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Alternate Refrigerants: An Equipment Perspective

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Overview

1. Introduction
2. Refrigerant Options
3. Refrigeration System Types
4. Summary
5. Questions

1. Introduction

The goal for the session is to compare and contrast HFC, CO_2, glycol and propane refrigeration systems by explaining (from an equipment perspective) the strengths and weaknesses of each system, and how supermarket operators can determine which system is right for their company and culture.

1. Introduction

- Three main refrigerant choices
- Two guiding principals
- One overriding issue

2. Refrigerant Options

Three main refrigerant choices:

- Synthetic refrigerants and blends that do not include HFO-1234yf or HFO-1234ze
  - Examples: R-134a and R-407A

- Synthetic blends that include HFO-1234yf and/or HFO-1234ze
  - Non Flammable (A1) – 1200 to 1600 GWP
  - Mildly Flammable (A2L) – 200 to 600 GWP

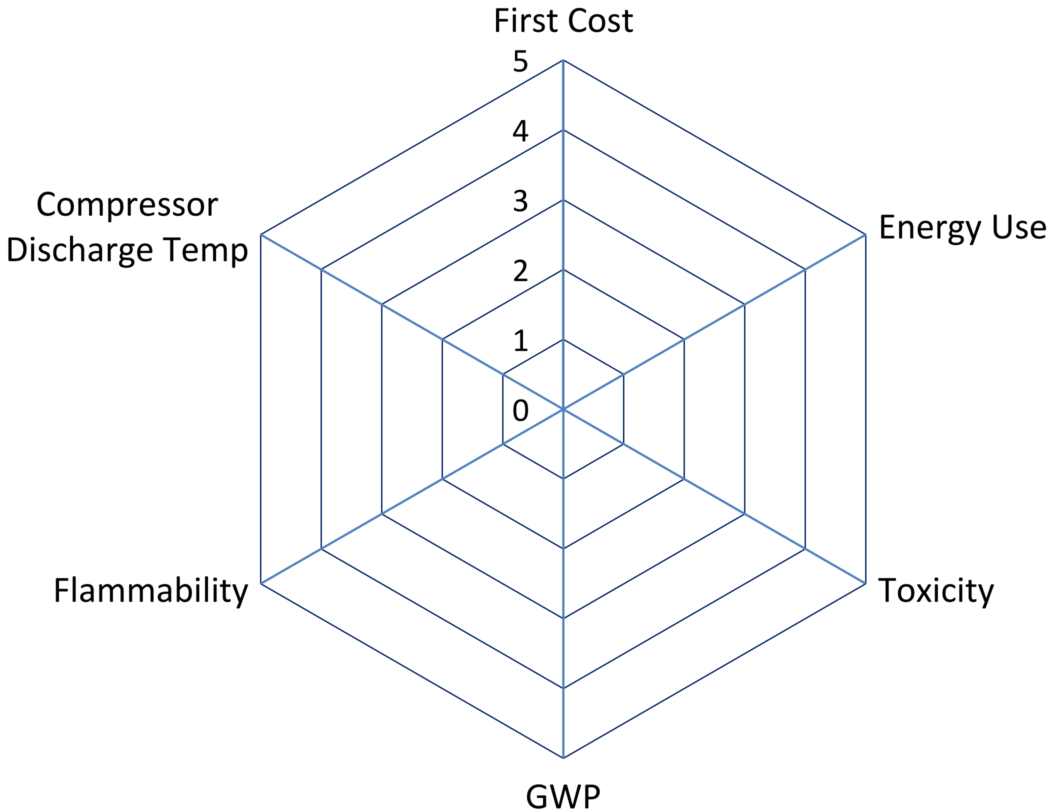
- Natural Refrigerants
  - Carbon Dioxide (R-744 or CO_2)
  - Hydrocarbons
    - Propane (R-290)
    - Isobutane (R-600a)
  - Ammonia (R-717)

2. Refrigerant Options

Two Guiding Principals:

- **There is no perfect solution.** Improving one thing always causes something else to get worse. Example: Lowering the environmental impact often means the blend will be flammable.
- **The refrigerant choice cannot be separated from the system choice.** Example: Propane not compatible with, and A2Ls not likely for centralized parallel direct-expansion systems.

Refrigerant Compromises



2. Refrigerant Options

One Overriding Issue: Flammability

Class 1:

- No Flame Propagation
- Many existing HFC's and blends and CO_2

Class 2L:

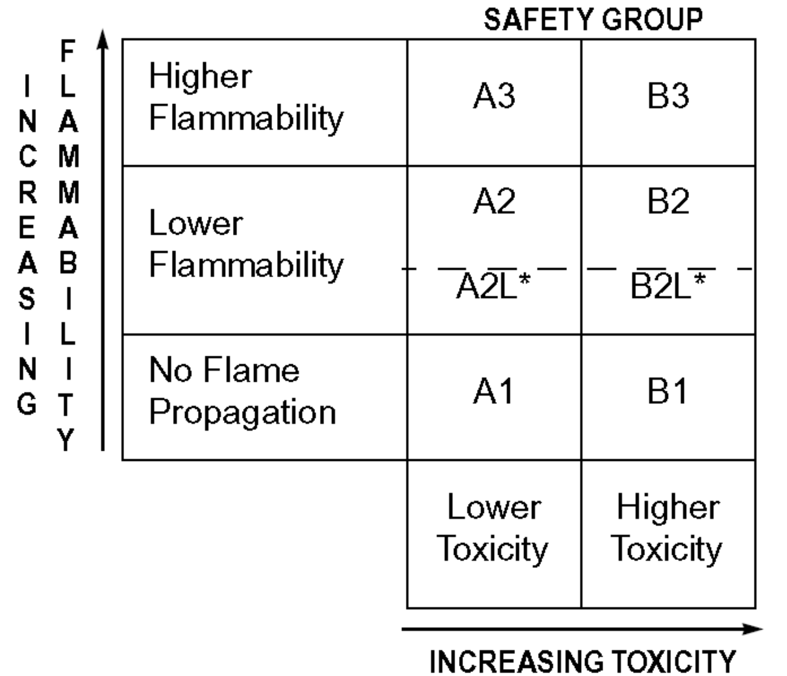
- "Low flammability"
- Examples: HFO-1234yf, R-32

Class 2:

- Flammable
- Example: R-152a

Class 3:

- Highly flammable
- Examples: Hydrocarbons such as R-290 and R-600a



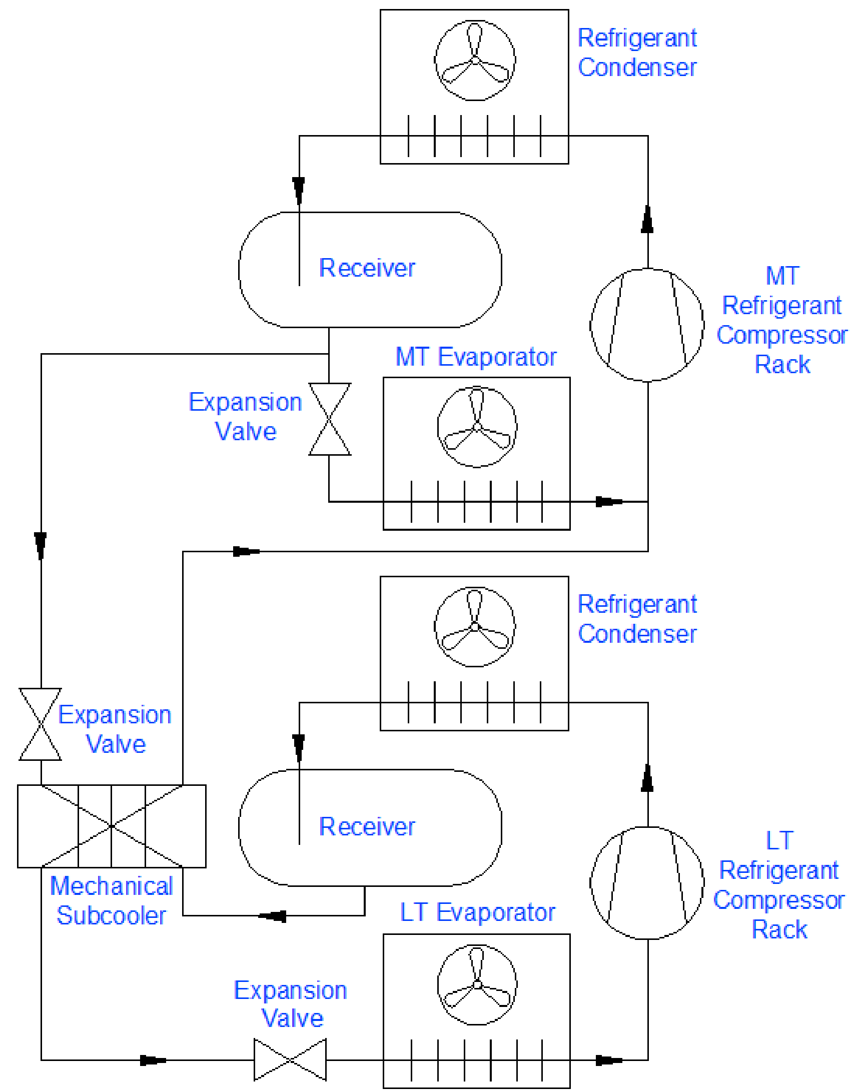
* A2L and B2L are lower flammability refrigerants with a maximum burning velocity of ≤3.9 in./s (10 cm/s).

3. Refrigeration System Types

- Centralized Parallel Rack with R-404A – Baseline
- Distributed System
- Secondary CO_2 LT & Glycol MT
- Cascade DX CO_2 LT & Secondary CO_2 MT
- Transcritical CO_2 MT & Cascade DX CO_2 LT
- Micro-Distributed System, Water Cooled

Centralized Parallel Rack– Baseline

- For baseline, R-404A
- Still most commonly used type of refrigeration system for supermarkets in N.A.
- Strengths:
  - Large, high-efficiency, semi-hermetic compressors
  - Well understood by technicians—mature technology
  - Low equipment first cost



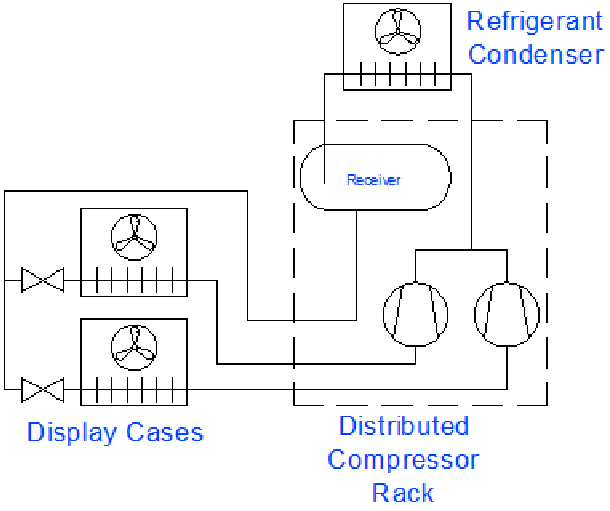
Centralized Parallel Rack

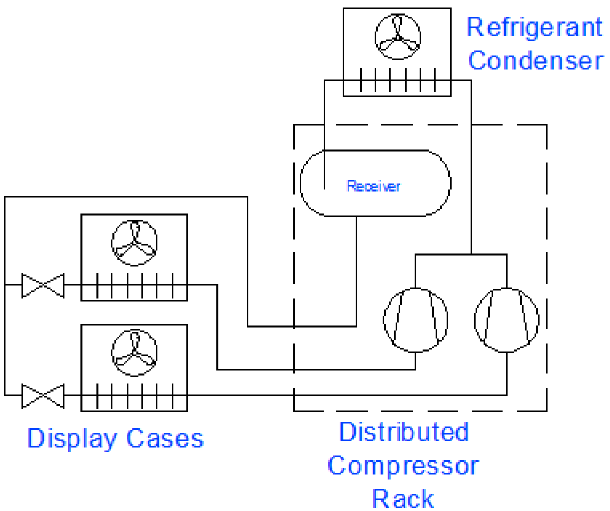
Centralized Parallel Rack– Baseline

- Weaknesses:
  - Higher parasitic losses—i.e., long line runs
  - Large refrigerant charge
  - High refrigerant leak rates
    - (10-25%)
    - Catastrophic leaks possible
  - Must operate at lowest suction temperature within a group—efficiency penalty

Distributed System

- “Distributed” = multiple units located around the store, closer to the loads
- ~30-35 percent of new refrigeration systems for supermarkets in N.A.





Distributed (Air Cooled)

Distributed System

- Other refrigerants: what's different vs R-404A?
  - R-507A*
    - GWP of 3985 (R-404A = 3922)
    - Not a good alternative at this time due to pending EPA regulations
  - R-407A / R-407F
    - GWP of 2107 and 1824 respectively
    - Single stage LT compressor (non-economized) needs liquid injection to lower discharge temperatures
    - Temperature glide of 7-9°R
    - Capacity similar to R-404A, efficiency slightly worse (with liquid injection)

*EPA proposing to delist R-507A from approved refrigerant list as early as 1/2016

Distributed System

- Other refrigerants: what's different vs R-404A?
  – R-448A (a.k.a. "N40")*
    - GWP of ~1280
    - Single stage LT compressor (non-economized) needs liquid injection to lower discharge temperatures (see chart at right from Emerson)
    - Temperature glide of 8-10°R
    - Capacity similar to R-404A, but efficiency slightly better (~5%)
- These comments also apply to centralized parallel racks

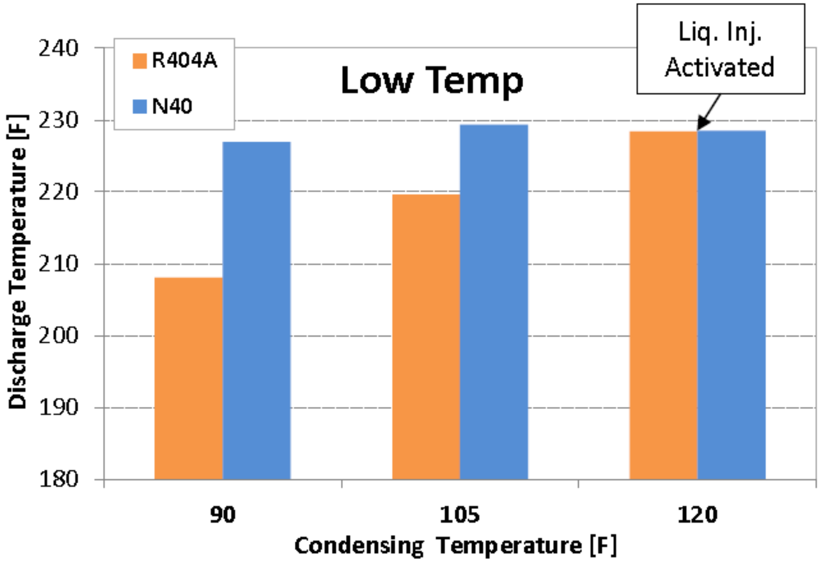


Figure from: Rajendran, R. (2013, September). *Refrigerants Update*. Presentation at FMI E&SD Conference, Baltimore, MD.

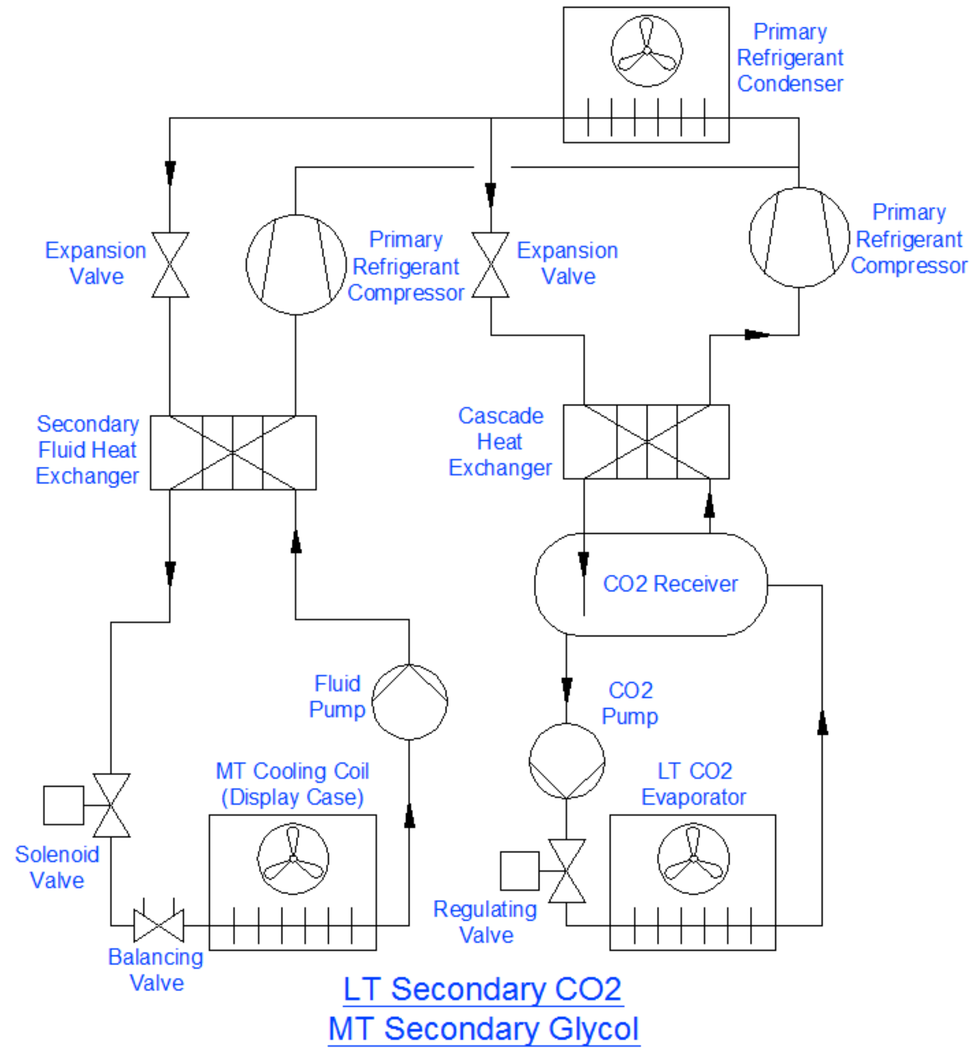
*Not yet approved by EPA for use nor commercially available at this time

Distributed System

- Strengths:
  - High-efficiency scroll compressors
  - Reduced refrigerant charge
    - 50-80% charge reduction (water cooled to get to 80)
  - Lower installation cost
    - 50-70% reduction in copper
  - Closer suction group matching for better energy efficiency
- Weaknesses:
  - Higher first cost of equipment
  - Water-cooled to achieve best refrigerant charge reduction

Secondary CO_2 LT and Glycol MT

- One commonly used alternative
- What's different vs a R-404A rack?
  - Secondary system uses two fluids –
    - Primary side of system uses refrigerant—e.g., R-404A
    - 'Secondary' fluid is cooled by HX, then pumped through cases and walk-in coils
  - Multiple heat exchangers—efficiency losses
  - Solenoids (LT & MT) and balancing valves (MT) control fluid flow
  - Fluid pumps required



Secondary CO_2 LT and Glycol MT

- Strengths:
  - Reduced HFC refrigerant charge
  - Low leak rate on primary HFC refrigerant
- Weaknesses:
  - Multiple working fluids
    - HFC, 35% P.G., CO_2
  - Fluid pumps—energy use and selection criteria per site
  - Higher energy consumption (~10-15%) on MT vs baseline
  - Higher equipment first cost & more expensive to install and commission vs baseline[1]

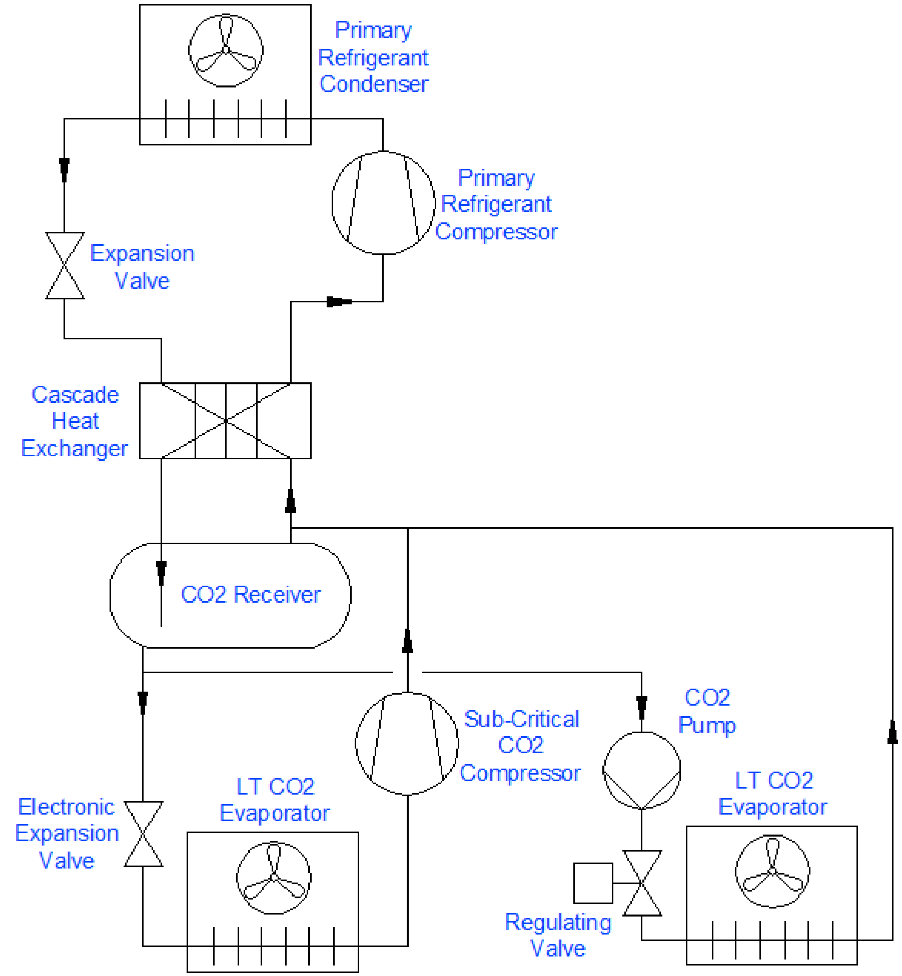
Med Temp (Glycol)

Low Temp (CO_2)

1. Anderson, P. (2012, September). *End-User Experience with CO2-Based Refrigeration Systems.* Presentation at FMI E&SD Conference, Phoenix, AZ.

Cascade DX CO_2 LT & Secondary CO_2 MT

- Less common alternative
- What's different vs a R-404A rack?
  - Fluid pump on MT system
  - EEVs required on LT cases
  - Multiple heat exchangers—efficiency losses
- Primary side could use ammonia for all natural refrigerant system, but typically an HFC like R-404A is used.



LT DX CO2 Cascade
MT Secondary CO2

Cascade DX CO_2 LT & Secondary CO_2 MT

- Strengths:
  - Reduced HFC refrigerant charge
  - Smaller line sets for CO_2 vs traditional HFCs
- Weaknesses:
  - Multiple working fluids
    - HFC, CO_2
  - Primary side of system uses refrigerant—E.g., R-404A
  - Higher working pressures (LT~200 psig, MT~400 psig)
  - Power loss can cause loss of refrigerant through pressure relief venting
  - Slight increase in energy consumption vs baseline[2]

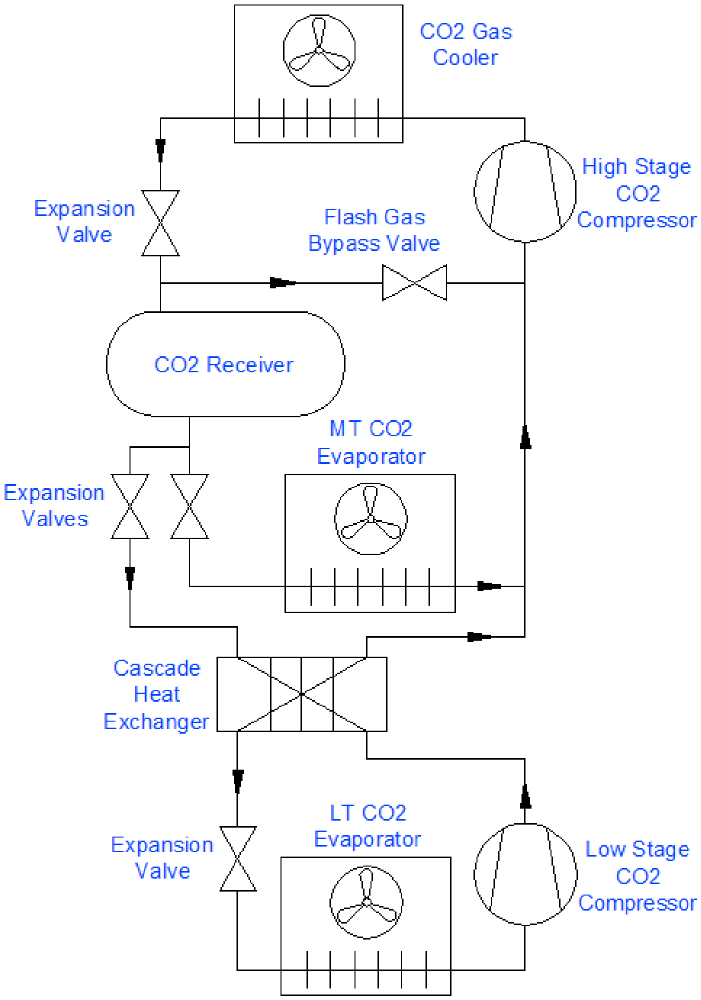
Secondary CO_2 MT

Cascade DX CO_2 LT

2. Mikhailov, A., Matthiesen, H.O. (2013). "System Efficiency for Natural Refrigerants." *ASHRAE Journal , 55* (8), 66-71.

Transcritical CO_2 MT & Cascade DX CO_2 LT

- Common for new stores in colder climates (e.g., Canada, northern Europe)
- What's different vs a R-404A rack?
  - EEVs on LT and MT cases
  - Subcritical CO_2 "booster compressors" for LT
  - Transcritical CO_2 compressors for high stage
  - Steel or heavy-wall copper tubing on high side
  - Multiple heat exchangers on LT—efficiency losses



CO2 Transcritical Booster

Transcritical CO_2 MT & Cascade DX CO_2 LT

- Energy consumption and cost comparison highly dependent on climate and utility rates [3]
  - Boston, MA
    - -14% annual energy vs baseline
    - +40% peak power demand (90°F)
  - Houston, TX
    - +7% annual energy vs baseline
    - +45% peak power demand (95°F)

3. Rajendran, R. (2013, September). *Refrigerants Update.* Presentation at FMI E&SD Conference, Baltimore, MD.

Transcritical CO_2 MT & Cascade DX CO_2 LT

- Strengths:
  - Zero HFC refrigerant charge—only CO_2, a "natural" refrigerant
  - Smaller line sets for CO_2 vs traditional HFCs

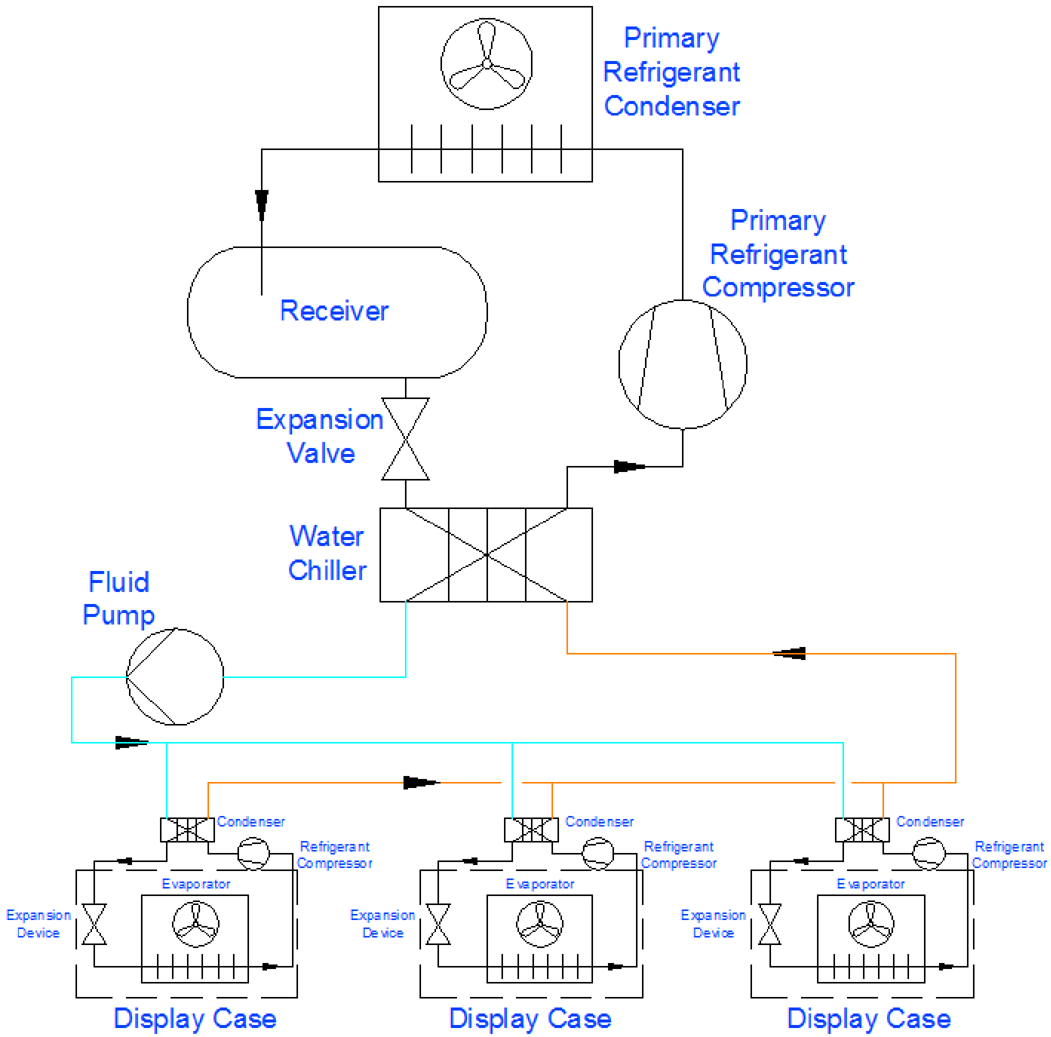
Transcritical CO_2 MT & Cascade DX CO_2 LT

- Weaknesses:
  - Very high working pressures
    - Low side: up to 580 psig
    - High side: up to 1680 psig
  - High peak loads during warmest months when operating transcritically
  - Difficult to locate leaks
  - Leak rates comparable to baseline (centralized HFC racks)
  - Power loss can cause loss of refrigerant through pressure relief venting
  - Higher first cost of equipment [4,5]

4. Patkos, G. (2013, June). *Delhaize Group Presentation.* Presentation at the CGF Retail Refrigeration Summit. London, England.
5. Pearson, A., Campbell, A. (2010). "Using CO_2 in Supermarkets." *ASHRAE Journal , 52* (2), 24-28.

Micro-Distributed Water Cooled

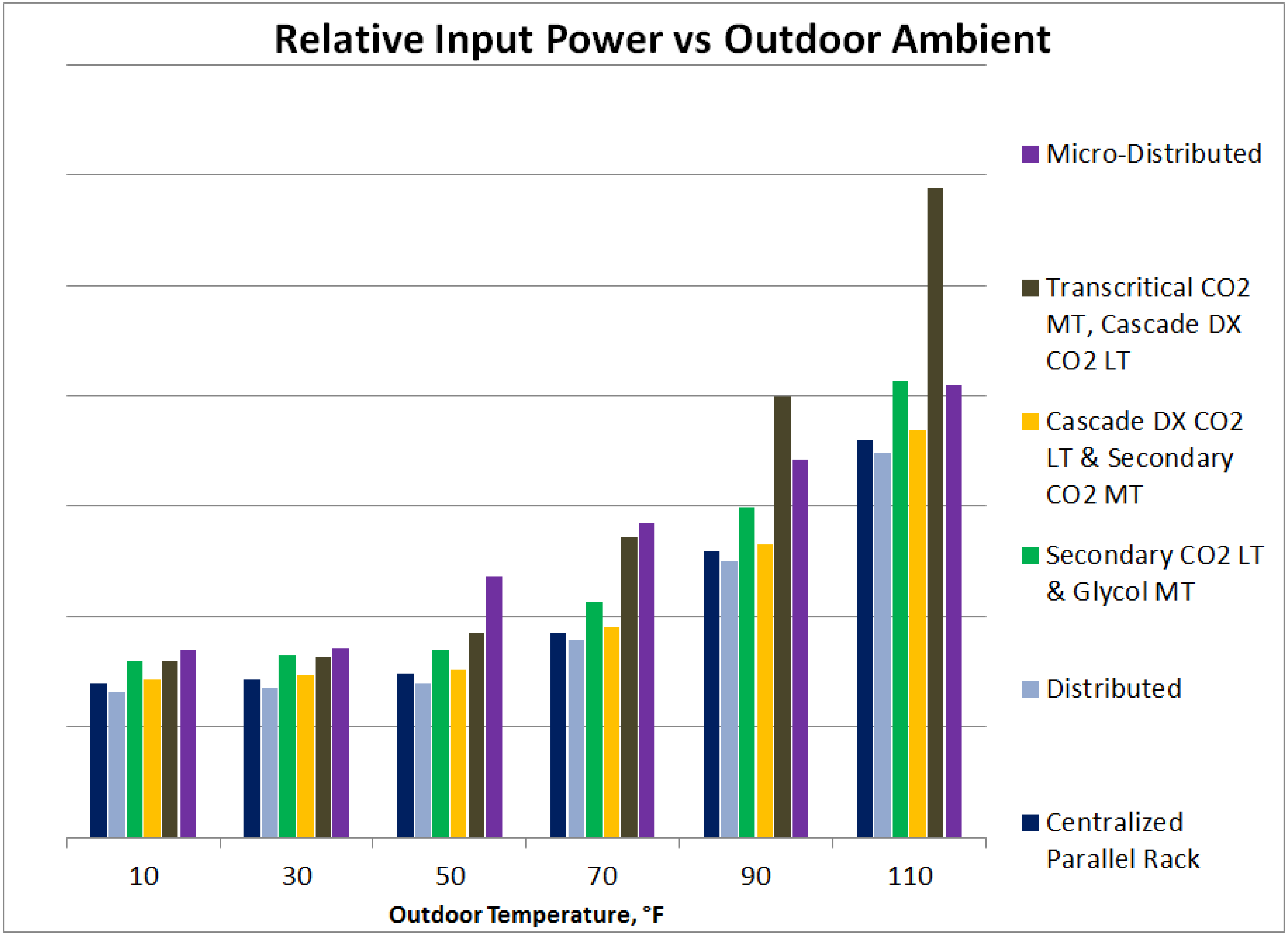
- Commonly used alternative in Europe
- What's different vs a R-404A rack?
  - More compressors
  - No refrigerant circulated through store
  - Refrigeration installation is faster and easier
    - Run water piping to and from cases rather than refrigerant piping
  - Distributed electrical installation (per case)
  - Cases are self-contained
    - Factory charged and tested

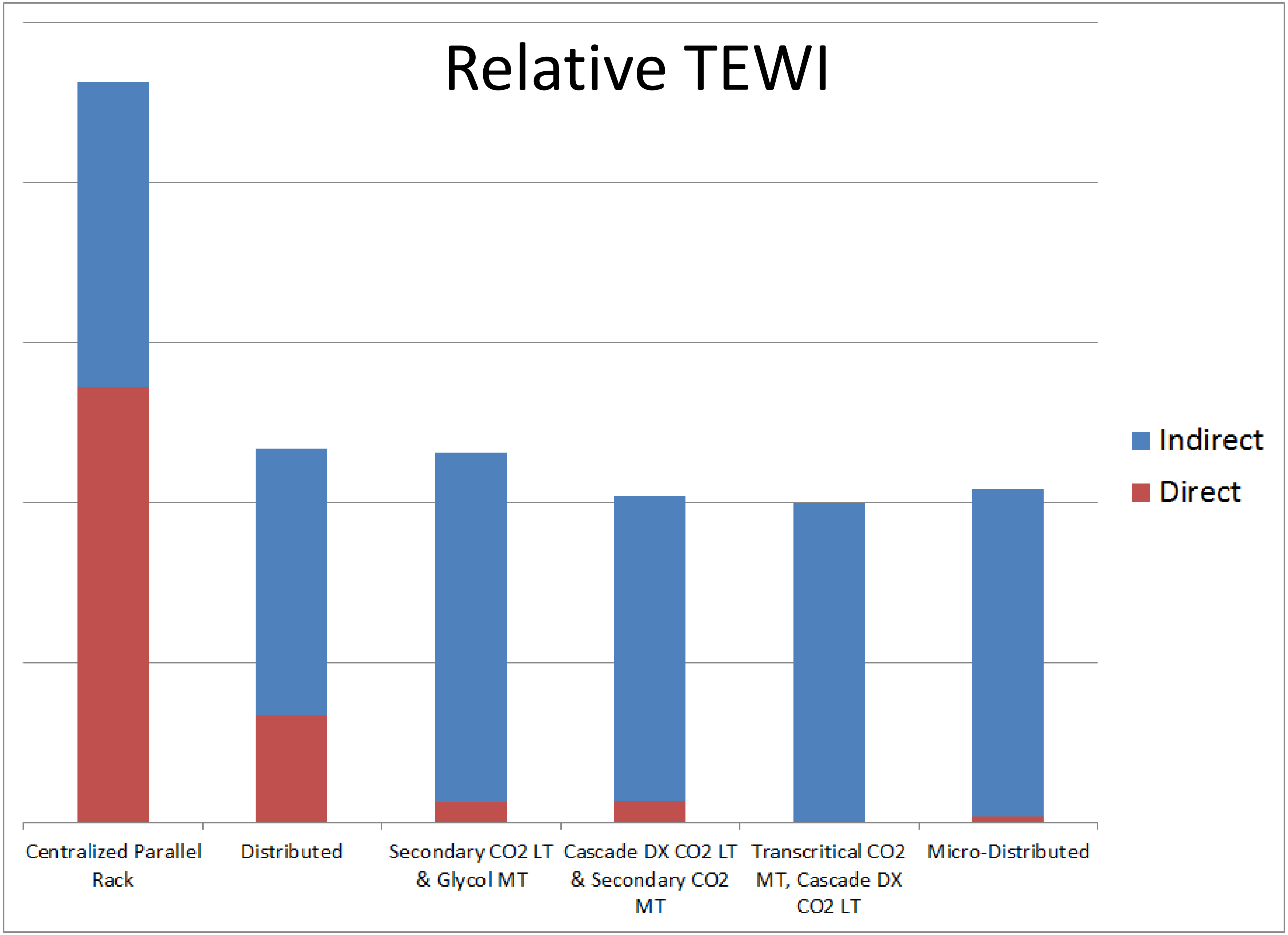


Micro-Distributed

Micro-Distributed Water Cooled

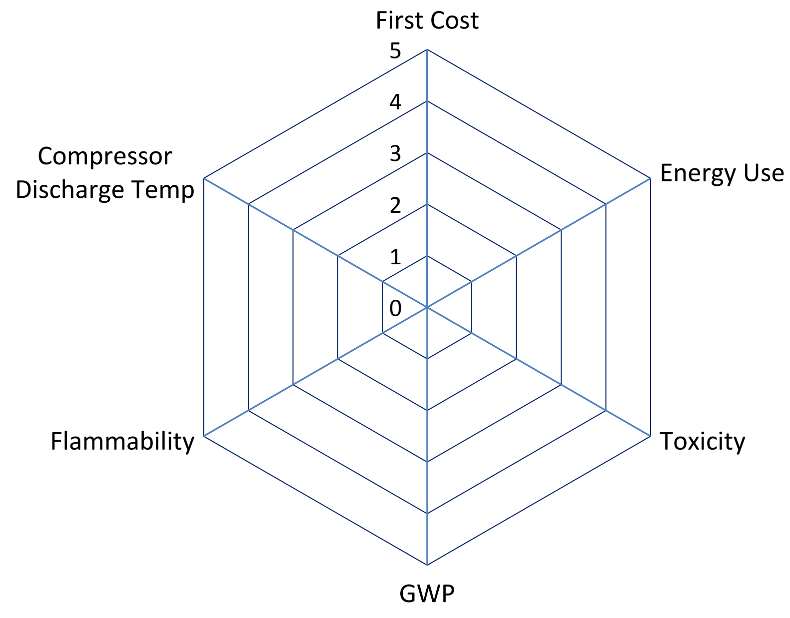
- Strengths:
  - Very small refrigerant charge
  - Simple system design
  - Very low leak rates
    - Each system hermetically sealed at factory
  - Exact suction matching
  - Enables alternative expansion devices
- Weaknesses:
  - New to North America
  - Charge size limit (for A3 refrigerants) can affect case configuration
  - Current efficiency of small hermetic compressors adversely affects total energy consumption.


Relative Input Power vs Outdoor Ambient
Micro-Distributed
Transcritical CO2 MT, Cascade DX CO2 LT
Cascade DX CO2 LT & Secondary CO2 MT
Secondary CO2 LT & Glycol MT
Distributed
Centralized Parallel Rack
10
30
50
70
90
110
Outdoor Temperature, °F


Relative TEWI
Indirect
Direct
Centralized Parallel Rack
Distributed
Secondary CO2 LT & Glycol MT
Cascade DX CO2 LT & Secondary CO2 MT
Transcritical CO2 MT, Cascade DX CO2 LT
Micro-Distributed

4. Summary

- **Three main refrigerant choices**
  - Synthetic refrigerants without HFOs
  - Synthetic blends with HFOs
  - Natural Refrigerants
- **Two guiding principals**
  - There is no perfect solution.
  - The refrigerant choice cannot be separated from the system choice.
- **One overriding issue**
  - Flammability



5. QUESTIONS?