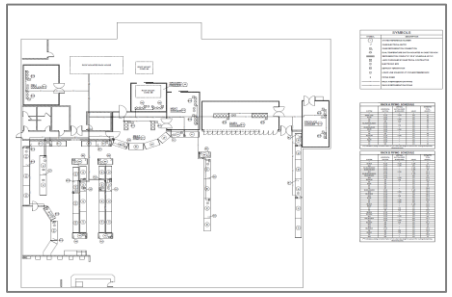
Desired Outputs: To understand the Total Cost of Ownership Relative to Centralized HFC
All Equipment, Installation, Commissioning, Service, Maintenance, Water Use & Energy over 20 years

Layout Consistent Across Systems
- 450MBH MT
- 91MBH LT

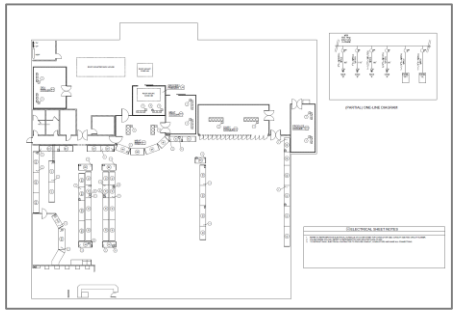
8x Refrigeration Schedules



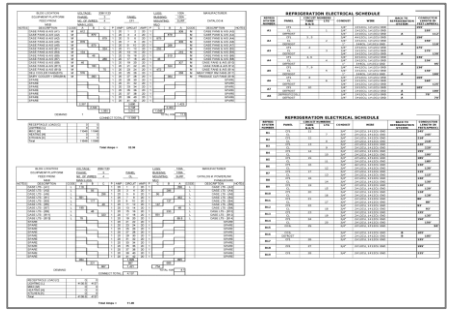
8x Refrigeration Floor Plan



8x Electrical Floor Plans



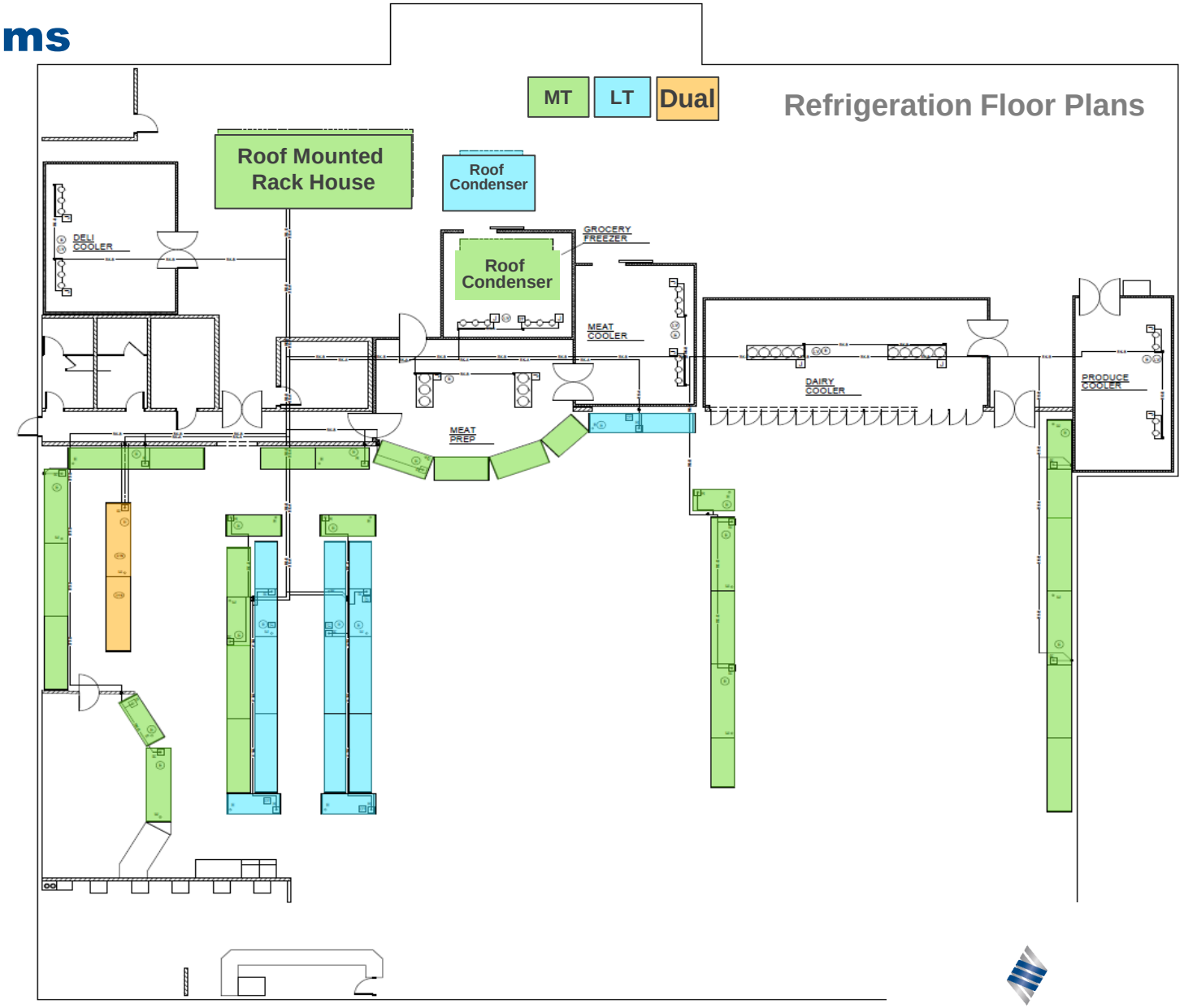
8x Electrical Schedules



25,000 ft² Store Size

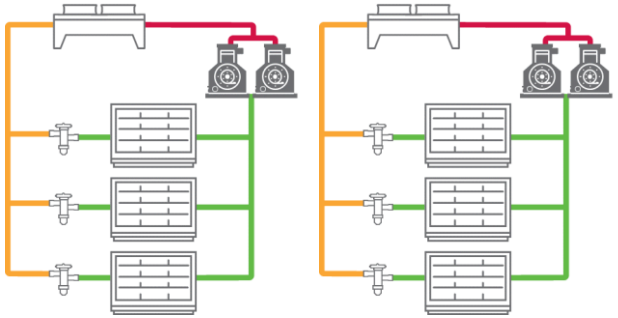
450MBH MT (30Cases + 5 Coolers)

91MBH LT (16 Cases + 1 Freezer)

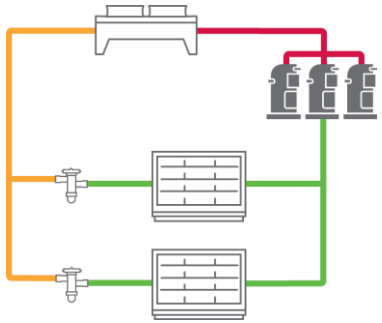


Total Cost of Ownership Study – Architectures

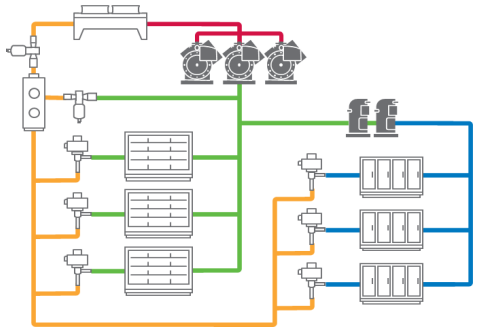
HFC Centralized R448/9A



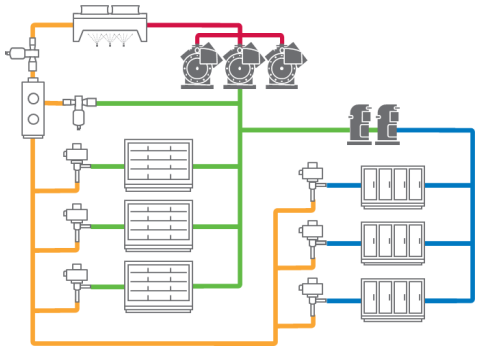
Distributed Scroll Pack R448/9A



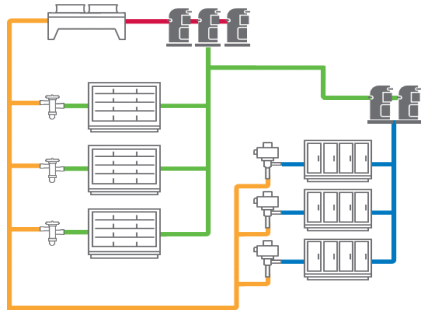
Transcritical Booster CO2 (Non-Adiabatic)



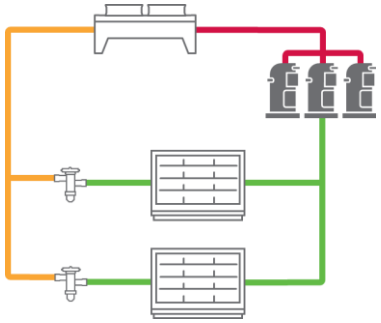
Transcritical Booster CO2 (Adiabatic)



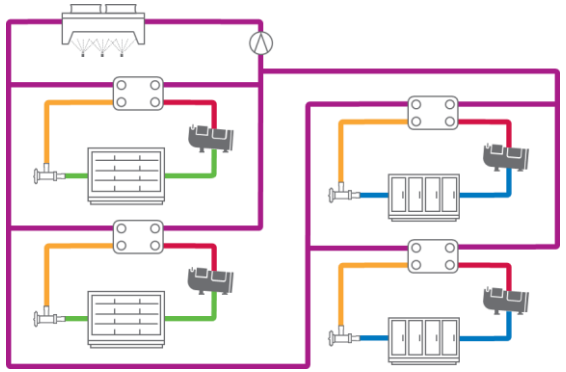
Scroll Booster R-513A LT Rack into MT Rack



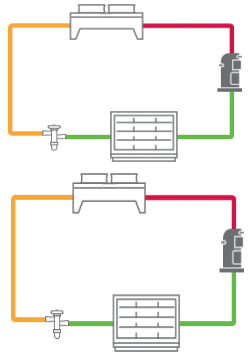
Distributed Scroll Pack A2L



Micro Distributed R290 Water Cooled



Single Condensing Units R448/9A



Location Assessments


Los Angeles

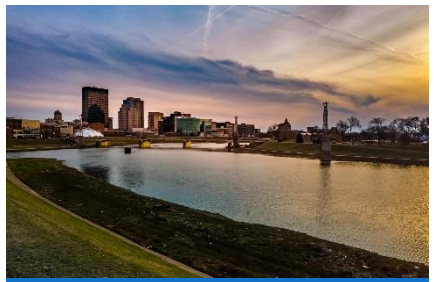

Bakersfield


Minneapolis


New York


San Francisco


Houston


Dayton


Atlanta

20 Year TCO

Energy
20 yrs
30% to 50%

Maintenance
20 yrs
20% to 30%

CapEx
25% to 40%

Emerson's

CO_2 Climate Zone Study

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Overview

- Selected 13 climate zones
  - ASHRAE and IECC
- Determine cities
- Compile ambient bin data
  - S.C. & T.C. hours for each
  - Dry and adiabatic hours
- Identify key strategies
- Build energy comparison
- Additional technologies
- External variables

Desired Outcome of Study

To provide a guideline on comparing high ambient strategies for CO_2 transcritical booster systems for the Americas

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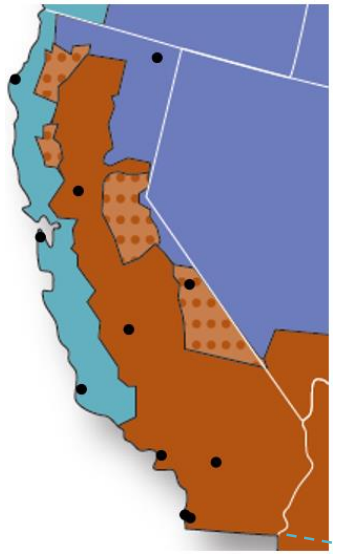
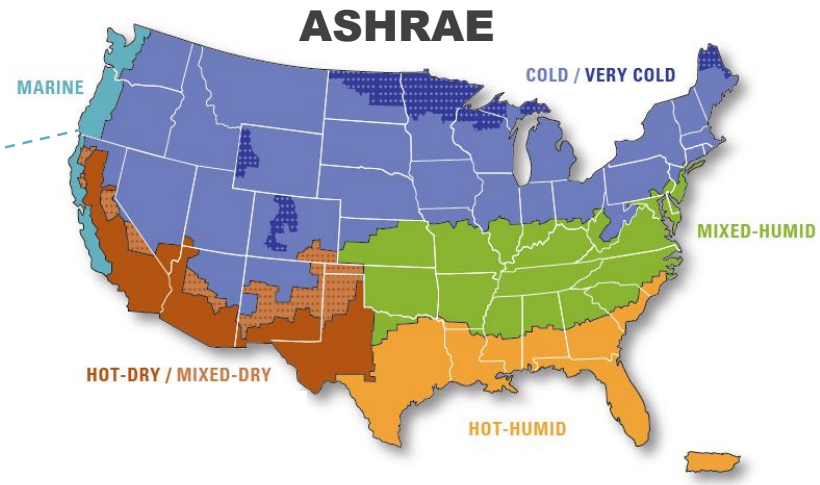
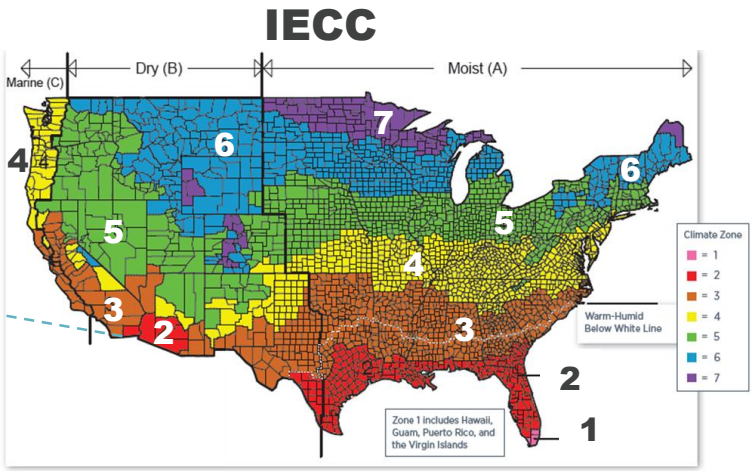
Climate Zone Categories

California
6 Zones







Select Climate Classifications

- California; 6 zones
  - 10 cities identified
  - San Francisco is in climate zone category Marine 3C
    - ASHRAE (Marine), IECC = 3C

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Dry Gas Cooler
vs.
Adiabatic
Gas Coolers

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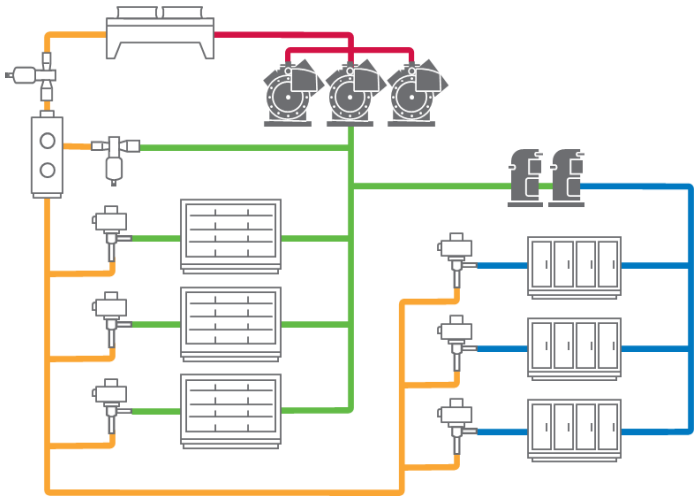
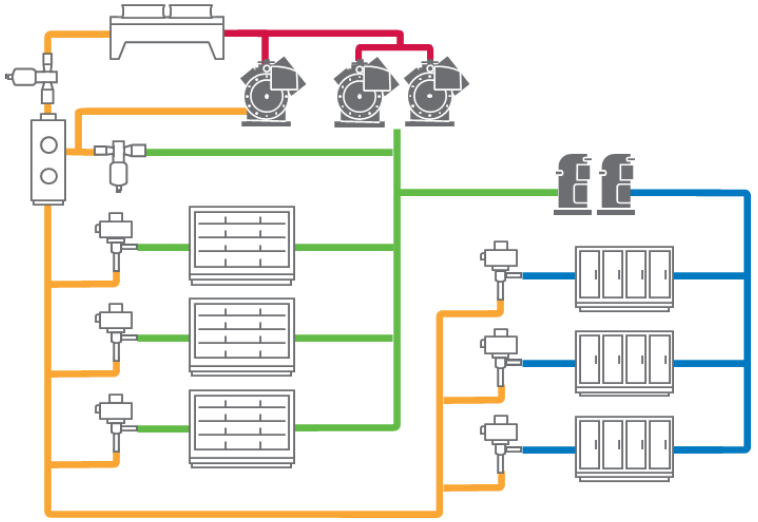
Additional Strategies Evaluated

Dry Gas Cooler + Parallel	Adiabatic Gas Cooler + Parallel	Dry Gas Cooler + Parallel + HP Ejector	Adiabatic Gas Cooler + Parallel + HP Ejector

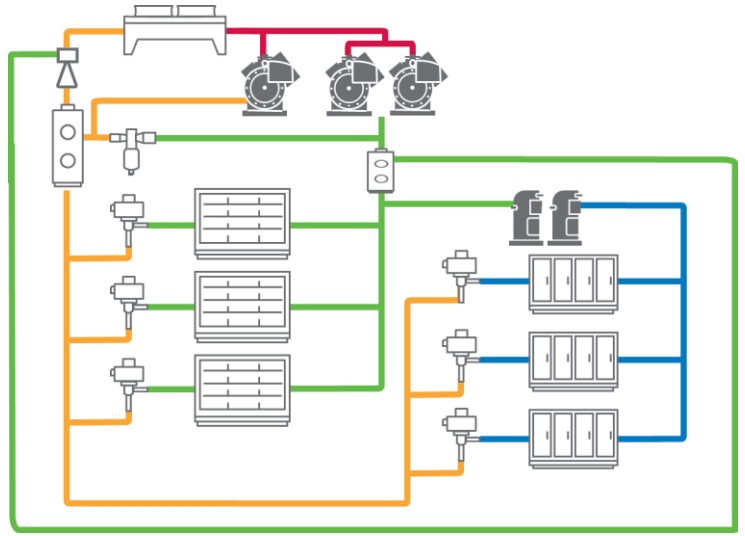
Dry Gas Cooler



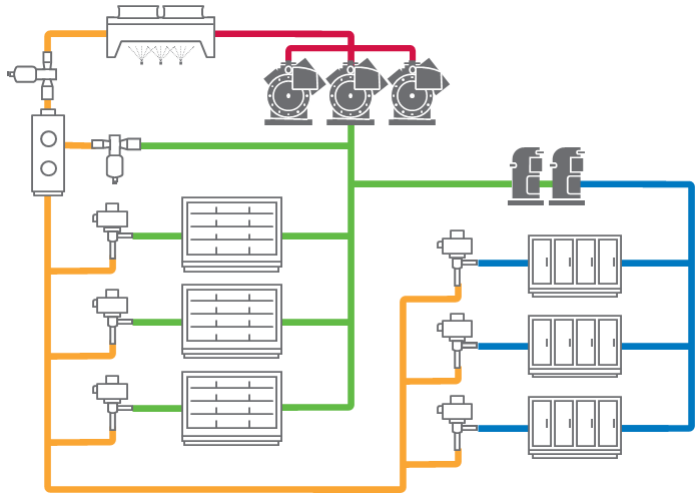
Dry Gas Cooler + Parallel



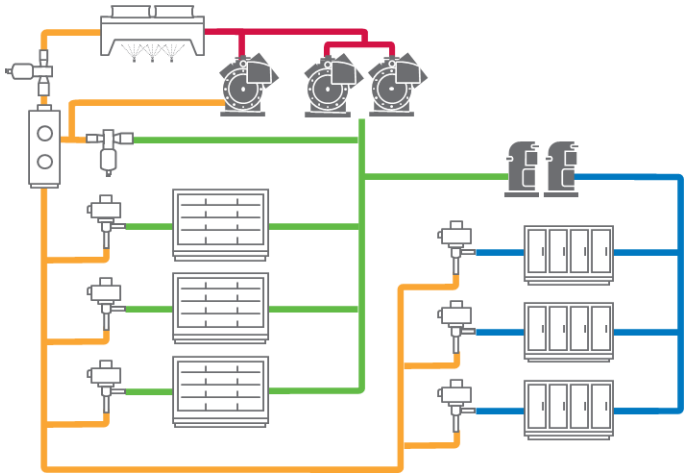
Dry + Parallel + HP Ejector



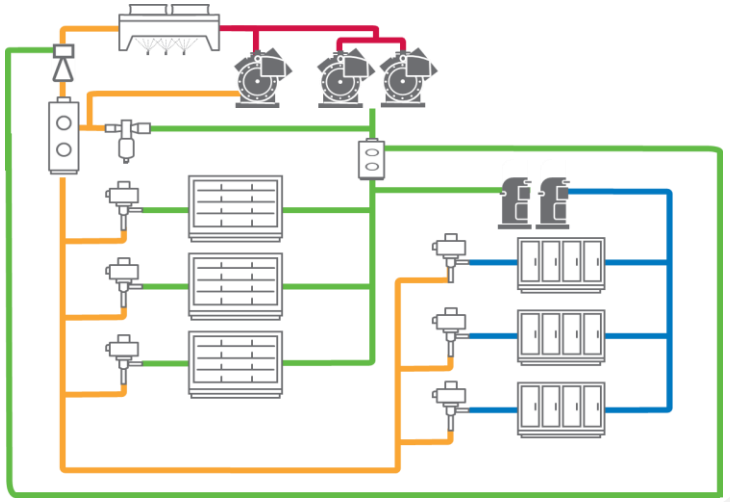
Adiabatic Gas Cooler



Adiabatic + Parallel



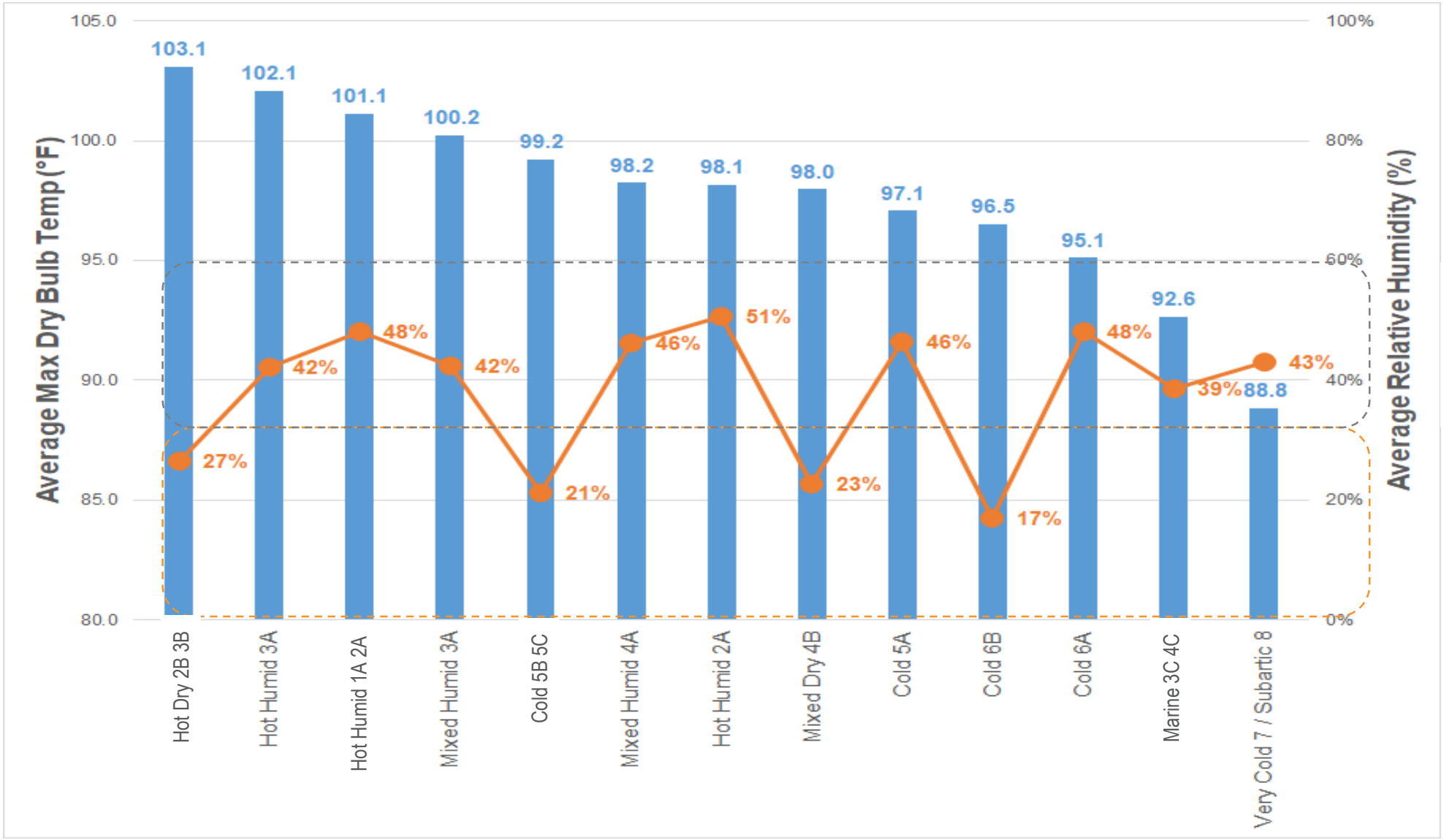
Adiabatic + Parallel + HP Ejector



Mechanical sub-cooling evaluated

Zero MT S.H. and liquid ejectors not part of high ambient study

Ave Max Dry Bulb and RH% Per Climate Zone



Parallel Compression Advantage over Adiabatic

Adiabatic Advantage Over Parallel Compression

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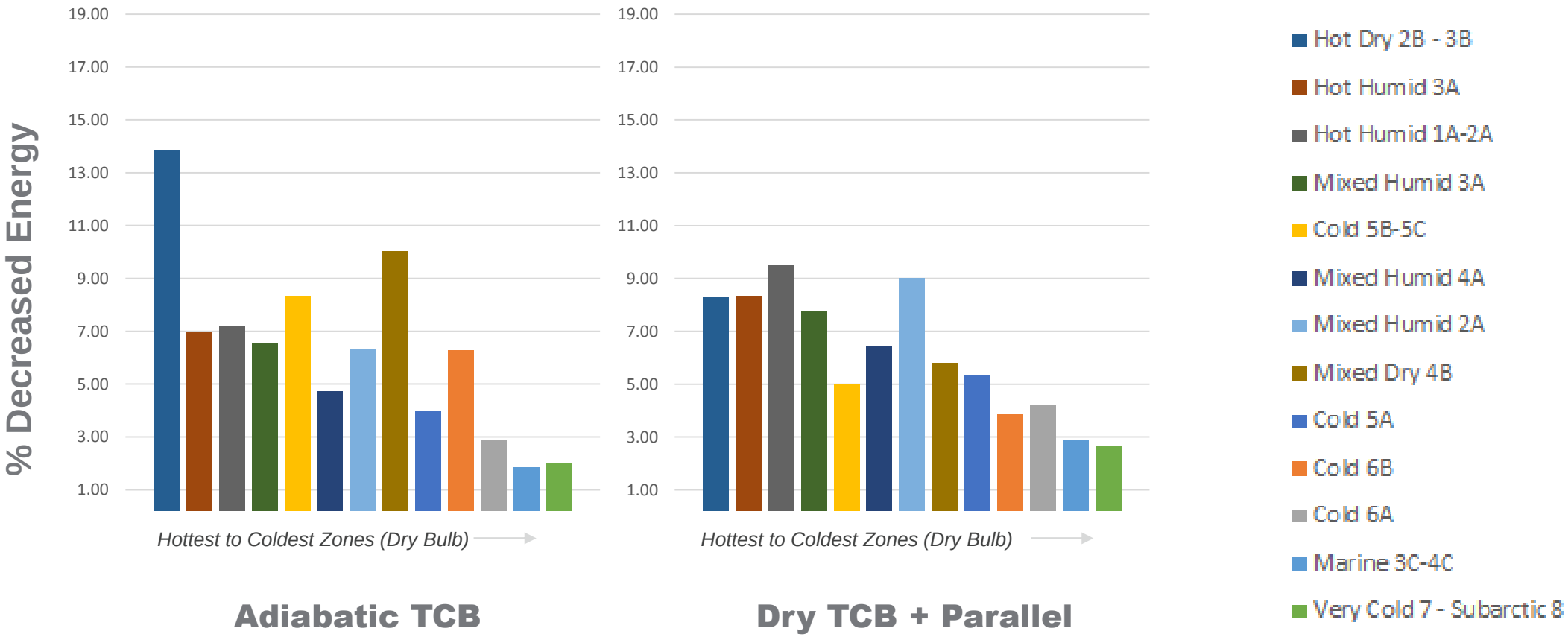
Percent of Energy Saving vs. Basic TCB Systems;
Charts Based on 13 Zones with Ave. Max Dry Bulb Temperatures



Weather Data: NREL TMY3 data, EES Software, 400MBH MT +18SST, 100MBH LT -20F

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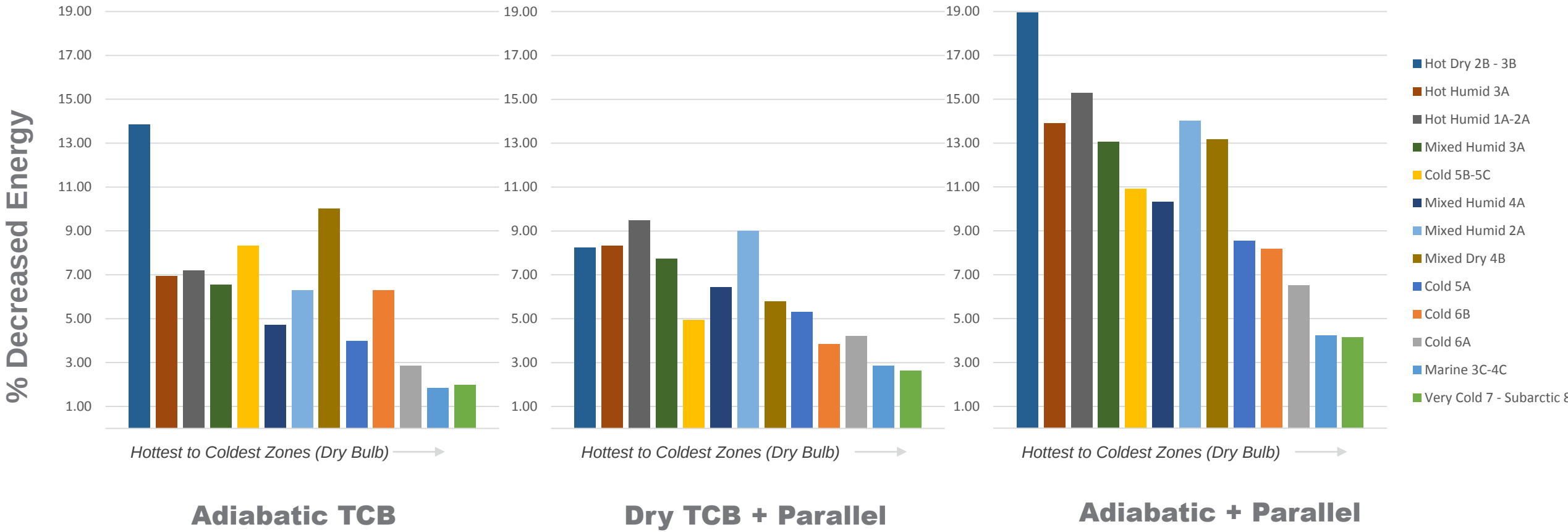
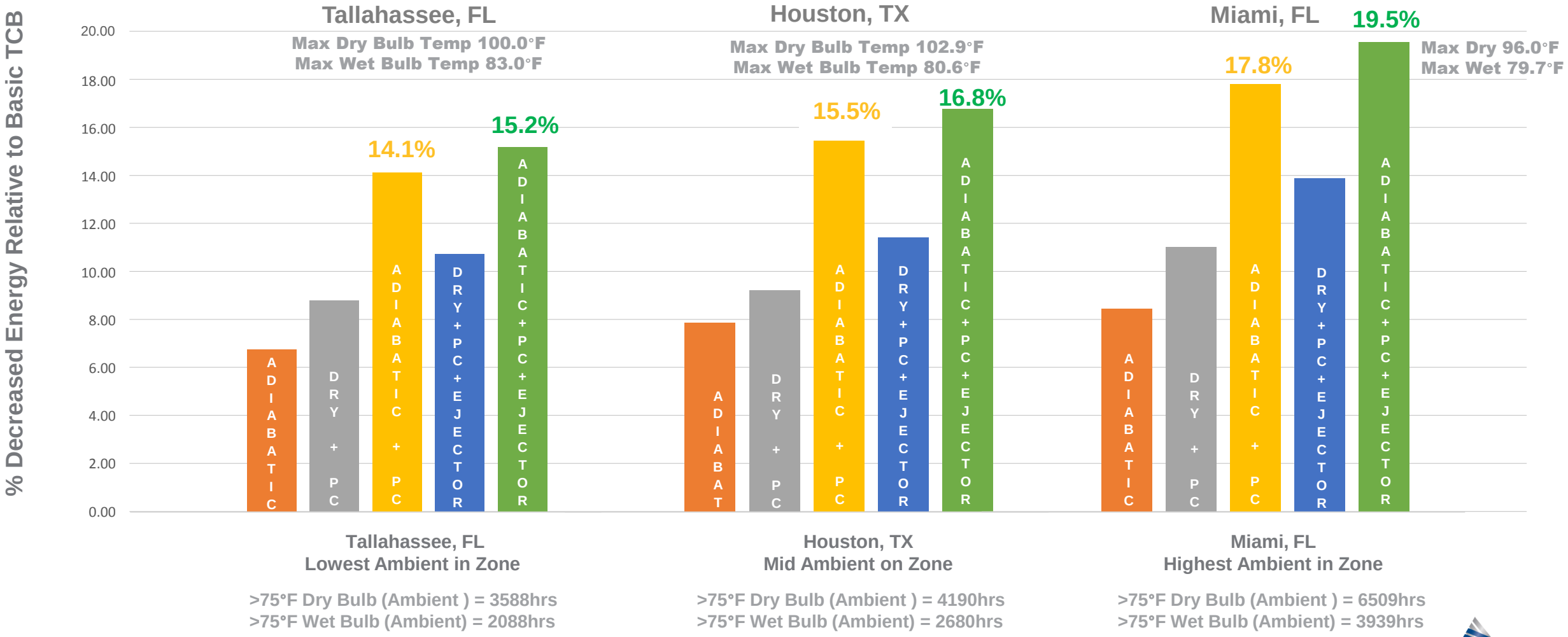


Weather Data: NREL TMY3 data, EES Software, 400MBH MT +18SST, 100MBH LT -20F

Hot Humid 1A, 2A Climate Zone with 10 Cities



Tallahassee, FL
Lowest Ambient in Zone

>75°F Dry Bulb (Ambient) = 3588hrs
>75°F Wet Bulb (Ambient) = 2088hrs

Houston, TX
Mid Ambient on Zone

>75°F Dry Bulb (Ambient) = 4190hrs
>75°F Wet Bulb (Ambient) = 2680hrs

Miami, FL
Highest Ambient in Zone

>75°F Dry Bulb (Ambient) = 6509hrs
>75°F Wet Bulb (Ambient) = 3939hrs

Weather Data: NREL TMY3 data, EES Software, 400MBH MT +18SST, 100MBH LT -20F

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Additional Considerations

Electrical rate

Rate structure, peak demand charges

Water resources

Availability, cost, sewage charges

Service and maintenance skill levels

Regional CO_2 experience or knowledge gap

Heat reclaim

Volume and intensity requirements

Carbon intensity, electrical generation sources

Impact on Net-zero 2040 goals for scope 2 emissions

Carbon Credits

Summary

This study was commissioned to provide industry stakeholders with an unbiased third-party engineering evaluation of energy comparison of the most common high ambient strategies to support the uptake with CO_2 Transcritical booster systems for the supermarket industry.

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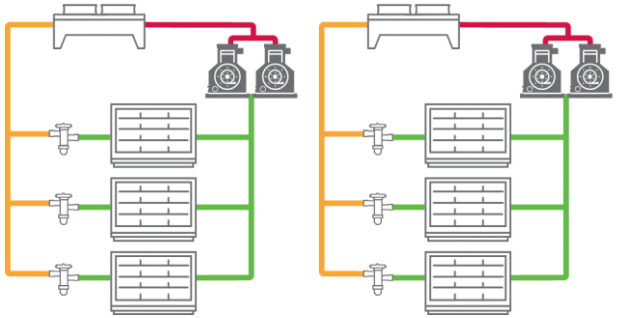
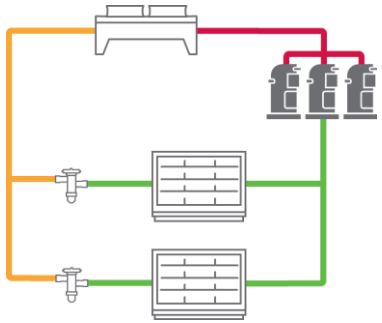
Total Cost of Ownership Study – Architectures

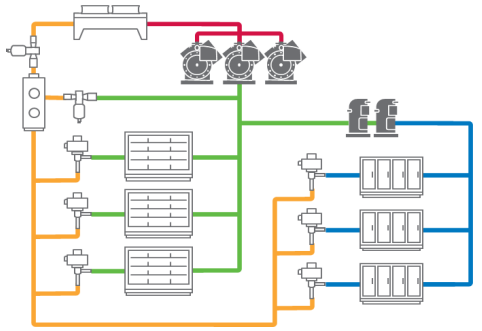
HFC Centralized
R448/9A



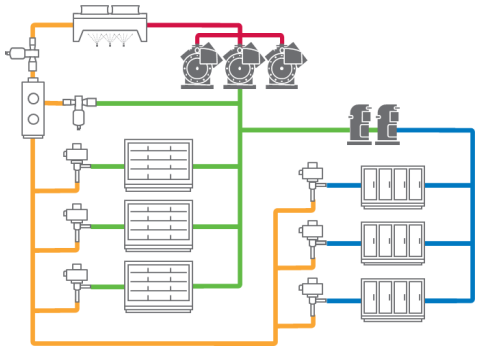
Distributed Scroll
Pack R448/9A



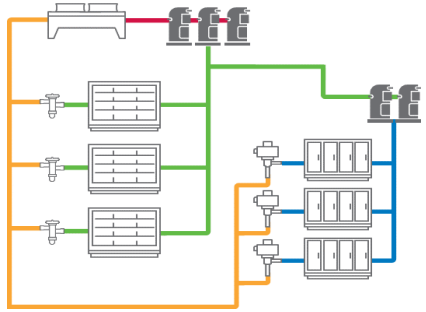
Transcritical Booster
CO2 (Non-Adiabatic)



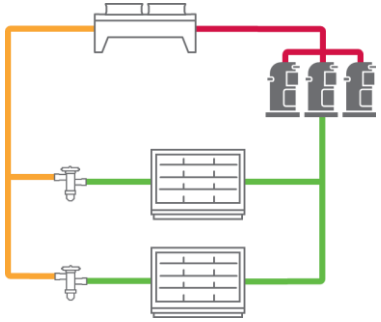
Transcritical Booster
CO2 (Adiabatic)



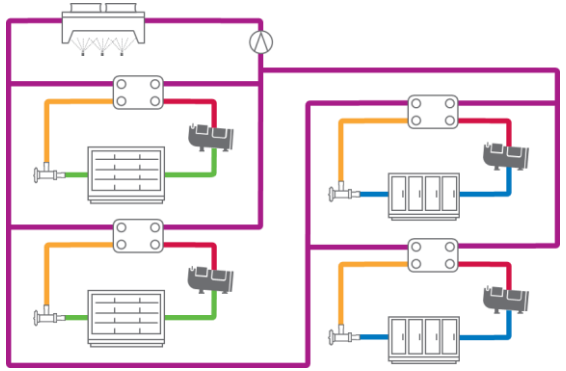
Scroll Booster R-513A
LT Rack into MT Rack



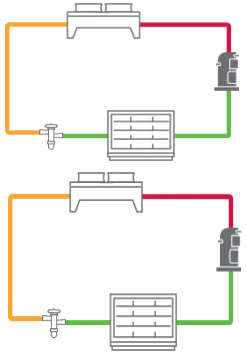
Distributed Scroll
Pack A2L



Micro Distributed
R290 Water Cooled



Single Condensing Units
R448/9A



Refrigerant Trends

Why CO_2 as a Refrigerant ?

Environmental Impact

Refrigerant		Type	GWP
CO2	R744	A1	1
HCFC	R22	A1	1810
HFC	R404A	A1	3922
HFC	R407A	A1	1923
HFC/HFO	R448A	A1	1273
HFC/HFO	R449A	A1	1282
Propane	R290	A3	3
NH3	R717	B2L	0

Benefits of CO2

0 ODP (Ozone Depleting Potential)

1 GWP (Global Warming Potential

ASHRAE A1 Refrigerant

Push to move away from HCFC/HFC/HFO refrigerants

Natural Refrigerant

Regulatory Compliance

Future Cost Avoidance

Energy Efficient

Carbon Emission Reduction

Refrigerant Trends

How does a CO_2 Systems Impact my TCO?

- **Electrical rate**
  - Rate structure, peak demand charges
- **Water resources**
  - Availability, cost, sewage charges
- **Service and maintenance skill levels**
  - Regional CO_2 experience or knowledge gap
- **Heat reclaim**
  - Volume and intensity requirements
- **Carbon intensity, electrical generation sources**
  - Impact on Net-zero 2040 goals for scope 2 emissions
- **Carbon Credits**

Technology to Reduce Energy Impact

Better Use on Available Heat reclaim with a focus on Integration with HVAC

Meeting your Carbon Emission Goals and the use of Refrigerant Carbon Credits

Refrigerant Trends

What do I Know

Regulatory Compliance Forcing a Change
Current design no longer an option

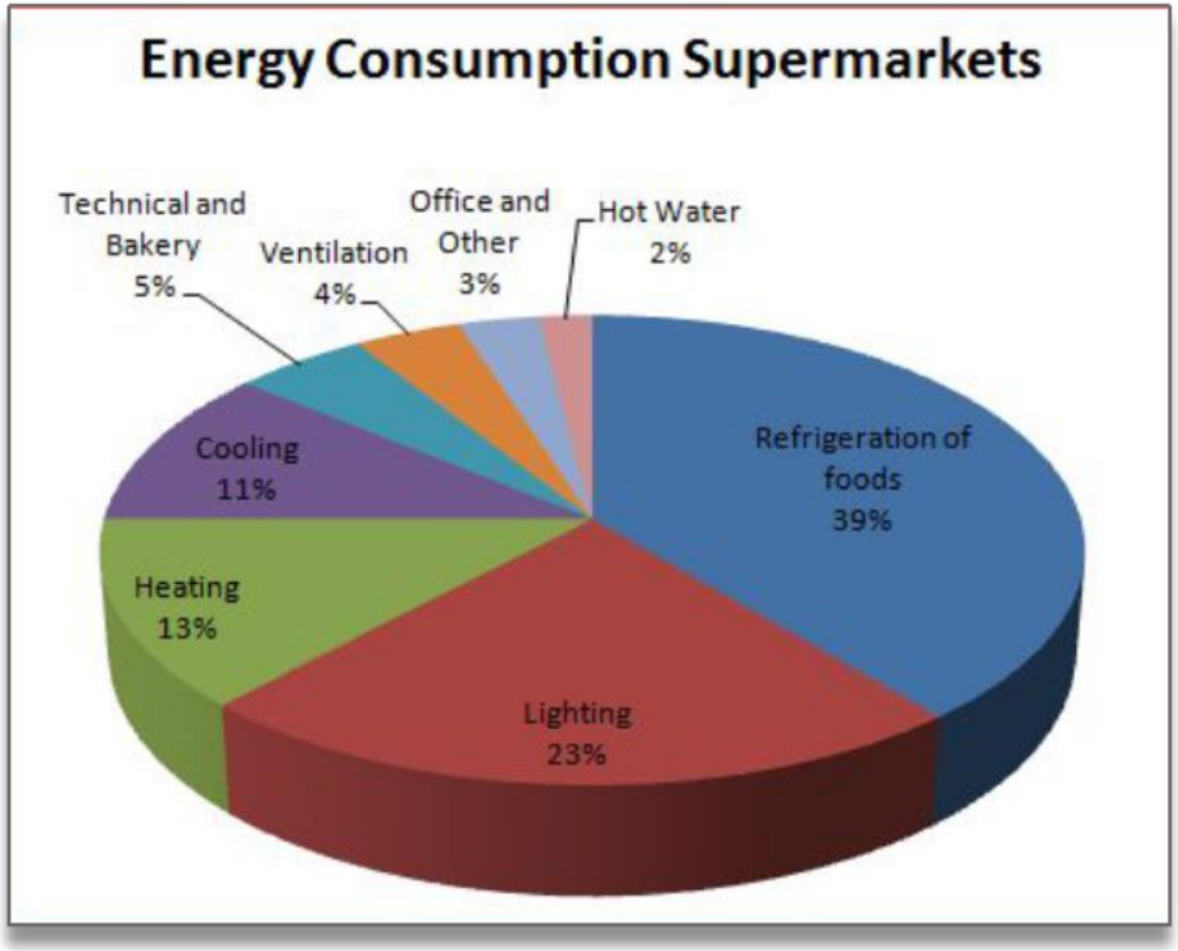
Cost of Current Design
From Design, Equipment, Installation & Maintenance
Known Baseline

What do I Need Know

What are my Options?
Low GWP or Natural Refrigerants
Impact on new stores and current stores

What will the change cost me?
Looking beyond first cost to understanding TCO

Energy Impact in a Supermarket



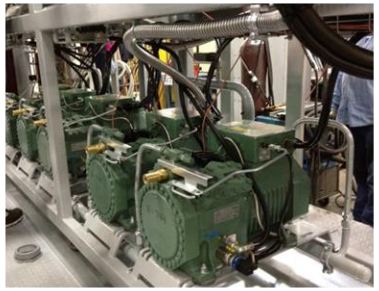
Industry Average:

39% Refrigeration
23% Lighting
24% HVAC (Heat & Cooling)

Development of Advancing Technology

Continuous investment is leading the industry in applied CO_2 technology

Sub-Cooling



Parallel Compression

Gas / Liquid Ejectors

Pressure Exchanger

Supporting the Industry for Continuous Advancements

- Water & Heat Reclaim Efficiency
- Refrigerant Integration with HVAC
- Mechanical & Natural Sub-Cooling
- Dedicated CO_2 Controls Strategy

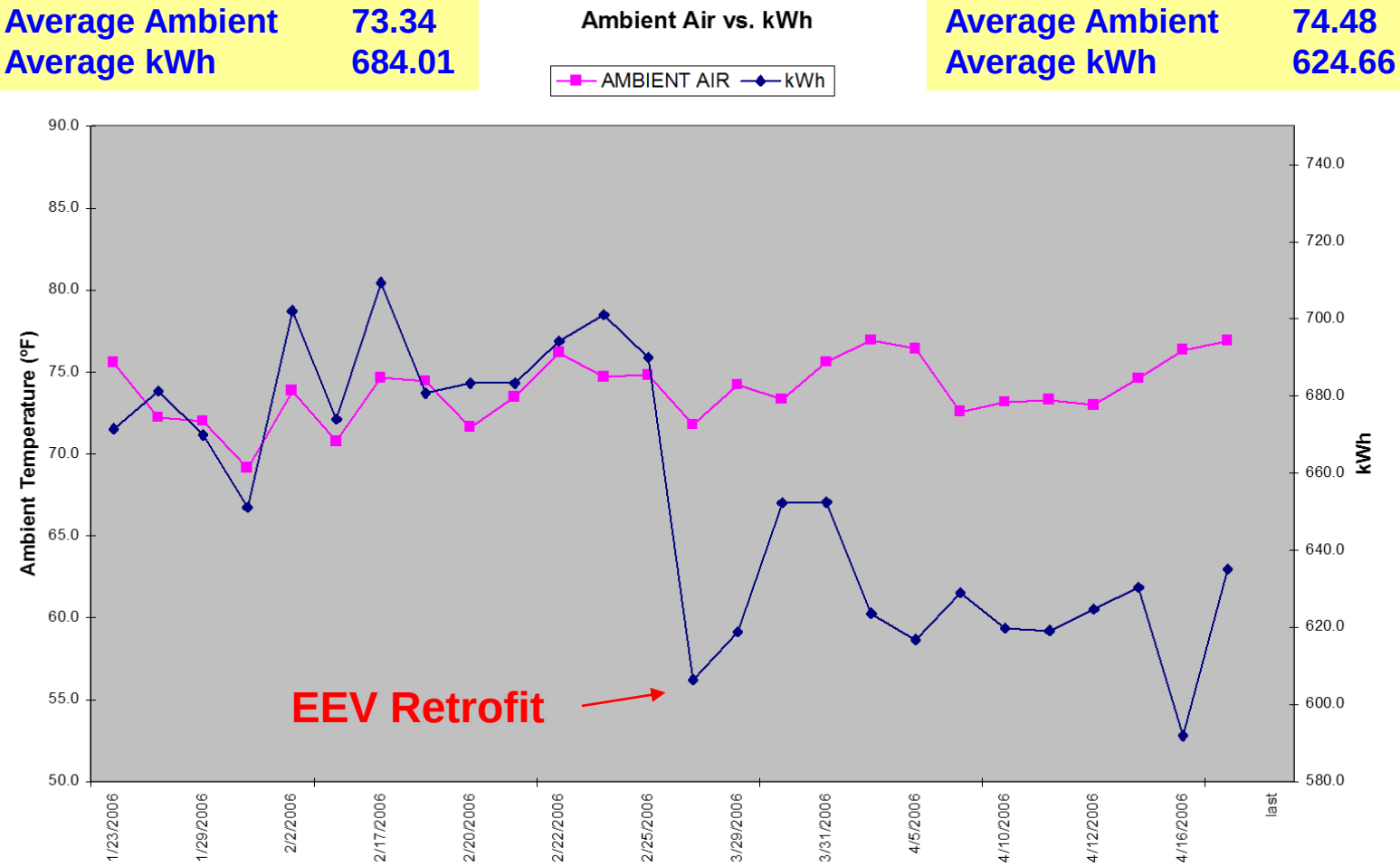
- Application for all Climates
- Improved Store Efficiency
- Reduced Utility Peak Rates
- Refrigerant Risk Management
- Sustainability and Carbon Reduction

Review of CO2 Energy Impact versus HFC

Utilization of Case Controller and Electronic Expansion Valves to Improve Case Performance

Mechanical	
Average Ambient	73.34
Average kWh	684.01

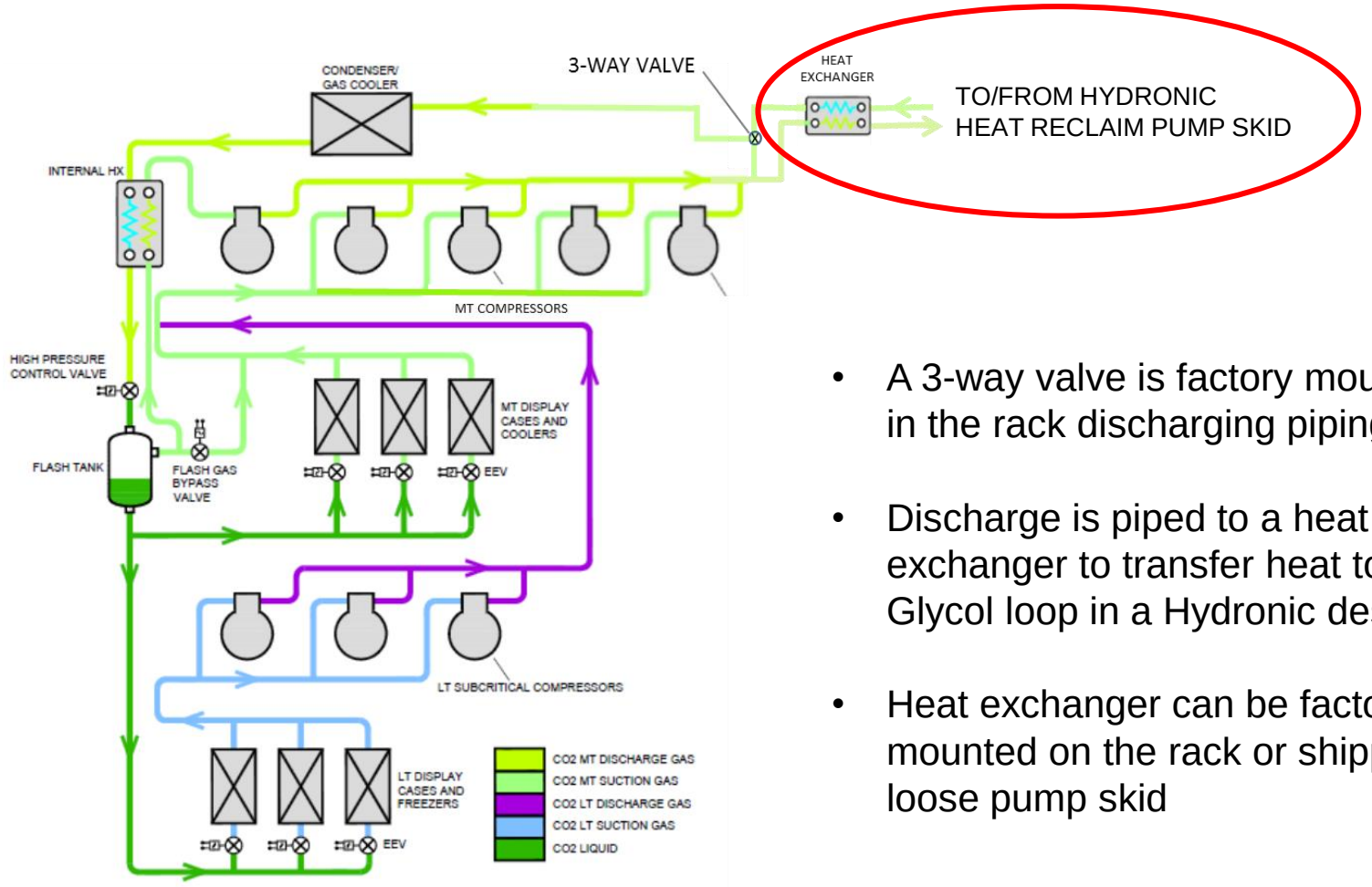
EEV	
Average Ambient	74.48
Average kWh	624.66



The use of case controller and electronic expansion valves (EEV's) will also contribute an estimated 8.7% in case energy input versus mechanical valves by improving:

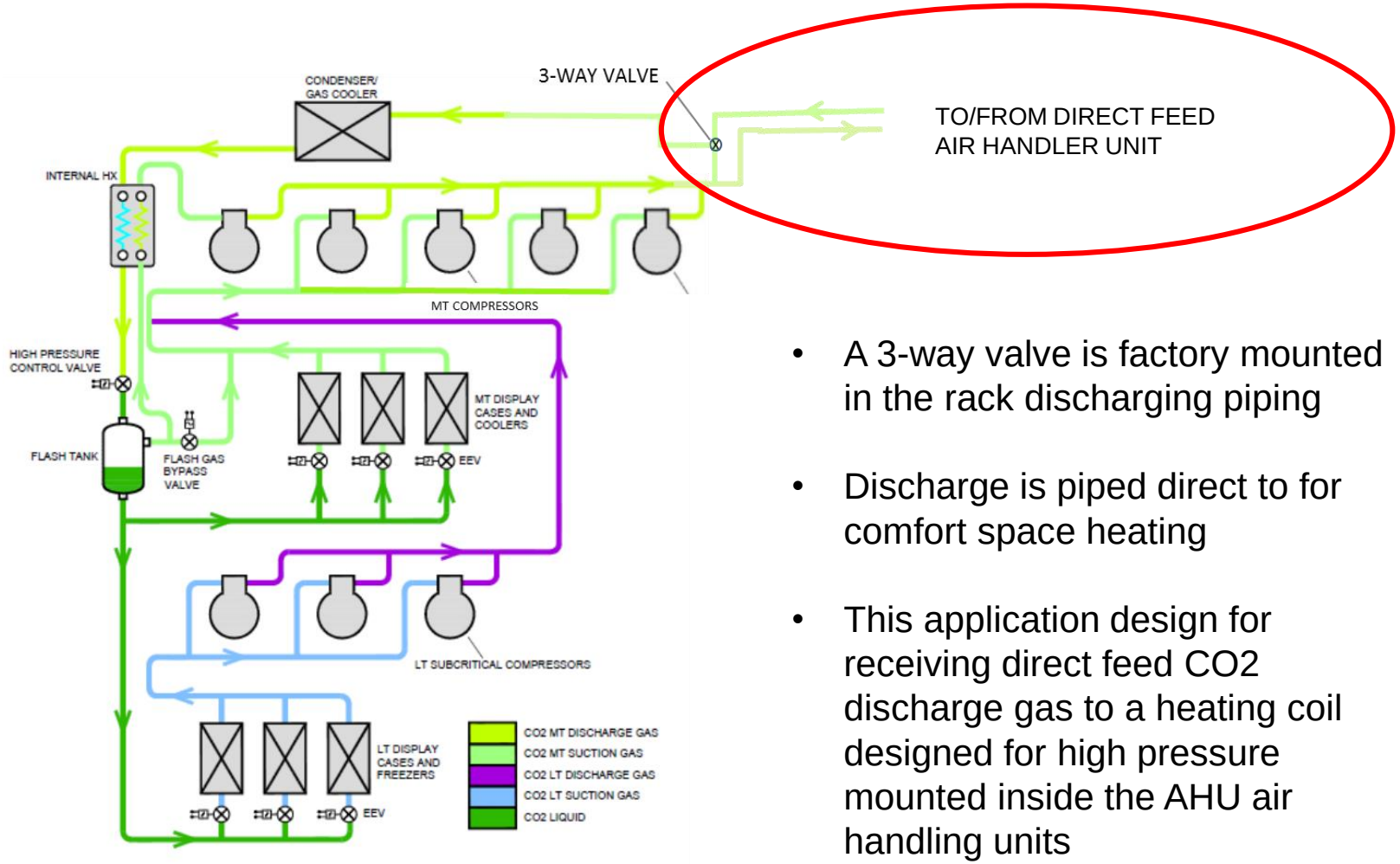
- Controlling super-heat
- Case performance
- Defrost control strategy
- Reduced required maintenance

Option - CO2 Transcritical Booster System with Basic Heat Reclaim & Hydronic Pump Skid



- A 3-way valve is factory mounted in the rack discharging piping
- Discharge is piped to a heat exchanger to transfer heat to Glycol loop in a Hydronic design
- Heat exchanger can be factory mounted on the rack or shipped loose pump skid

Option - CO2 Transcritical Booster System with Basic Heat Reclaim for Direct Feed

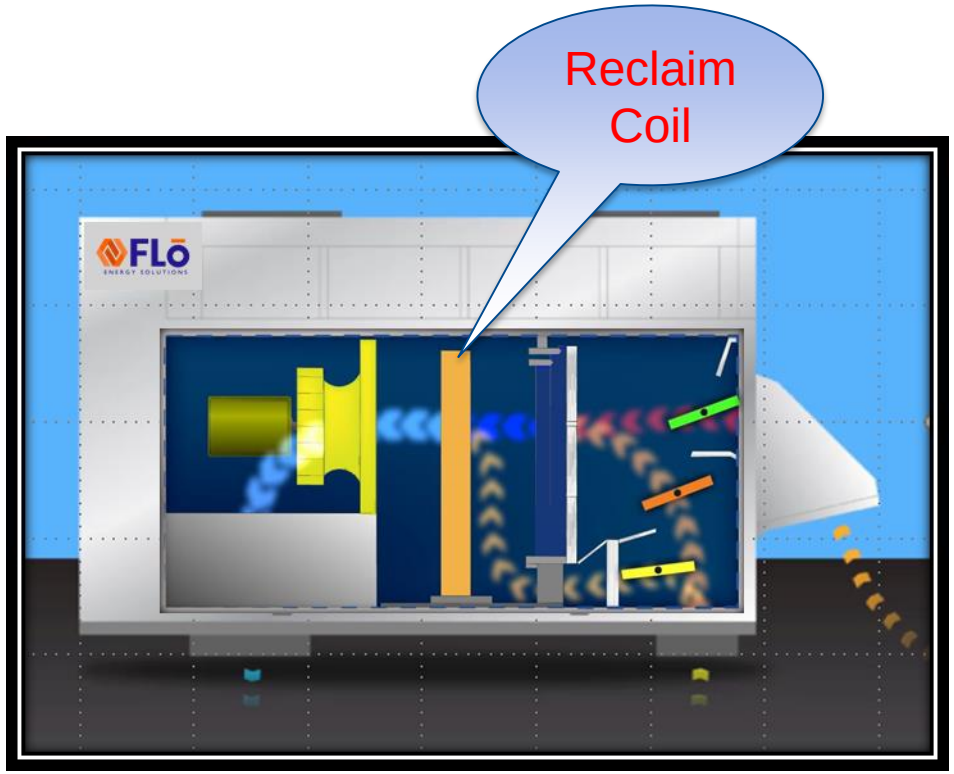


- A 3-way valve is factory mounted in the rack discharging piping
- Discharge is piped direct to for comfort space heating
- This application design for receiving direct feed CO2 discharge gas to a heating coil designed for high pressure mounted inside the AHU air handling units

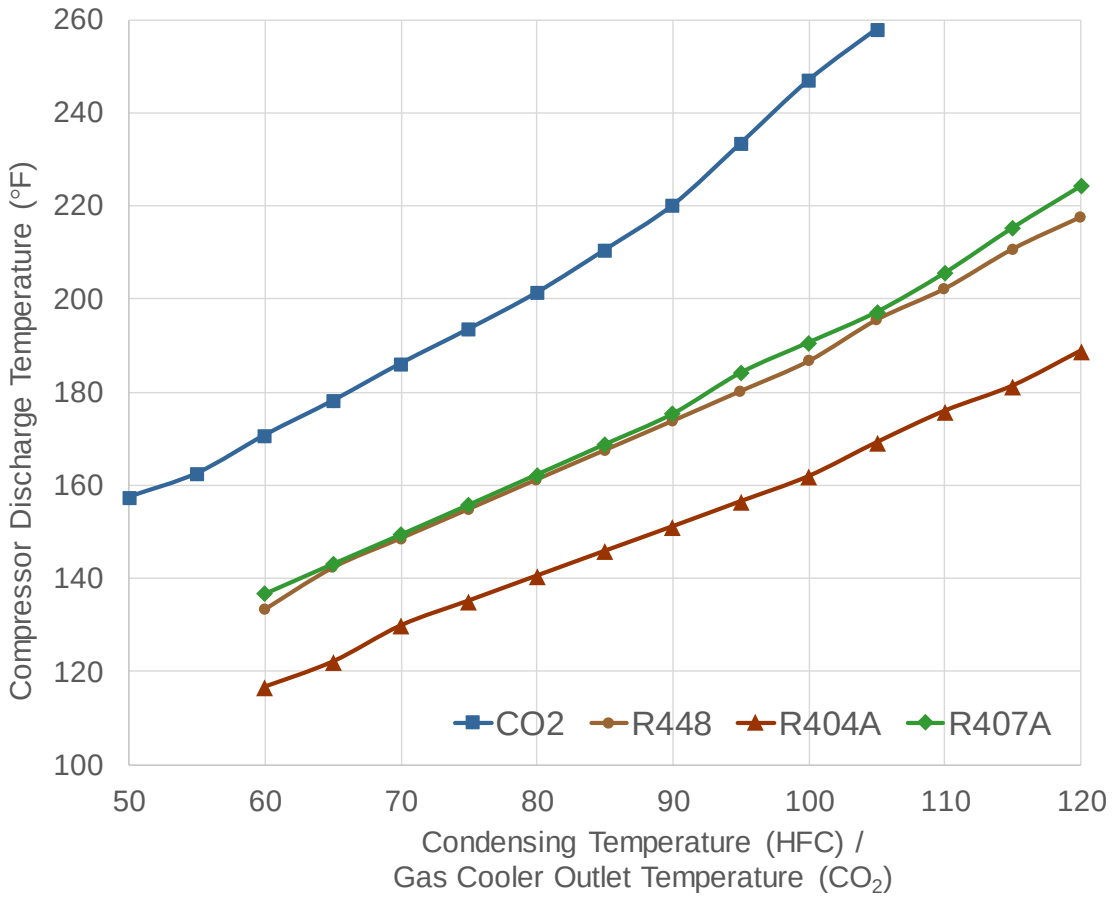
Review of CO2 Refrigeration Systems use of Heat Reclaim

Continuous Improvement in Supporting a Total Solution

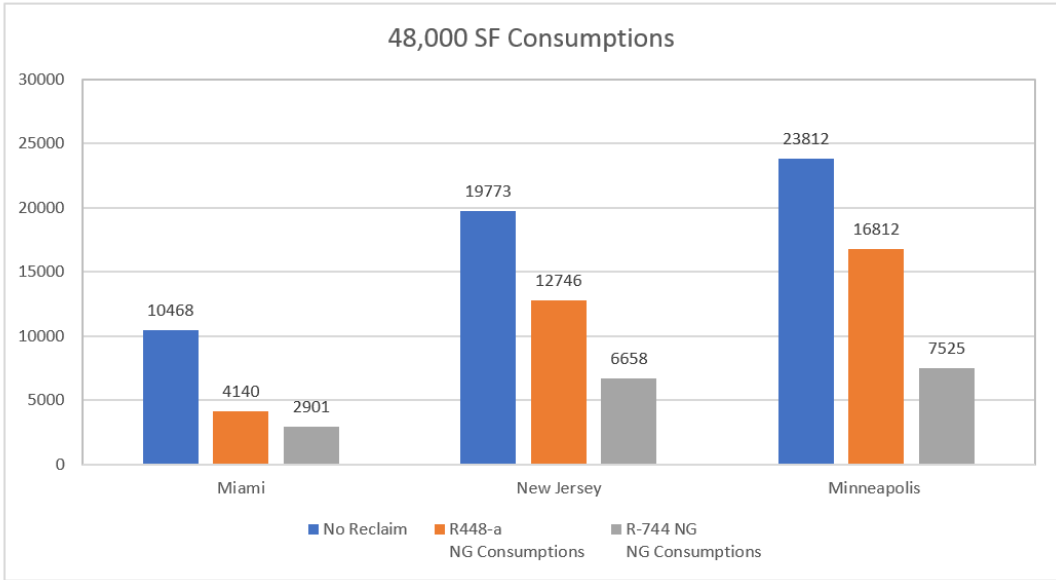
- Modernized HVAC equipment that enables heat reclaim
- Direct refrigerant heat reclaim to a single DOAS+ unit
- Utilize all the refrigeration waste heat possible
- Reduces or Eliminates the use of Natural Gas
- Supporting a reduction in Carbon Emissions



Utilization of Compressor Discharge Gas for Store Heating and Reducing use of Natural Gas



48,000 SF Store Consumptions (Therms)						
	No Reclaim	R448-a NG Consumptions	Savings	R-744 NG NG Consumptions	Savings	Co2 vs 448 Saving%
Miami	10468	4140	6328	2901	7567	20%
New Jersey	19773	12746	7027	6658	13115	87%
Minneapolis	23812	16812	7000	7525	16287	133%
			Energy Cost ($)			Co2 vs 448 Saving $
Miami @ 1.11/therm	$ 11,578	$ 4,579	$ 6,999	$ 3,209	$ 8,369	$ 1,370
New Jersey @ 0.84/therm	$ 16,609	$ 10,707	$ 5,903	$ 5,593	$ 11,017	$ 5,114
Minneapolis @ 058/therm	$ 13,716	$ 9,684	$ 4,032	$ 4,334	$ 9,381	$ 5,349



Better Heat Reclaim to reduce HVAC Energy and use of Natural Gas

Scope 1-2-3; Examples

1

Direct Emissions

Owned Assets

- Fuel Combustion: heating
- Fuel Combustion: kitchens
- Fuel Combustion: vehicles
- Refrigeration Emissions (Impact from refrigerant leaks)

2

Indirect Emissions

Energy Purchased

- Purchased electricity
- Purchased
  - Heating/Cooling
  - Refrigeration

3

All Other Indirect Emissions

3rd Party

- Supply Chain
- Distribution
- Staff/Customer travel
- Use of sold products

Refrigerant Carbon Credits
Reduce First Cost, Improve CO_2 ROI

Your System Qualifies for Refrigerant Carbon Credits™ (RCC)

RCC: A financial incentive unique to refrigerant upgrade projects, similar to a utility rebate

1. Replace refrigerant with a more sustainable choice for new construction or remodel projects

2. Issue RCCs for the emission reductions created by project

3. Sell RCCs to Fortune 500s with sustainability targets and climate goals

Project Quote

- CO_2 System Cost
+ RCC Revenue

= Reduced CO_2 System Cost

We are a preferred partner of THERM

Example Economics

Distribution Upgrade
2022 | 120K SF | Most US States

Ammonia refrigerant charge

Estimated carbon credit value
~$160,000 to $260,000

Grocery Retrofit
2021 | 40K SF | Most US States

CO2 refrigerant charge

Estimated carbon credit value
~$60,000 to $100,000

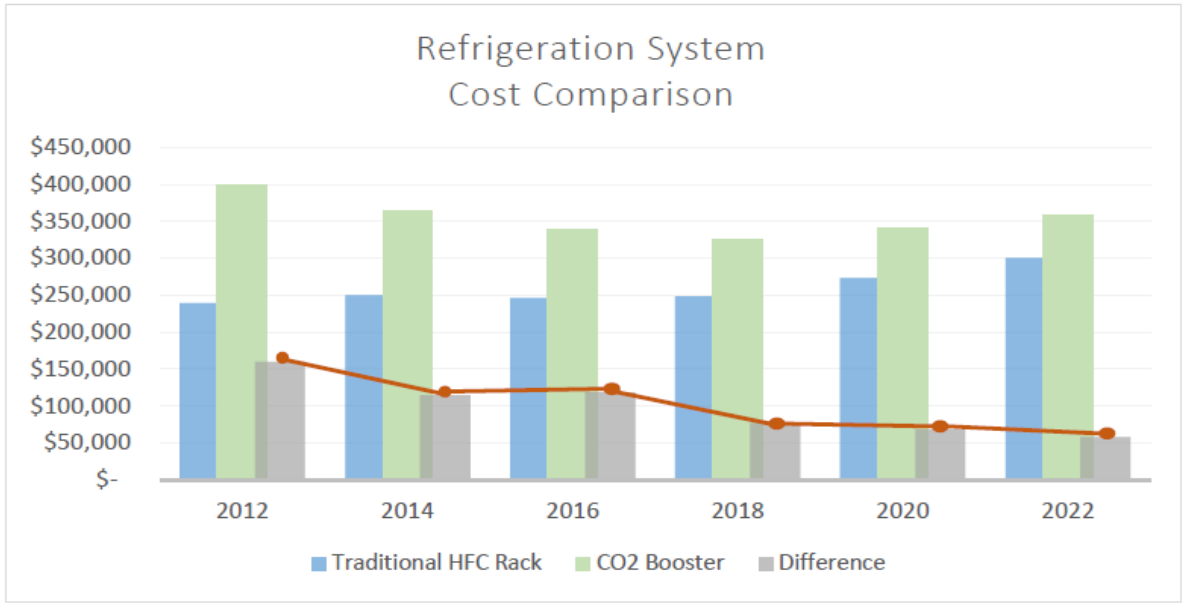
New Grocery Store
2021 | 40K SF | Most US States

CO2 refrigerant charge

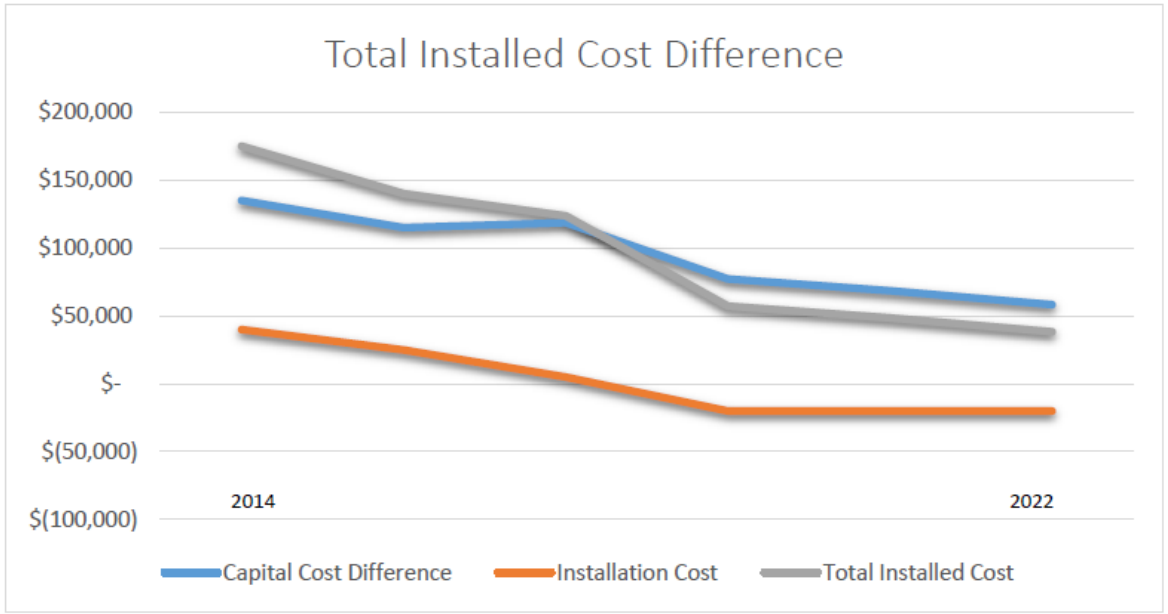
Estimated carbon credit value
~$80,000 to $140,000

THERM

Taking another look at the Impact of TCO

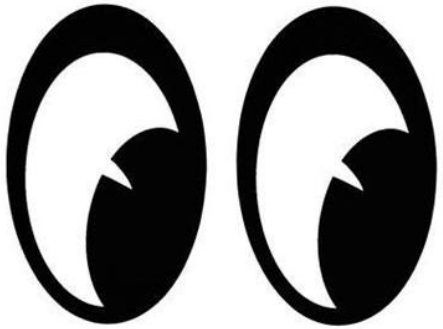


Cost of Refrigeration Systems are Increasing
Difference between HFC vs CO2 Racks is closing



Impact of a Lower Total Installed Cost

Taking another look at the Impact of TCO



Re-Looking at the ROI Statement

DX HFC/HFO baseline verses CO2 with Adiabatic

Having the right information to make the best business decisions

Cost of the Display Cases	+ $$$
Cost of the Refrigeration System	+ $$$
Reduction in Refrigerant Charge & Cost	- $$$
Saving in Refrigeration Installation	- $$$
Providing a Lower Installed Cost (Equipment cost plus Installation)	$$$
Energy Efficiency	- $$
Regulatory Compliance	- $$
Cost Avoidance of Future Retrofits	- $$
Refrigerant Carbon Credits	- $$
Integration of Heat Reclaim	- $$
Incentives (CARB FRIP Program)	- $$

Disclaimer

Always consult with experts and use properly licensed and trained professionals to perform any work on your facilities. Individual installation performance will vary due to a number of factors which can impact design strategies and performance, including but not limited to regional climate, low critical point and high system pressures. Please contact your Emerson or Hillphoenix representative if you are interested in discussing optimal design strategies for a particular installation.