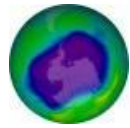




Regulatory Requirements Driving Change



Montreal Protocol /
Ozone Depletion Concerns



Kyoto Protocol /
Global Warming Concerns

**CFC
Phase-out**

**HCFC
Phase-out**

CFCs

HCFCs

HFCs

HFOs

✗ Ozone

✗ Global warming

✗ Ozone

✗ Global warming

✓ Ozone

✗ Global warming

✓ Ozone

✓ Global warming



Simple
Chemistry
Enhanced
Chemistry



New Molecule
Development



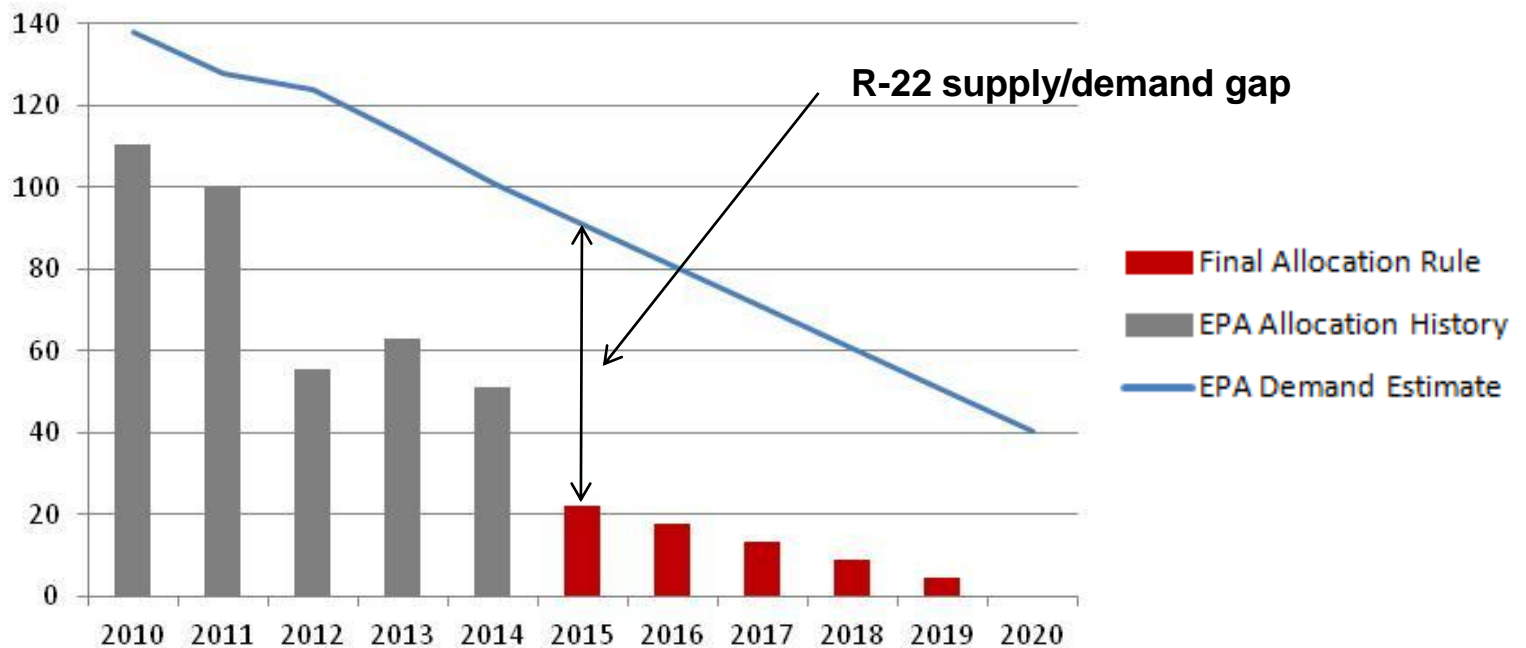
Advanced Molecules
Development
+ Complex Chemistry

R12

R134a

R1234yf

US R-22 Phase Out



- Final rule for 2015-2019 published October 2014
- Supply/demand gap needs to be filled by reclaim and channel inventory

R-22 allocation rights 57% lower in 2015 than 2014

What is SNAP?

The **Significant New Alternatives Policy (SNAP) Program** is EPA's program to evaluate and regulate substitutes for the ozone-depleting chemicals that are being phased out under the stratospheric ozone protection provisions of the Clean Air Act (CAA).

In Section 612(c) of the Clean Air Act, the Agency is authorized to identify and publish lists of acceptable and unacceptable substitutes for class I or class II ozone-depleting substances.

The Administrator has determined a large number of alternatives exist that reduce overall risk to human health and the environment. The purpose of the program is to allow a safe, smooth transition away from ozone-depleting compounds by identifying substitutes that offer lower overall risks to human health and the environment.

The SNAP program has reviewed substitutes for the following industrial sectors:

Refrigeration & Air Conditioning

Foam Blowing Agents

Cleaning Solvents

Fire Suppression and Explosion Protection

Aerosols

Sterilants

Tobacco Expansion

Adhesives, Coatings & Inks



Summary of U.S. SNAP Regulation

End Use	Delisted Products	Date of Delisting
Supermarkets - New	R-404A, R-507 and 8 Other High GWP blends	January 1, 2017
Supermarkets - Retrofit	R-404A, R-507 and 7 Other High GWP blends	July 20, 2016
Remote Condensing Units - New	R-404A, R-507 and 8 Other High GWP blends	January 1, 2018
Remote Condensing Units - Retrofit	R-404A, R-507 and 7 Other High GWP blends	July 20, 2016
Stand-Alone Medium Temp Units – New - less than 2200 BTU/hour	R-404A, R-507, R-134a, R-410A, and 26 others	January 1, 2019
Stand-Alone Medium Temp Units – New - more than 2200 BTU/hour	R-404A, R-507, R-134a, R-410A and 26 others	January 1, 2020
Stand-Alone Low Temp Units – New	R-404A, R-507, R-407 Series, and 18 others	January 1, 2020
Stand-Alone – Retrofit	R-404a and R-507	July 20, 2016
Vending Machines - New	R-134a, R-404A, R-507, R-407C, R-410A and 15 more	January 1, 2019
Vending Machines - Retrofit	R-404A and R-507	July 20, 2016
Mobile Air Conditioning	R-134a	2021 Model Year

R-404A, R-507 and R-134a are the main targets

EPA list of Potential applications for next SNAP Rule

Change of Status EPA is Considering

- Change of listing status from acceptable to unacceptable
 - EPA thinking potentially later transition dates than in July 20th final rule
 - End-uses based on stakeholder comments and EPA analysis
- Sectors and end-uses where safer alternatives may be available
 - Refrigeration and A/C
 - Chillers: e.g., HFC-134a, R-407C, R-410A
 - Refrigerated food processing and dispensing: e.g., HFC-134a, R-404A, R-507A
 - Household refrigerators and freezers: e.g., HFC-134a
 - Cold storage warehouse: e.g., HFC-134a, R-407C, R-404A, R-507A
 - MVAC: HCFC/HFC blends retrofit Light Duty vehicles
 - Rigid PU spray foam: e.g., HFC-134a, HFC-245fa, HFC-365mfc, HFC-227ea, methylene chloride, formic acid
 - Fire suppression: e.g., PFCs, SF₆, HFC-23

EC's Latest Proposal to Regulate HFCs

- **Phase Down similar to R-22 (baseline, allowance system and phase-down schedule)**

2018	90%
2023	65%
2029	30%
2035	15%

- **Product Specific Controls for Centralised Commercial Refrigeration Systems**

- New systems: any HFC with a GWP > 1500, by 1 January 2019; or a blend that contains any HFC where that blend has a GWP > 1500, by 1 January 2019 **(Still allowed: Solstice[®] N40)**
- New systems: any HFC with a GWP > 1000, by 1 January 2024; or a blend that contains any HFC where that blend has a GWP > 1000, by 1 January 2024 **(Still allowed: blends in development)**
- Retrofits: the retrofit with: any HFC with a GWP > 2000, by 1 January 2019; or a blend that contains any HFC where that blend has a GWP > 2000, by 1 January 2019 **(Still allowed: Solstice N40, Performax[®] LT)**

R-404A, R-507, R-407A & others are targeted

Refrigerant Selection Criteria

Superheat

Need to protect compressors and ensure full use of refrigerating capacity.

Capacity

Is there enough capacity to keep the food at required temperatures?

Will the system have to run longer and reduce equipment life?

Efficiency

How much does the refrigerant add to the total and peak power consumption of the system? (include all powered systems)

Mass Flow

Higher mass flow means more refrigerant moving through the system. Different mass flow requires changes to TXV valves.

Oil Return

Is refrigerant miscible with oil so that oil returns and protects the compressor?

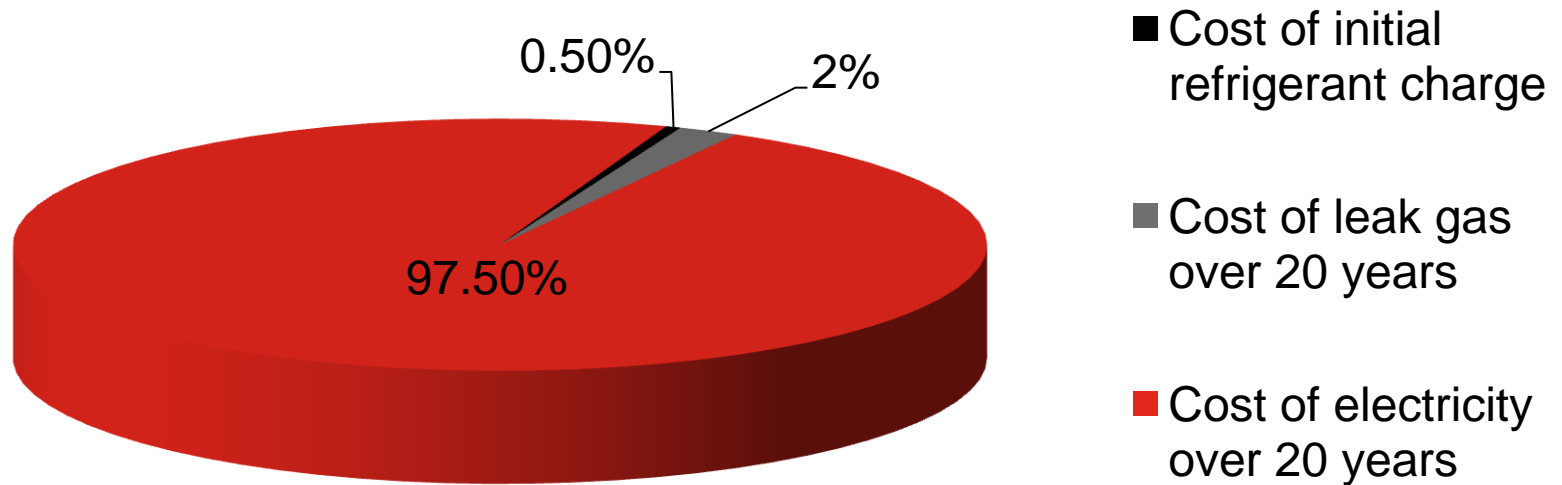
GWP

Lower is better. (possible future GWP tax)

BEST REFRIGERANT CHOICE

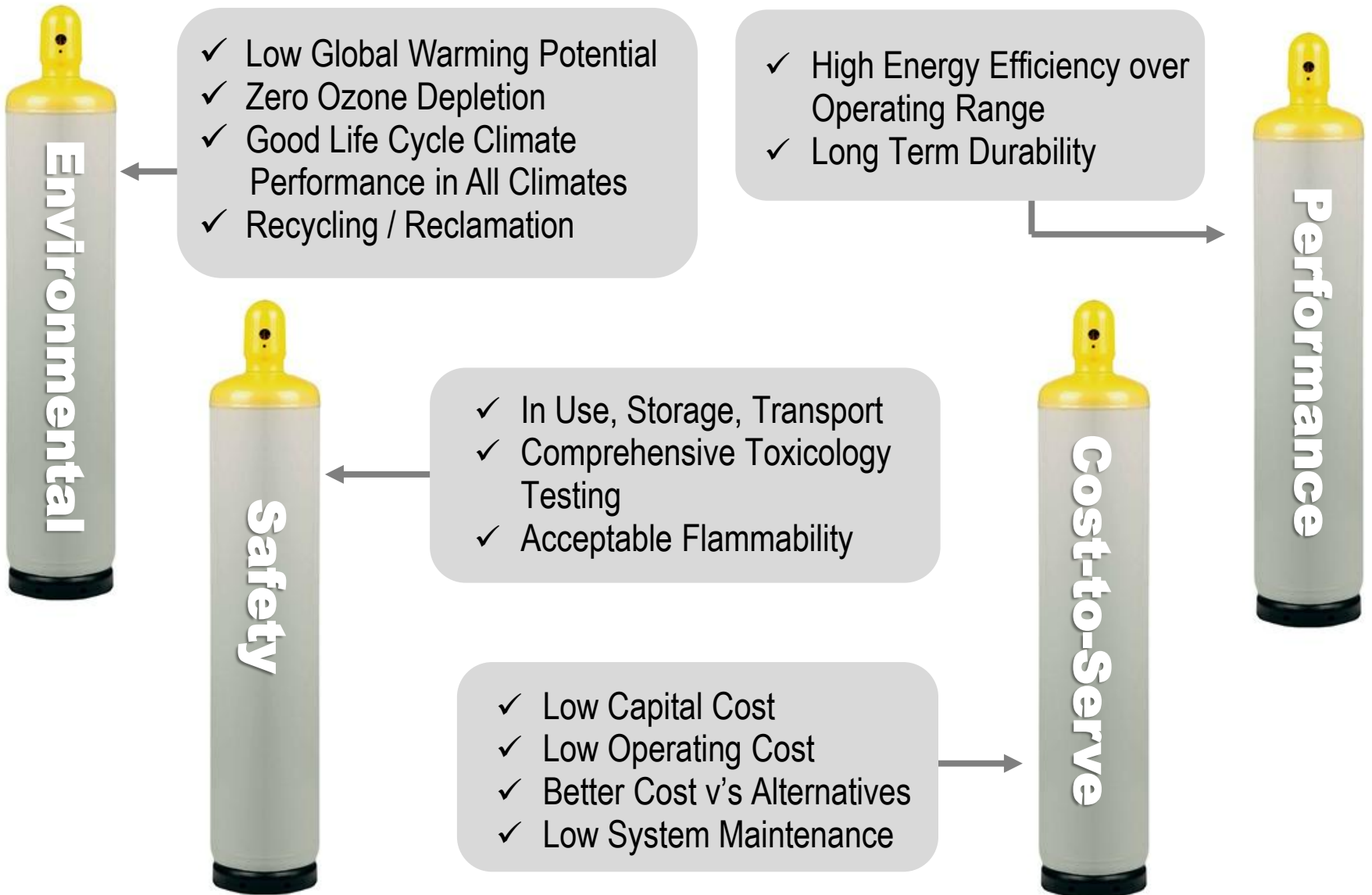
Key Selection Criteria for New Installations and Retrofits

Why is Energy Efficiency Important?



Energy Efficiency is the Key Selection Criteria

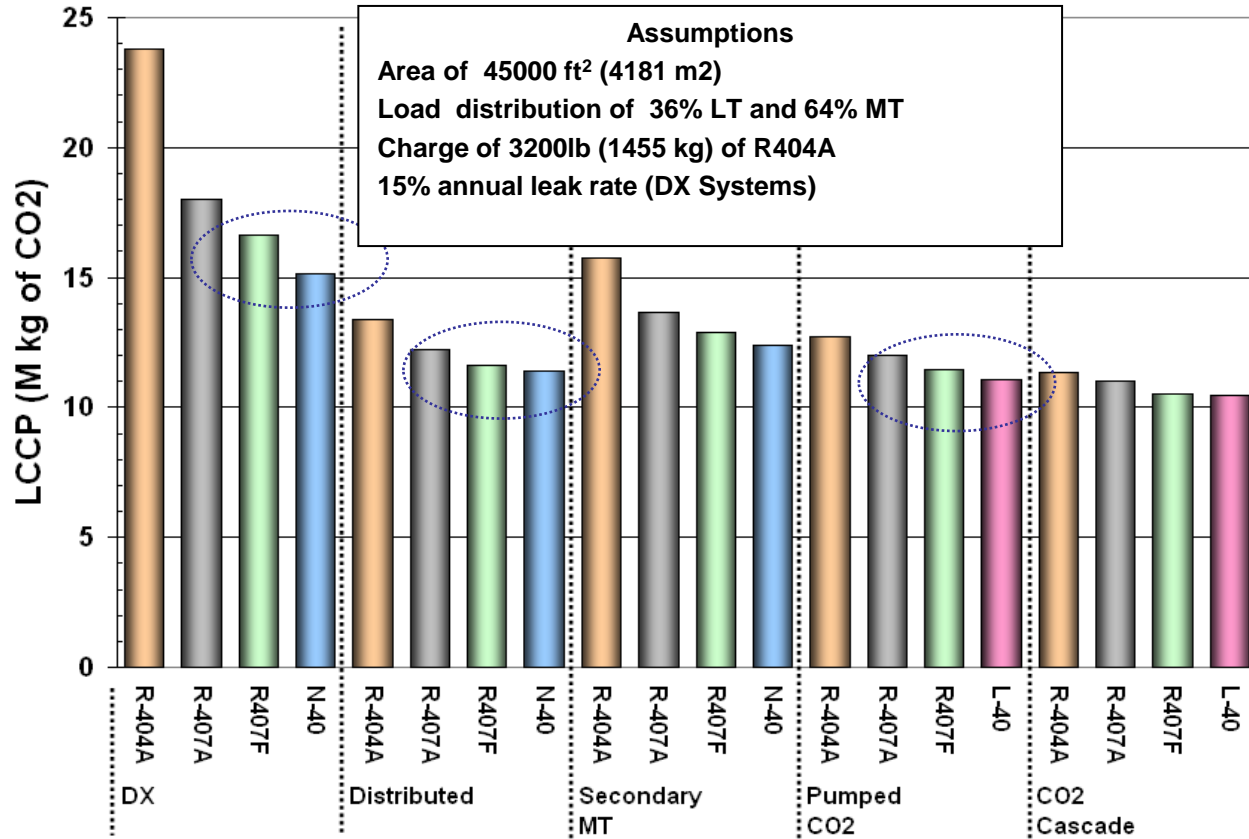
Decision-Making Criteria



LCCP- Life Cycle Climate Performance

LCCP calculations account for global warming impacts due to direct greenhouse gas emissions associated with the energy consumption of the product. In applications such as domestic and commercial refrigeration and stationary and mobile air conditioning equipment with the lowest LCCP rating produces the lowest global warming impact.

Environmental impact of different technologies



- The use of R448A (and even R407F) allows a considerable reduction of environmental impact when retrofitting existing systems (~50%).
- Among current DX technologies, distributed systems using R448A produce an environmental impact similar to more sophisticated technologies (cascade and pumped CO₂).

Looking Forward, Reduced/Low GWP Options

Ultra-Low GWP[®] Refrigerants

Examples of Applications	Current Product	Non-Flammable (ASHRAE A1)	Mildly Flammable (ASHRAE A2L)
MAC, Vending, Refrigerators	HFC-134a GWP-1300		yf GWP<1
Chillers, CO ₂ Cascade Refrigerators			ze GWP<1
Centrifugal Chillers	R-123 GWP-79	zd GWP=1	



[®] for Low and Medium Pressure Applications

Lower GWP[®] Blends

Examples of Applications	Current Products	N Series Reduced GWP Option Non-Flammable (ASHRAE A1)	L Series Lowest GWP Option Mildly Flammable (ASHRAE A2L)
Chillers, Medium Temp Refrigeration	HFC-134a GWP-1300	N-13 GWP<600 (R-450A)	
Stationary AC, Refrigeration	HCFC-22 GWP-1760	N-20-GWP<1000	L-20-GWP<300 (*R-444B)
Low-and Med-Temp Refrigeration	R-404A GWP-3943	N-40-GWP<1300 (R-448A)	L-40-GWP-200-300
Stationary AC Applications	R-410A GWP-1924		L-41-GWP<600 (R-447A)





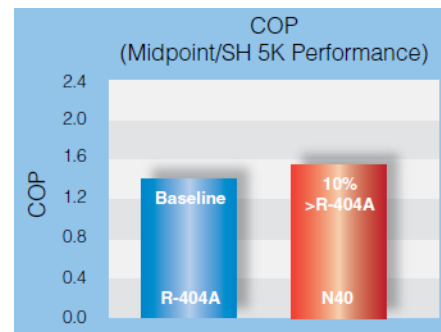
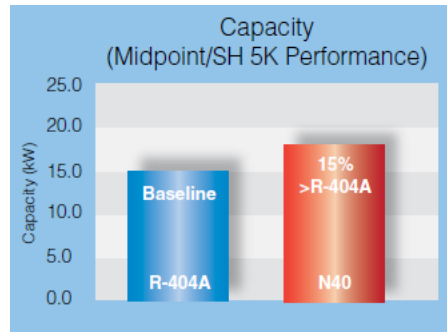
R448A / R450A

® R448A (R-448A)

R448A (R-448A) is the lowest GWP / A1 alternative to R-404A for existing R-404A equipment

R448A is an *HFO blend* designed to replace R-404A in low and medium temperature refrigeration equipment such as supermarket fridge and freezer cases and transport refrigeration. The performance and properties of R448A have been calculated to closely match that of R-404A and R-22 for both new and retrofit applications.

- **Attributes Composition - R32 (26%) / R125 (26%) / R134a (21%) / R1234ze (7%) / R1234yf (20%)**
 - ✓ Approved for Use by Major Compressor Manufacturers (Copeland / Bitzer ...)
 - ✓ Simple replacement / retrofit* of R-404A → Minor adjustment to settings
 - ✓ Significant Energy Savings over R-404A → Lower total cost of ownership
 - ✓ Improved Capacity v R-404A → Longer equipment life
 - ✓ Significant reduction in GWP (65%) → Reduced impact on environment
 - ✓ Performance proven in Supermarket trials and Laboratory Tests in EU and US



Emerson – Supermarket Laboratory Results

Lowest GWP, Best Performing A1 Alternative to R-404A

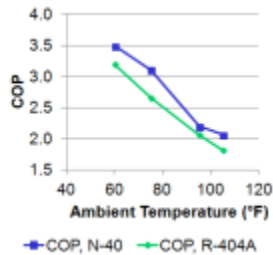
® R448A (R-448A)

3rd Party Evaluations on Product Performance

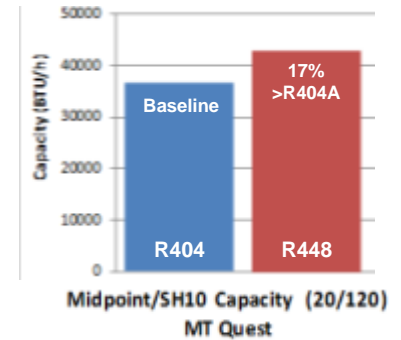
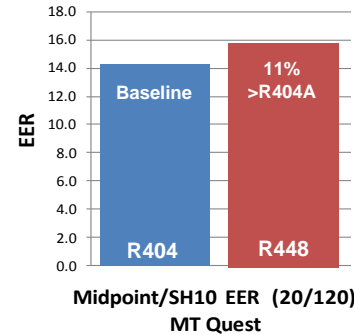
Oak Ridge National Laboratory (US)

- Supermarket System Evaluation
 - ✓ Reduced compressor power by 3.7%
 - ✓ Increased refrigeration capacity by 7.5%
 - ✓ Increased system COP by 11.6%

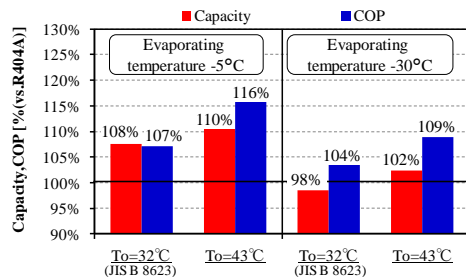
U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy



- Full 'Mock-Up' Supermarket Lab Trial
 - ✓ Tested on both Semi-Hermetic & Scroll
 - ✓ 'R448A provides superior Energy Efficiency to that of R-404A with reduced GWP'



- Condensing Unit Performance trial
 - ✓ Ambient tests at 90° & 110° C to JIS 8623 (std)
 - ✓ R448A showed 4-16% higher COP and excellent match in capacity



'R448A is well engineered refrigerant to meet requirement as an alternative to R404A'

- Successful >16 months trial store comparison
 - ✓ Improved capacity and efficiency vs. R404A
 - ✓ Simple retro-fit with minimal system adjustment
 - ✓ Discharge Temp close to R404A level (no liq injection required on LT)



R404 Replacement Overview

R-404A Replacement (MT/LT supermarket and LT self-contained)	R-404A	R-407A	Performax LT R407F	Solstice N40 R448A
Competitor(s)	All	All	HON	HON
Capacity	100%	101%	104%	107%
Efficiency	100%	108%	113%	114%
GWP	3943	1923	1674	1273
Discharge Temperature (LT)	210	265	280	250
Glide	1.1	8.1	8.0	8.5
Equipment Modifications	n/a	Adjust valves	Adjust valves	Adjust valves
Equipment Modifications LT	n/a	add mitigation	add mitigation	add mitigation

- *All candidates will require valve adjustments if retrofitting 404*
- *All replacements may require discharge temp mitigation in low temp applications*
- *All blends are only suitable for DX applications.*

R404A to [®] R448A (R448A) Retrofit

- Recover R404A using industry best practices (Green Chill Guidelines)
- Evaluate expansion devices
 - Most TXVs will need adjustment (close)
 - Input R448A curve into electronic TXVs
 - NI type TXVs will require adjustment kits
- Replace filter driers and oil system filters if required
- Evacuate and check for leaks, current leak detection equipment is suitable
- Charge the system with R448A,(+4%)
- Set controller to P-T curve of R448A
 - Set all operating controls/valves

No oil change required – R448A utilizes POE oil

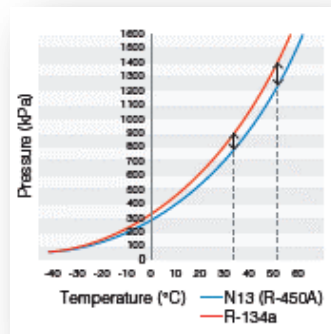
R450A (R-450A)

R450A (R-450A) is the lowest GWP / A1 alternative to R-134a for existing R-134a equipment

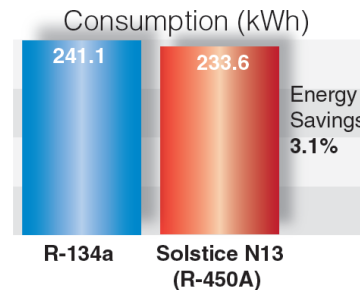
R450A is an *HFO blend* designed to replace R-134a medium temperature refrigeration equipment such as 'plug-in' cabinets, supermarket cabinets and vending machines. The performance and properties of R450A have been calculated to closely match that of R-134a for new applications.

- **Attributes Composition - R134a (42%) / R1234ze (58%)**

- ✓ Approved for Use by Major Compressor Manufacturers (Copeland / Bitzer ...)
- ✓ Similar system operating characteristics as R-134a → easy-to-use /apply
- ✓ Improved COP at higher ambient temperatures → energy savings
- ✓ Maintain A1 category / non-flammable → ease of use
- ✓ Significant reduction in GWP (58%) → Reduced impact on environment
- ✓ Lower discharge temperature than R-134a → Longer equipment life



Energy savings



Lowest GWP non-Flammable Alternative to R-134a

R134a Replacement Overview

134A Replacement (MTsupermarket and MT/LT self-contained)	R-134a	Solstice N13 R450A
Competitor(s)	All	HON
Capacity	100%	90%
Efficiency	100%	101%
GWP	1300	547
Discharge Temperature	na	na
Glide	0	0.8
Equipment Modifications	n/a	Add capacity?

The target for R450A is both new and retrofit.

- New designs can increase displacement to offset capacity shortfall
- Completed supermarket retrofit of 134a to R450A in a medium temperature DX application shows efficiency increase over 134a.
- Most systems can accommodate capacity ~ 10%, evaluate prior.
- Same lubricant as 134a, minimal to no txv adjustment required.
- XP 10 0°F glide is of no advantage in DX systems.

Summary & Conclusions

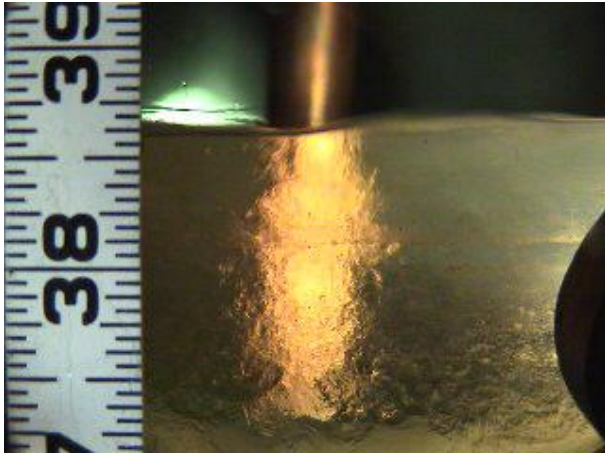
- HFO's and HFO blends should be considered as part of the solution to transition away from High GWP refrigerants.
- There is no single refrigerant solution, application and selection criteria/market will determine final application of available solutions.
- Energy efficiency will always be a major factor in determining equipment/refrigerant design choice.
- System and refrigerant comparisons should be done scientifically using proper experimental protocols.
- True environmental performance should be considered when making refrigerant/system choices.

Retrofitting Notes from the Field

Lubricant Issues when retrofitting

- R-22 is miscible with mineral oil over most of the commercial refrigeration and air-conditioning operating temperature range
- HFCs and HFC/Hydrocarbon blends are not miscible with mineral oil
- The addition of hydrocarbons to HFCs can increase solubility and assist the return of lubricant from **evaporators**. Liquid receivers do not benefit from this addition.

How important is miscibility?



A building
oil layer



Liquid receiver of a low temperature R22 refrigeration system using mineral oil.

An experiment was run to simulate a liquid flood back event and approximately 1/3 of the compressor lubricant left the crankcase.

Oil can be seen fully entrained in the liquid refrigerant, the lubricant left the receiver with the refrigerant and returned to the compressor.

Above: same liquid receiver using leading HFC/HC blend advertised as a drop in R-22 replacement. The lubricant is mineral oil.

The same experiment was run as for the R22 mineral oil experiment.

Oil can be seen floating on the surface of the liquid HFC. The hydrocarbon in this blend is not capable of duplicating the original HCFC/mineral oil relationship.

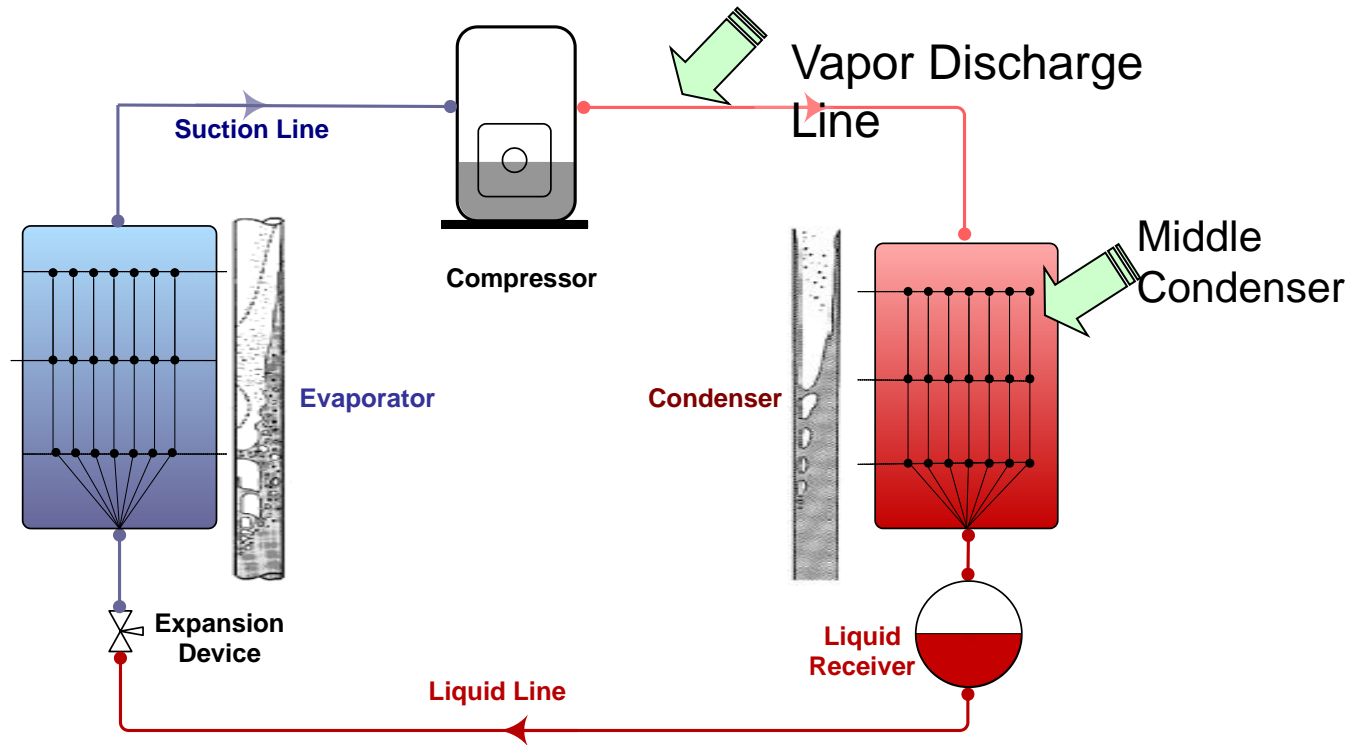
Lower than normal oil levels were measured in the compressor sump under these conditions.

Tested “Drop-ins” Using Hydrocarbons Did Not Duplicate R-22 / Mineral Oil Performance

Retrofitting: Notes from the Field

- Seals and gaskets in the “O” Ring configuration must be changed when going from an HCFC to any HFC
 - The exposure of many elastomers to chlorine has created a set which will not be duplicated after converting to an HFC. This is a refrigerant issue, not a lubricant issue.
 - This includes:
 - Schrader valves
 - Receiver level indicators and alarms
 - Heat reclaim and condenser splitting valves
- Fractionization of moderate glide blends in operating systems due to leaks has not materialized.
 - Proper charging of 400 series refrigerants mandates that only liquid be removed from the cylinder.

Fractionation of Blends during Leak Events



- Test System/Operating Leak events were simulated using a 0.1mm ID orifice and two scenarios:
 - System ON: 1) Vapor discharge line, 2) Middle of condenser (liquid-vapor)
 - System OFF: in the middle of the condenser (vapor while system OFF)
 - Small refrigerant samples (4g each) were analyzed using Gas Chromatography.

R448A Leak - composition and performance results (Fractionation)

			System OFF
R448A (R448A)	Description	Start	Vapor leak at suction line
	Time (hours)	0	197.0
	Charge (%)	100%	80%
Composition	R32	26.0%	23.70%
	R125	26.0%	25.57%
	R134a	21.0%	22.90%
	R1234yf	20.0%	20.77%
	R1234ze	7.0%	7.06%
Performance before top-off	Capacity	100%	98%
	COP	100%	100%
Performance after top-off	Capacity (%)	N/A	99%
	COP (%)	N/A	100%

- Leak in the suction line with system OFF caused minor changes in composition, within 2%
- Capacity decreased less than 2% while COP was maintained during leakage
- Top-off with nominal R448A recovers composition and performance to the original values

If the charge is topped-off, composition and performance return original values

Setting TD controls for blends with glide

	R22	AZ-20 (410A)		404A		Performax LT (407F)	
Temp.	Pressure	Bubble Pressure	Dew Pressure	Bubble Pressure	Dew Pressure	Bubble Pressure	Dew Pressure
(°F)	[psig]	[psig]	[psig]	[psig]	[psig]	[psig]	[psig]
100	195.9	318.5	317.6	236.8	234.6	249.3	220.6
106							
110	226.4	366.4	365.4	272.5	270.4	287.2	256.9
114							
120	260	419.4	418.3	312	309.9	329	297.4

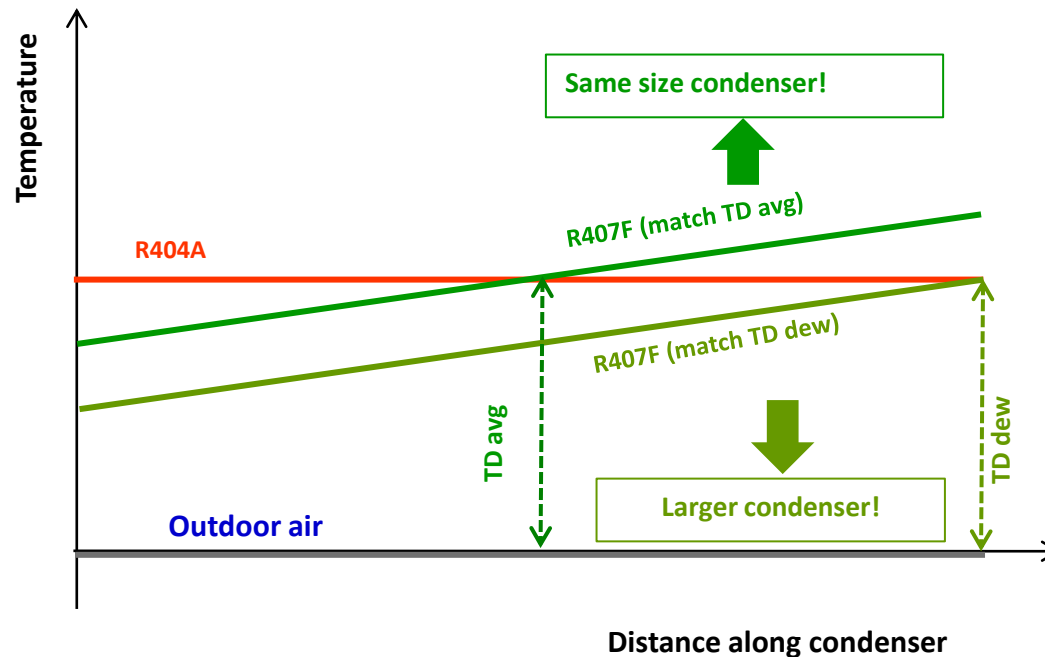
Do not forget to update the P-T curve on your controller

$$\text{Average pressure} = (287+257)/2 = 272 \text{ psig}$$

Always use the average when setting up EPR's and Fan Controls

Condenser Sizing

- Condenser sizing is typically carried out using TD based on dew point temperature.
- For a blend with glide, however, design TD should be based on the average coil temperature. (bubble and dew points)



While sizing a condenser for a blend, design TD should be based on the average coil temperature (average of bubble and dew points) and not solely on dew point

Fractionation of Blends during Leak Events

			System ON	System ON	System OFF
Description		Start	Vapor leak at discharge line	Two-phase leak in the middle of the condenser	Slow Vapor leak in the middle of the condenser
Time (hours)		0	26.7	22.1	20.3
Charge (%)		100%	82%	78%	79%
Composition	R32	30%	31.8%	28.3%	29.2%
	R125	30%	30.0%	28.0%	29.8%
	R134a	40%	38.2%	43.7%	41.1%
Performance before top-off	Capacity	100%	102%	96%	99%
	COP	100%	100%	100%	100%
Performance after top-off	Capacity (%)	N/A	101%	97%	99%
	COP (%)	N/A	100%	100%	100%

If the charge is topped-off, composition and performance return original values

Resources

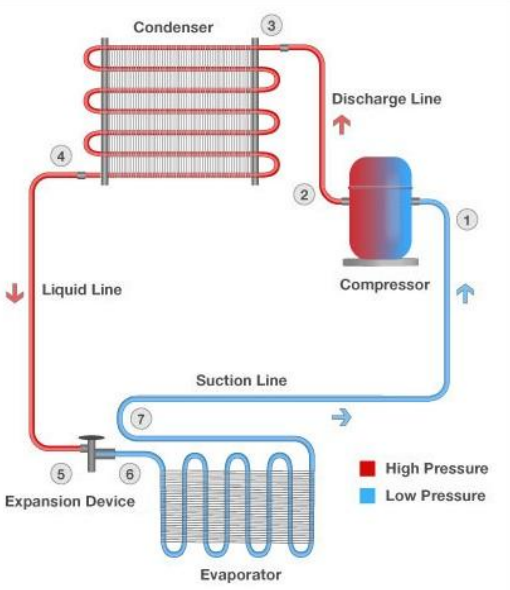
Genetron Properties Software

Genetron Properties

File Edit Options Refrigerants Tools Windows Help

Basic Cycle (S) X

Input Cycle



Condenser
Discharge Line
Compressor
Suction Line
Evaporator
Expansion Device

High Pressure
Low Pressure

Cycle Default Conditions

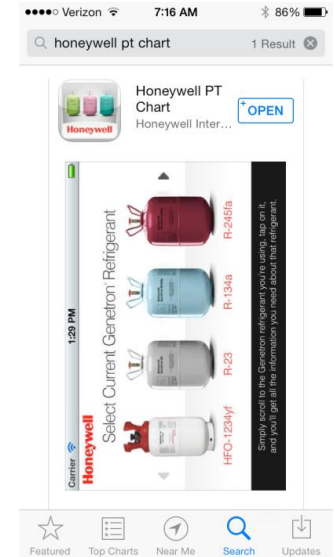
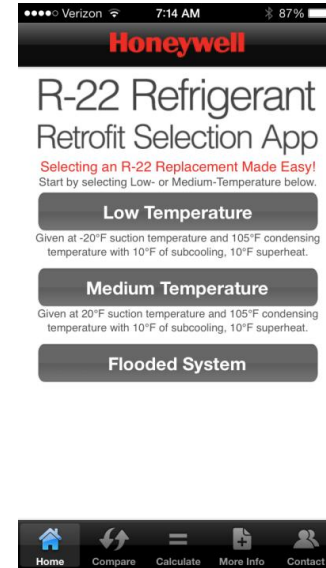
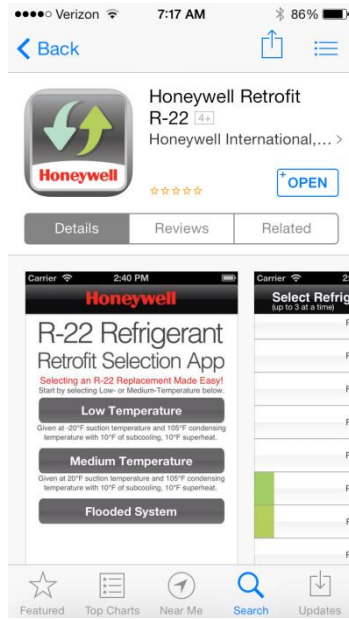
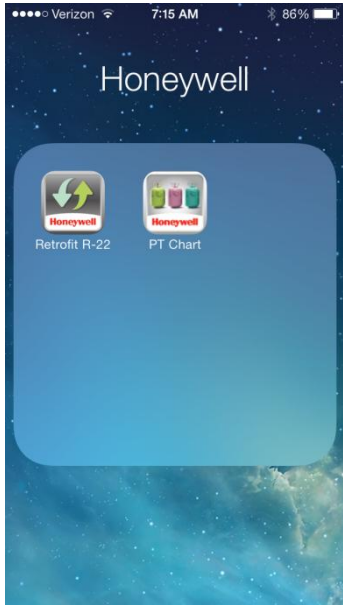
LT MT AC

Input Cycle

Parameters	Option	Unit	Value
Refrigerant	R404A		
Project Description	Low Temperature Refrig		
Compressor			
Volumetric Capacity	Compressor Displac	ft ³ /min	2118.88
Isentropic Efficiency			0.65
Volumetric Efficiency			1
Discharge Line			
Temperature Change	Temperature Chang	°F	0
Pressure Change	Drop Of Saturation	°F	0
Condenser			
Condensing Parameter	Condensing Temper	°F	113
Temperature Setting	Outlet Subcooling	°F	9
Pressure Setting	Pressure Drop	psia	0
Liquid Line			
Temperature Change	Temperature Chang	°F	0
Pressure Change	Drop Of Saturation	°F	0
Evaporator			
Evaporating Parameter	Evaporating Temper	°F	-25.6
Temperature Setting	Outlet SuperHeat	°F	10.08
Pressure Setting	Pressure Drop	psia	0
Suction Line			
Temperature Change	Temperature Rise	°F	36
Pressure Change	Drop Of Saturation	°F	0

Create Multicase

There's an App for that!



QR info for App

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Free R-22 Retrofit
Refrigerant Selection
Mobile App

Free Pressure-
Temperature Chart
Mobile App

Visit the App Store or GooglePlay, or scan the codes below



R-22 Retrofit App
(iOS)



R-22 Retrofit App
(GooglePlay)



Pressure
Temperature App
(iOS)



Pressure
Temperature App
(GooglePlay)

Supermarket Calculator



One-Stop Resource Shop

Resources

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- [All Technical Brochures](#)
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- [All Case Studies](#)
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- [Pressure Temperature Charts](#)

What's New in the Refrigerants Resource Center

- [Refrigerant modeling software](#)
- [Genetron 407C One-Page Information Sheet](#)
- [Mise a niveau Systemes de refrigeration et climatisation au R-22](#)
- [Guide to retrofitting A/C systems from R-22 to R-422D or R-407C](#)

Retrofit Guidelines

Honeywell Genetron® Refrigerants

HCFC Air Conditioning Retrofits

HCFC-22 to: Genetron 407C
 Genetron 422D

Honeywell Genetron® Refrigerants

HFC Retrofit Guidelines

HFC-404A & HFC-507 to: HFC-407F
Genetron® Performax™ LT

Questions?

Genetron Refrigerants Technical Service
1-800-631-8138

www.honeywell-refrigerants.com

Ralph.vergara@honeywell.com

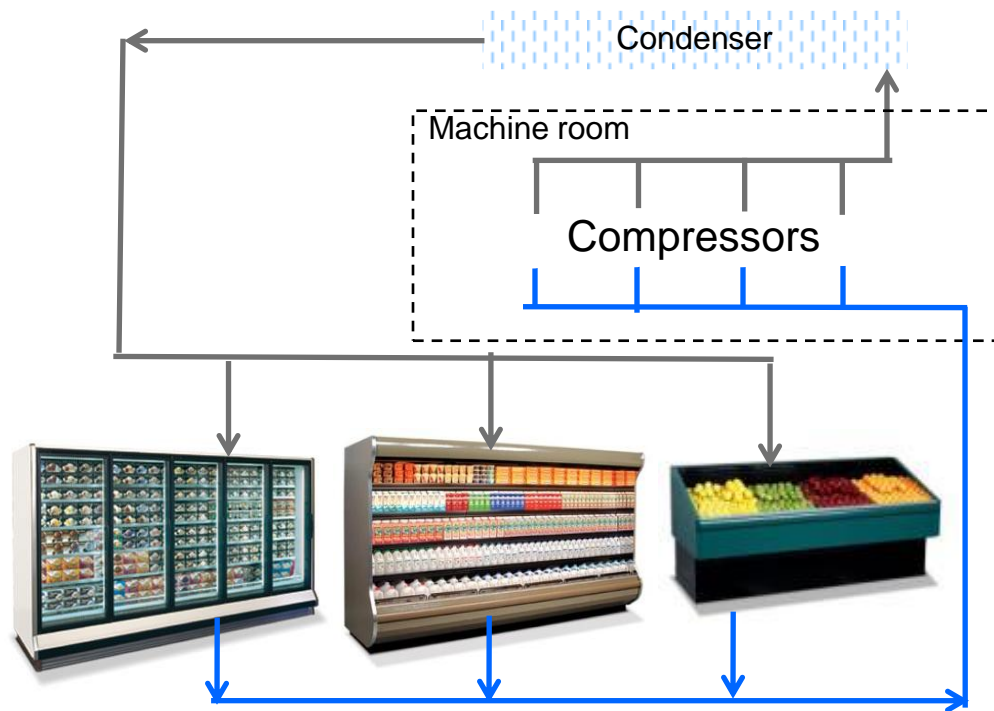
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Thank you!

BACK UP

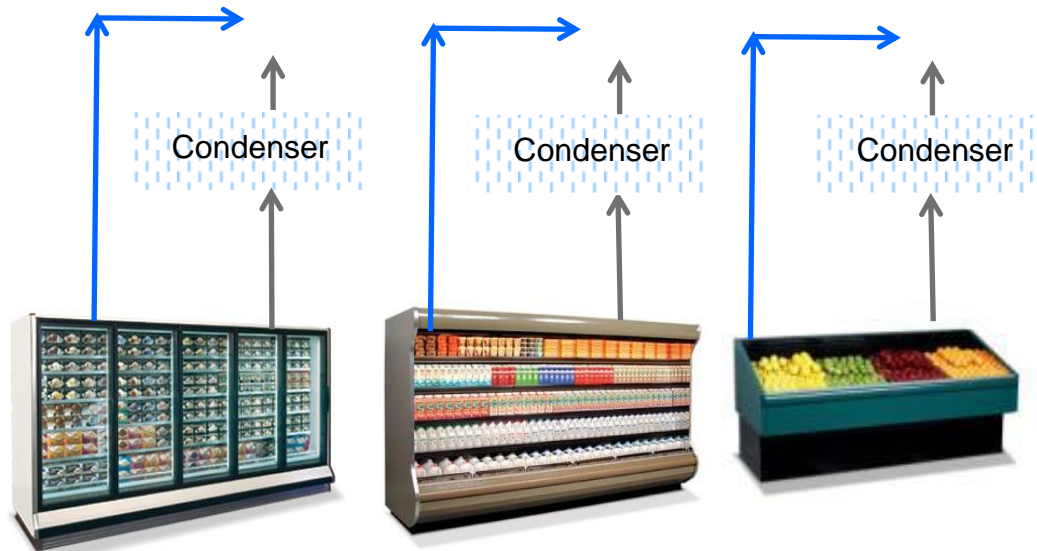
Commercial Refrigeration

Centralized DX System



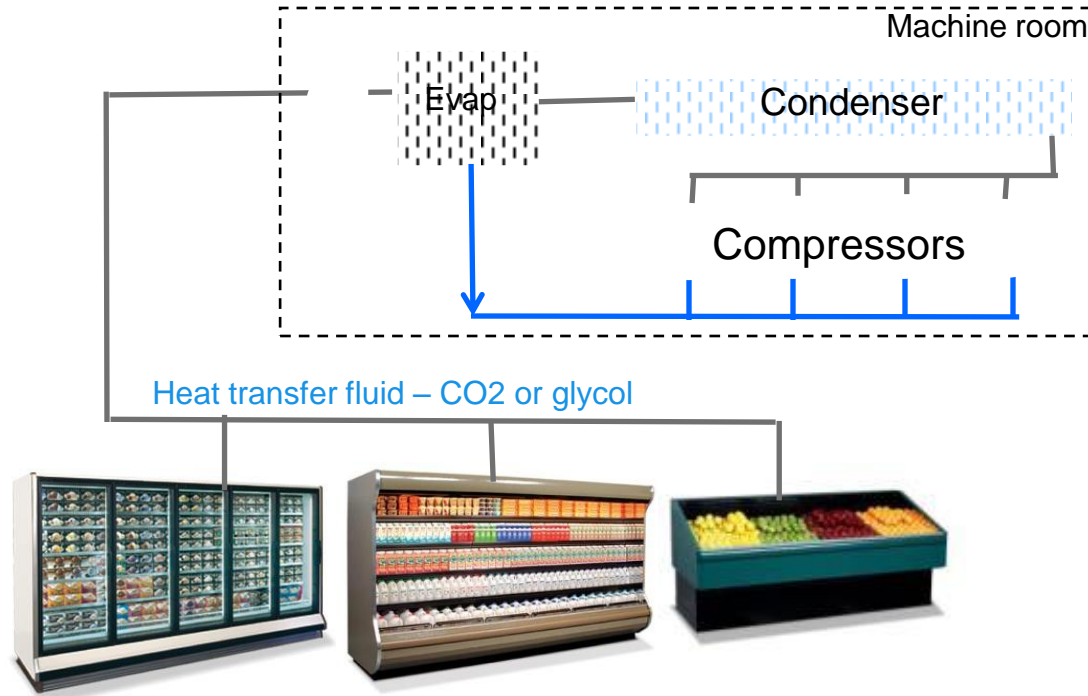
Features	Pros	Cons	Current	Future
<ul style="list-style-type: none"> - Compressor rack in machine room far from cases - Long connecting lines 	<ul style="list-style-type: none"> - Convenient installation in most buildings – in common practice - Very familiar to store owners and contractors 	<ul style="list-style-type: none"> - Larger refrigerant charge - Higher leak rates 	<p>R22 R404A R407A R407F</p>	<p>R448A</p>

Distributed DX System



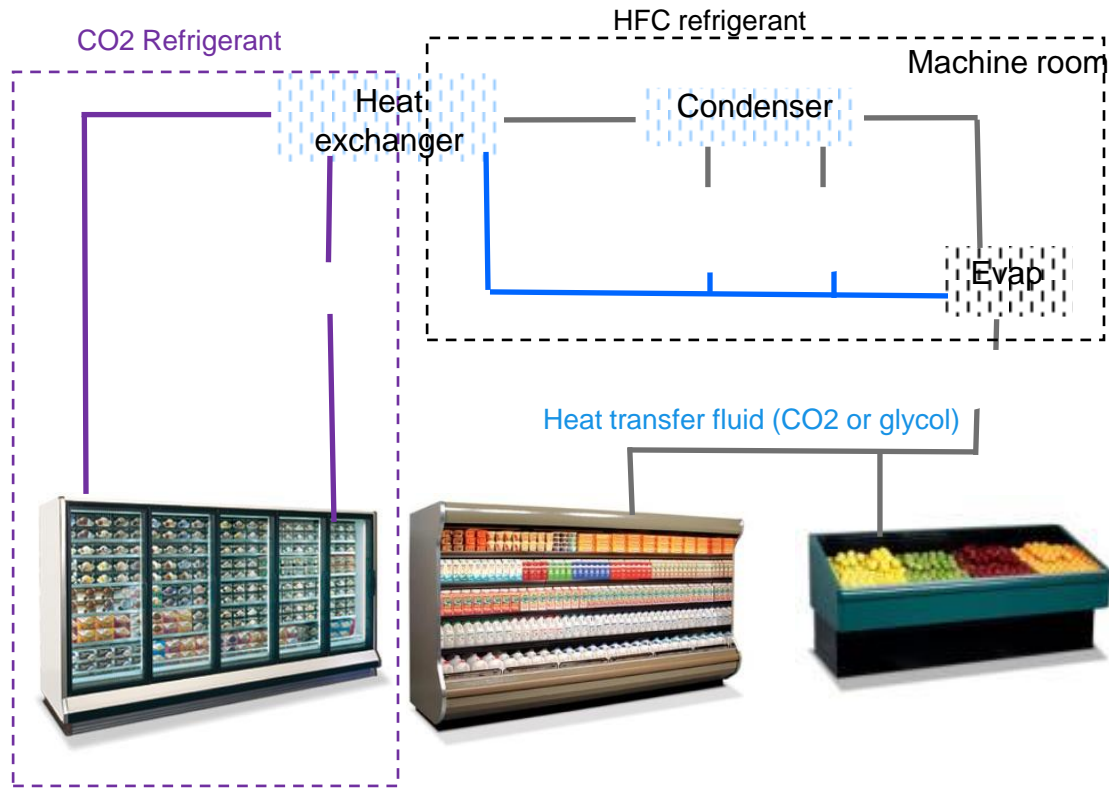
Features	Pros	Cons	Current	Future
<ul style="list-style-type: none"> - Condenser in rooftop and compressor at store level closer to cases - Short connecting lines 	<ul style="list-style-type: none"> - Lower refrigerant charge (about 1/2 of centralized systems) - Lower leak rates since condensing units are factory assembled - potentially more efficient than centralized – better match of suction groups, shorter lines 	<ul style="list-style-type: none"> - Not always feasible in some buildings 	<p>R404A R407F R407A</p>	<p>R448A</p>

Secondary Loop System



Features	Pros	Cons	Current	Future
<ul style="list-style-type: none"> - Secondary fluid (CO2 or glycol) distributed to the cases - Short connecting lines on the refrigerant side 	<ul style="list-style-type: none"> - Lower refrigerant charge (about 1/4 of centralized systems) - Very low leak rates - Refrigerant confined in machine room may allow mildly flammable options with very low GWP 	<ul style="list-style-type: none"> - Compressor can operate at lower pressures leading to higher energy consumption, also adds pumping power 	<p>R404A R407F 134a</p>	<p>R448A L40 R450A</p>

CO2 Cascade Systems with Secondary Loop



Features	Pros	Cons	Current	Future
<ul style="list-style-type: none"> - Secondary fluid (glycol) for medium temp cases - DX CO2 for the low temp cases - Short connecting lines on the refrigerant side 	<ul style="list-style-type: none"> - Very low refrigerant charge - Very low leak rates - Refrigerant confined in machine room may allow mildly flammable options with very low GWP - Higher efficiency 	<ul style="list-style-type: none"> - Higher initial cost 	<p>R404A R407F R134a</p>	<p>R448A L40 R450A R1234ze</p>