Making Sense of the Latest Rulemaking on Acceptable Refrigerants

E360 Forum • Raleigh, N.C. • March 1, 2017

Disclaimer

This presentation is intended to highlight changing developments in the law and industry topics. The law is frequently evolving and information and publications in this presentation may not reflect the latest changes in the law or legal interpretations. The statements and information provided in this presentation should not be construed as legal advice or legal opinion regarding any specific facts or circumstances, but is intended for general informational purposes only. The views and statements expressed during this presentation are the personal opinions of the presenter and do not represent those of Emerson Climate Technologies, Inc. or its affiliated companies. You should consult an attorney about your situation and specific facts and you should not act on any of the information in this presentation as the information may not be applicable to your situation. Although all statements and information contained herein are believed to be accurate and reliable, they are presented without warranty of any kind. Information provided herein does not relieve the user from the responsibility of carrying out its own tests and experiments. Statements or suggestions concerning the use of materials and processes are made without representation or warranty that any such use is free of patent infringement and are not recommendations to infringe on any patents. This presentation may not be copied or redistributed without the express written consent of Emerson Climate Technologies, Inc.

Presenters

Dr. Rajan Rajendran
Vice President — System Innovation Center and Sustainability

Emerson, The Helix Innovation Center

Matt Ritter
Global Business Director, Fluorochemicals

Arkema

Dr. Charles Allgood
Technology Leader — Refrigerants

Chemours

Dr. Gustavo Pottker
Refrigerants Technology Lead

Honeywell International

Agenda

• Global, national and regional regulations	Rajan
• Refrigerant options: Arkema perspective	Matt
• Refrigerant options: Chemours perspective	Charles
• Refrigerant options: Honeywell perspective	Gustavo
• Questions	All

Global, National and Regional Regulations

Dr. Rajan Rajendran

Vice President – System Innovation Center and Sustainability

Emerson

EPA and SNAP: Some Basics

Reference: https://www.epa.gov/snap

Under Section 612 of the Clean Air Act (CAA), program reviews substitutes within a compara

- Adhesives, Coatings & Inks
- Aerosols
- Cleaning Solvents
- Fire Suppression and Explosion Protection

The SNAP program does not provide a static li makes decisions that are informed by its overa health impacts as well as its current knowledg that EPA must prohibit the use of a substitute available substitutes that pose less overall risk

End Uses

Chillers

Chillers typically cool water, which is then circulated to provide comfort cooling throughout a building or other location. Chillers can be classified by compressor type, including centrifugal, reciprocating, scroll, screw, and rotary compressors. Chillers used to cool industrial processes are included under Industrial Process Refrigeration.

Cold Storage Warehouses

Cold storage warehouses store meat, produce, dairy products, and other perishable goods. The majority of cold storage warehouses in the United States use ammonia as the refrigerant in a vapor compression cycle, although some rely on other refrigerants.

Commercial Ice Machines

Commercial ice machines are used in commercial establishments (e.g., hotels, restaurants, convenience stores) to produce ice for consumer use. Ice machines produce ice in various sizes and shapes, and with different retrieval mechanisms (e.g., dispensers or self-retrieval from bins). Ice makers that are part of a refrigerator-freezer are considered part of the latter end-use, while equipment that is solely used to make ice, even if used in a domestic setting, is considered part of the commercial ice machine's end-use.

Household Refrigerators and Freezers

Household refrigerators and freezers are intended primarily for residential use, although they may be used outside the home. Household freezers only offer storage space at freezing temperatures. Products with both a refrigerator and freezer in a single unit are most common. Small refrigerated household appliances may also include chilled kitchen drawers, wine coolers, and mini fridges.

Ice Skating Rinks

Ice skating rinks are used by the general public for recreational purposes and also include professional rinks. These systems frequently use secondary loop refrigeration systems.

Industrial Process Air Conditioning

Industrial process air-conditioning units, which are distinct from commercial and residential air conditioning, provide comfort cooling for operators and protect process equipment. This end-use is often used when ambient temperatures approach 200°F (93°C) and corrosive conditions exist.

Industrial Process Refrigeration

Industrial process refrigeration systems cool process streams in industrial applications. The choice of substitute for specific applications depends on ambient and required operating temperatures and pressures.

Motor Vehicle Air Conditioning

Motor vehicle air-conditioning systems (MVACs) provide comfort cooling for passengers in light-duty cars and trucks, buses, trains, and other forms of transportation.

Non-Mechanical Heat Transfer Systems

Non-mechanical heat transfer systems include cooling systems that do not rely on a vapor compression cycle, such as those using convection to remove heat from an area. Two types of such systems are *recirculating cooler*s, i.e., systems with fluid pumps, and *thermosiphons*, i.e., those that rely on natural convection currents. This end-use also includes Organic Rankine Cycle (ORC) devices that typically pump refrigerant to recover and utilize energy from lower-temperature heat rejected from other processes.

EPA and SNAP: Some Basics

Reference: https://www.epa.gov/snap

Residential and Light Commercial Air Conditioning and Heat Pumps

This end-use includes equipment that cools enclosed spaces in households and commercial industries, but excludes chillers—which include room air conditioning such as window units, packaged terminal air conditioners (PTAC) and heat pumps (PTHP), and portable air conditioners; central air conditioners (i.e., ducted); non-ducted systems (both mini and multi splits); packaged rooftop units; water-source and ground-source heat pumps; and other products. Residential and light commercial air conditioning and heat pumps are often distinguished from chillers by the fact that they condition the air directly, rather than cool (or heat) water that is then used to condition air.

Residential Dehumidifiers

Residential dehumidifiers are primarily used to remove water vapor from ambient air or directly from indoor air for comfort or material preservation purposes. While air-conditioning systems often combine cooling and dehumidification, this application serves only the latter purpose.

Refrigerated Transport

Refrigerated transport moves products (e.g., perishable goods) from one place to another by various modes of transportation while maintaining necessary temperatures, including refrigerated ship holds, truck trailers, railway freight cars, ships, and other shipping containers.

Retail Food Refrigeration

Retail food refrigeration, or commercial refrigeration, includes equipment designed to store, display, process, or dispense chilled or frozen goods for commercial sale. This end-use includes these categories of equipment: *stand-alone equipment*, *remote condensing units*, *supermarket systems, and refrigerated food processing and dispensing equipment*.

Vending Machines

Vending machines are self-contained units that dispense goods that must be kept cold or frozen.

Very Low Temperature Refrigeration

Very low temperature refrigeration systems require maintaining temperatures at approximately -80 degrees Fahrenheit (-62 degrees Celsius) or lower. Examples include medical freezers and freeze-dryers, which generally require extremely reliable refrigeration cycles to maintain low temperatures and must meet stringent technical standards that do not normally apply to refrigeration systems.

Water Coolers

Water coolers are self-contained units providing chilled water, and possibly heated water, for drinking. They may or may not feature detachable containers of water.

Contact Us to ask a question, provide feedback, or report a problem.

EPA and SNAP: Some Basics

Retail Food Refrigeration

Reference: https://www.epa.gov/snap

Categories of Equipment

Stand-alone Equipment

Stand-alone equipment includes refrigerators, freezers, and reach-in coolers (either open or with doors) where all refrigeration components are integrated and, for the smallest types, the refrigeration circuit is entirely brazed or welded. These systems are fully charged with refrigerant at the factory and typically require only an electricity supply to begin operation.

Refrigerated Food Processing and Dispensing Equipment

Refrigerated food processing and dispensing equipment dispenses and often processes a variety of food and beverage products. For instance, some such equipment will process the product by combining ingredients, mixing and preparing it at the proper temperature, while others function mainly as a holding tank to deliver the product at the desired temperature or to deliver chilled ingredients for the processing, mixing and preparation. Some may use a refrigerant in a heat pump, or utilize waste heat from the cooling system, to provide hot beverages. Some may also provide heating functions to melt or dislodge ice or for sanitation purposes.

This equipment can be self-contained or can be connected via piping to a dedicated condensing unit located elsewhere. Equipment within this end-use category include but are not limited to: chilled and frozen beverages (carbonated and uncarbonated, alcoholic and nonalcoholic); frozen custards, gelato, ice cream, Italian ice, sorbets and yogurts; milkshakes, "slushies" and smoothies, and whipped cream.

Remote Condensing Units

Remote condensing units have typical refrigerating capacities from 1 kW to 20 kW (0.3 to 5.7 refrigeration tons) and are composed of one (and sometimes two) compressor(s), one condenser, and one receiver assembled into a single unit, which is normally located external to the sales area. The condenser (and often other parts of the system) is located outside the space or area cooled by the evaporator, typically ejecting heat to the outdoor ambient environment. Remote condensing units are commonly installed in convenience stores, specialty shops (e.g., bakeries, butcher shops), supermarkets, restaurants, and other locations where food is stored, served or sold.

Supermarket Systems

This equipment category includes multiplex or centralized systems, which operate with racks of compressors installed in a machinery room. Two main design classifications are used: Direct and indirect systems.

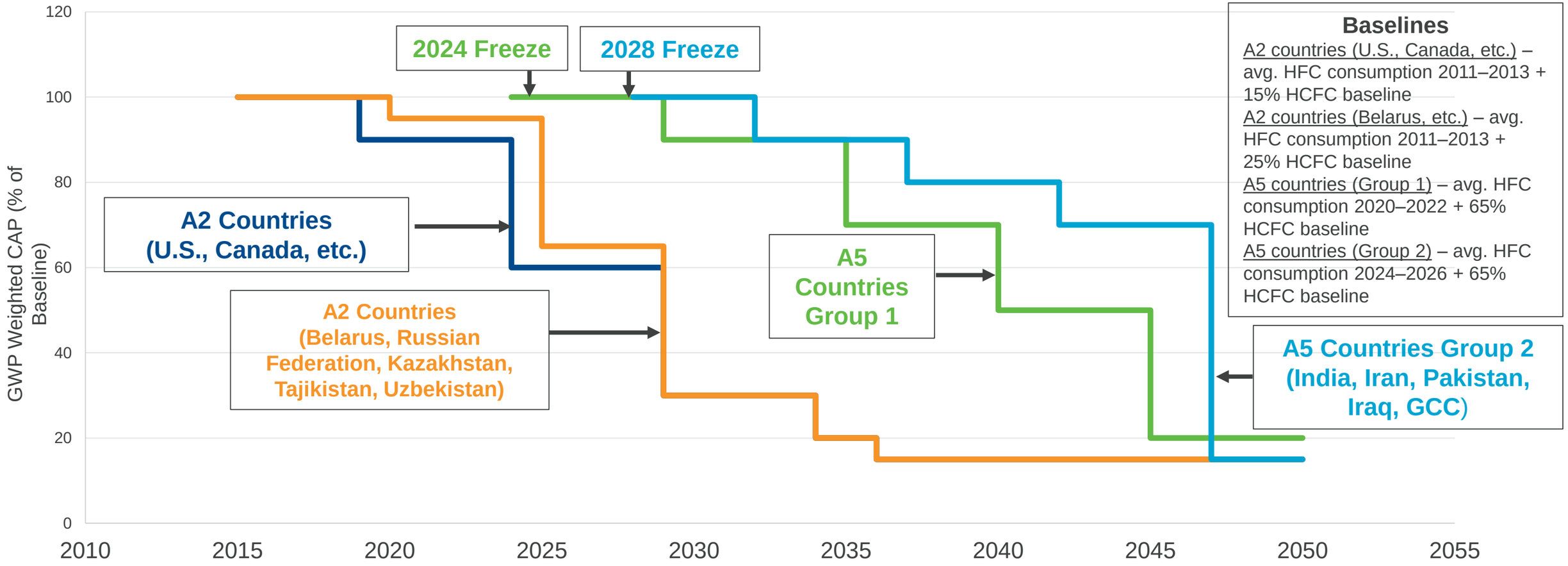
In direct systems, the refrigerant circulates from the machinery room to the sales area, where it evaporates in display-case heat exchangers, and then returns in vapor phase to the suction headers of the compressor racks. Another direct supermarket design, often referred to as a distributed refrigeration system, uses an array of separate compressor racks located near the display cases rather than having a central compressor rack system.

Indirect supermarket designs include secondary loop systems and cascade refrigeration. Indirect systems use a "chiller" (not to be confused with the "chiller" end-use) or other refrigeration system to cool a secondary fluid that is then circulated throughout the store to the cases.

Contact Us to ask a question, provide feedback, or report a problem.

Kigali Amendment to the Montreal Protocol
October 15, 2016

"38th Meeting of the Parties to the Montreal Protocol on Substances That Deplete the Ozone Layer"
October 8, 10–14 in Kigali, Rwanda



Ref: http://conf.montreal-protocol.org/meeting/mop/mop-28/crps/SitePages/Home.aspx

Global Agreement on HFC Phase-Down Reached by 197 Countries of the World, in Kigali, Rwanda, on October 15, 2016

Refrigerants and the EPA

EPA's Final Rule, July 20, 2015
Phase-Out Candidates*, Likely Alternatives* and Dates

Phase-Out Refrigerant	Super-market New	Super-market Retrofit	Remote Cond. Unit New	Remote Cond. Unit Retrofit	Stand-Alone			
					MT <2,200 BTU/hr. and not contain flooded evap. New	MT ≥2,200 BTU/hr. with or without flooded evap. New	LT New	LT and MT Retrofit
R-404A/507A	Jan 1, 2017	July 20, 2016	Jan 1, 2018	July 20, 2016	Jan 1, 2019	Jan 1, 2020	Jan 1, 2020	July 20, 2016
R-410A	OK	-	OK	-	Jan 1, 2019	Jan 1, 2020	Jan 1, 2020	-
R-407A/C/F	OK	OK	OK	OK	Jan 1, 2019	Jan 1, 2020	Jan 1, 2020	OK
HFC-134a	OK	OK	OK	OK	Jan 1, 2019	Jan 1, 2020	OK	OK

- Foam, motor vehicle AC, also affected by final rule (see reference for all details)
- Stationary HVAC and transport refrigeration not impacted by the July 20, 2015 final rule

**** Refer to Tables 4, 5 and 6 of Final Rule for complete details***

Reference: Federal Register / Vol. 80, No. 138 / Monday, July 20, 2015 / Rules and Regulations, 42870-42959

Refrigerants and the EPA

www.epa.gov/snap

ET

heric Ozone: Significant New
w and Changed Listings

ACCEPTABLE ALTERNATIVES, WITH USE CONDITIONS

End-Uses	Substitutes	Effective Date
Refrigeration		
Self-contained commercial ice machines (new)	Propane (R-290)	30 days after publication of final rule
Water coolers (new)	Propane (R-290)	30 days after publication of final rule
Very low temperature refrigeration equipment (new)	Propane (R-290)	30 days after publication of final rule
Motor Vehicle Air Conditioning (MVAC)		
MDPVs, HD pickup tr manufactured)		
Fire Suppression and		
Total flooding agent f power units on aircra		
Streaming agent for u		

CHANGE OF LISTING STATUS

End-Uses	Substitutes	Date of Change of Status
Air Conditioning		
Centrifugal chillers (new)	FOR12A, FOR12B, HFC-134a, HFC-227ea, HFC-236fa, HFC-245fa, R-125/134a/600a (28.1/70/1.9), R-125/290/134a/600a (55.0/1.0/42.5/1.5), R-404A, R-407C, R-410A, R-410B, R-417A, R-421A, R-422B, R-422C, R-422D, R-423A, R-424A, R-434A, R-438A, R-507A, RS-44 (2003 composition), and THR-03	Unacceptable, except as otherwise allowed under a narrowed use limit, as of January 1, 2024

SNAP New and Changed Listings — Final, Sept. 26, 2016

https://www.epa.gov/sites/production/files/2016-09/documents/snap_action_scr_2_factsheet.pdf

Refrigerants and the EPA

www.epa.gov/snap

End-Uses	Substitutes	Date of Change of Status
Centrifugal chille (new)		
Centrifugal chille (new)		
Positive displacement chillers (new)		
Positive displacement chillers (new)		
Positive displacement chillers (new)		

Refrigeration		
Cold storage warehouses (new)	HFC-227ea, R-125/290/134a/600a (55.0/1.0/42.5/1.5), R-404A, R-407A, R-407B, R-410A, R-410B, R-417A, R-421A, R-421B, R-422A, R-422B, R-422C, R-422D, R-423A, R-424A, R-428A, R-434A, R-438A, R-507A, and RS-44 (2003 composition)	Unacceptable, as of January 1, 2023
Retail food refrigeration – refrigerated food processing and dispensing equipment (new)	HFC-227ea, KDD6, R-125/290/134a/600a (55.0/1.0/42.5/1.5), R-404A, R-407A, R-407B, R-407C, R-407F, R-410A, R-410B, R-417A, R-421A, R-421B, R-422A, R-422B, R-422C, R-422D, R-424A, R-428A, R-434A, R-437A, R-438A, R-507A, RS-44 (2003 formulation	Unacceptable, as of January 1, 2021
Household refrigerators and freezers (new)	FOR12A, FOR12B, HFC-134a, KDD6, R-125/290/134a/600a (55.0/1.0/42.5/1.5), R-404A, R-407C, R-407F, R-410A, R-410B, R-417A, R-421A, R-421B, R-422A, R-422B, R-422C, R-422D, R-424A, R-426A, R-428A, R-434A, R-437A, R-438A, R-507A, RS-24 (2002 formulation), RS-44 (2003 formulation), SP34E, and THR-03	Unacceptable, as of January 1, 2021

SNAP New and Changed Listings — Final, Sept. 26, 2016

https://www.epa.gov/sites/production/files/2016-09/documents/snap_action_scr_2_factsheet.pdf

Other Refrigerant Regulation Activity

F-Gas (EU): effective May 20, 2014

Commercial application	GWP limit	Date
Self-contained refrigeration	2,500	2020
Stationary refrigeration	2,500	2020
Self-contained refrigeration	150	2022
Centralized refrigeration	150	2022
– Except top side of cascade	1,500	2022

CARB: Short-lived climate pollutant reduction strategy — proposal Nov. 28, 2016 (comments Jan. 17, 2017)

Commercial application	GWP limit	Date
All refrigerant sales	2,500	?
Non-residential refrigeration	150	?
AC (non-residential and residential)	750	?

Environmental Canada (EC)**: proposal November 26, 2016

Commercial application	GWP limit	Date
Refrigeration – centralized systems (MT/LT racks)	1,500	2020
Refrigeration – condensing units	2200	2020
Refrigeration – LT stand-alone	1,500	2020
Refrigeration – MT stand-alone	700	2020
Foams	150	2021
Mobile refrigeration	2,200	2025
AC – chillers	700	2025
Domestic refrigeration	150	2025

- Phase-down (NAP) option also proposed (2019 — 90%; 2024 — 65%; 2030 — 30%; 2036 — 15%; baseline 2011–2013)

** http://www.gazette.gc.ca/rp-pr/p1/2016/2016-11-26/html/reg1-eng.php

Comment period ends Feb. 8, 2017.

Many of the Current Regulatory Proposals Target 150 GWP for Refrigeration and ~750 GWP for AC Applications. A Global Agreement Like the Kigali Amendment Can Help Eliminate Patchwork of Refrigerant Regulations.

Other Refrigerant, Standards, Code-Related Activity

Federal acquisition regulation encouraging low-GWP usage in federal buildings

Section 608 revisions to refrigerant management now include HFCs

https://www.epa.gov/section608/revised-section-608-refrigerant-management-regulations

Safety standards under revision to include mildly flammable refrigerant (A2L) accommodations

- U.S.: UL 1995, ASHRAE 15
  - Target late 2017
- International: ISO 5149, IEC 60335, EN378
  - Target late 2017

Evaluating revisions on increasing charge limits for flammables

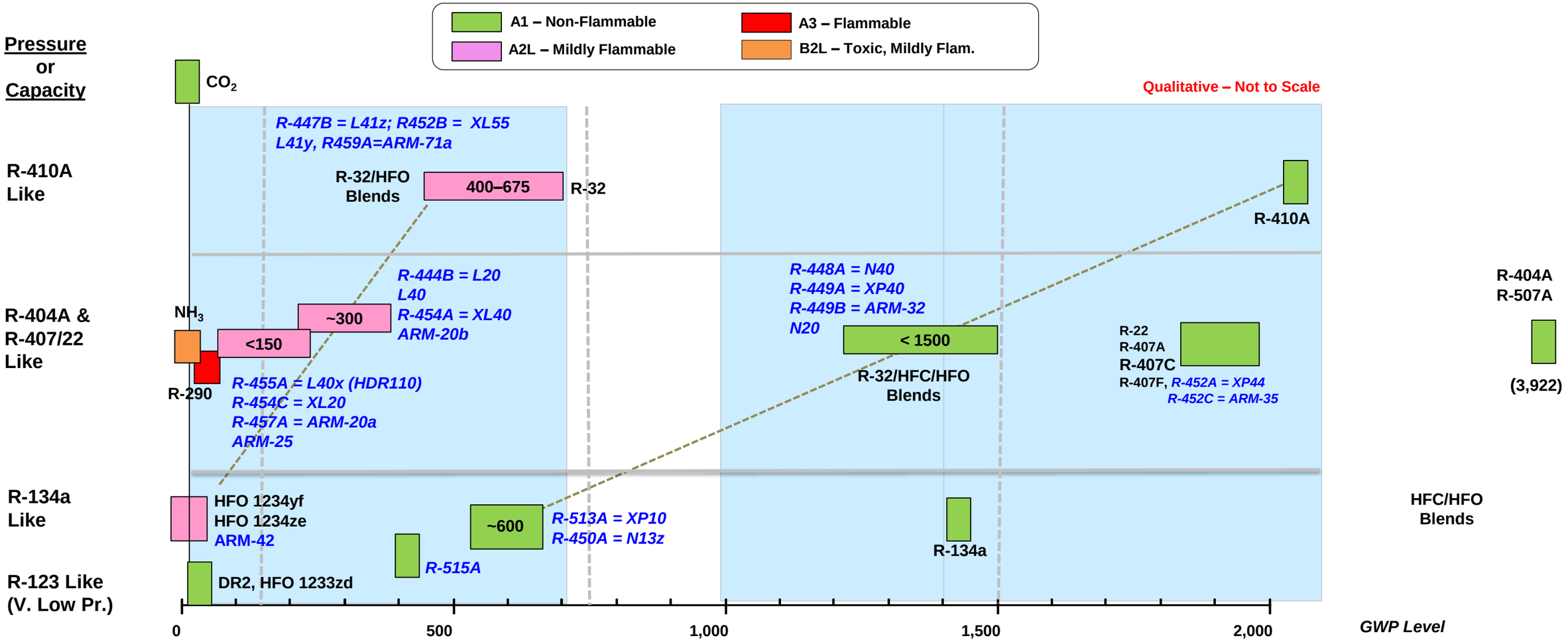
- U.S. A3 charge limit from 150g to 300g–500g

Building codes for mildly flammable (A2L) refrigerants being expedited for adoption in 2021 code cycle

$5.2M partnership by AHRI, ASHRAE, DOE to study flammable refrigerant behavior in real-world applications

Refrigerant-related Changes Are Global in Scope; We Have to Stay on Top to Remain Competitive.

Refrigerant Options



Lower-GWP Synthetic Refrigerants, Blends and Natural Refrigerants Are Available Options in Various Applications.

Refrigerant Options: Arkema Perspective

Matt Ritter
Global Business Director – Fluorochemicals
Arkema

Alternatives – Arkema Perspective

	*Final Rule: July 20, 2015								*Final Rule: September 26, 2016				
Phase-out refrigerant	Super-market (New**)	Super-market (Retrofit***)	Remote condensing unit (New)	Remote condensing unit (Retrofit***)	Stand-Alone				Refrigerated food processing and dispensing equipment (New)	Cold storage warehouses (New)	Ice machines (New)	Very low-temp refrigeration (New)	Positive displ. chiller (New)
					MT < 2,200 BTU/hr. and not contain flooded evap. (New)	MT ≥ 2,200 BTU/hr. with or without flooded evap. (New)	LT (New)	LT and MT (Retrofit***)					
R-404A/507A	Jan. 1, 2017	July 20, 2016	Jan. 1, 2018	July 20, 2016	Jan. 1, 2019	Jan. 1, 2020	Jan. 1, 2020	July 20, 2016	Jan. 1, 2021	Jan. 1, 2023	OK	OK	Jan. 1, 2024
R-410A	OK	-	OK	-	Jan. 1, 2019	Jan. 1, 2020	Jan. 1, 2020	-	Jan. 1, 2021	Jan. 1, 2023	OK	OK	Jan. 1, 2024
R-407A/C/F	OK	OK	OK	OK	Jan. 1, 2019	Jan. 1, 2020	Jan. 1, 2020	OK	Jan. 1, 2021	R-407C/F OK R-407A: Jan. 1, 2023	OK	R-407C only	Jan. 1, 2024 R-407C
HFC-134a	OK	OK	OK	OK	Jan. 1, 2019	Jan. 1, 2020	OK	OK	OK	OK	OK	-	
Likely alternatives													
R-449B	OK	OK	OK	OK	✓	✓	OK	OK	OK	✓	OK	✓	
R-452C	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
ARM-25	✓ indirect		✓		✓	✓	✓	✓	✓		✓		
R-457A	✓ indirect		✓		✓	✓	✓	✓	✓		✓		
R-516A	✓ indirect		✓		✓	✓	✓	✓	✓		✓		✓
R-459A													✓

OK = SNAP-approved for application
✓ = Areas of possible use in the future

- Abbreviated – For complete listing, see EPA final rules; go to: https://www.gpo.gov/fdsys/pkg/FR-2015-07-20/pdf/2015-17066.pdf https://www.gpo.gov/fdsys/pkg/FR-2016-04-18/pdf/2016-08163.pdf

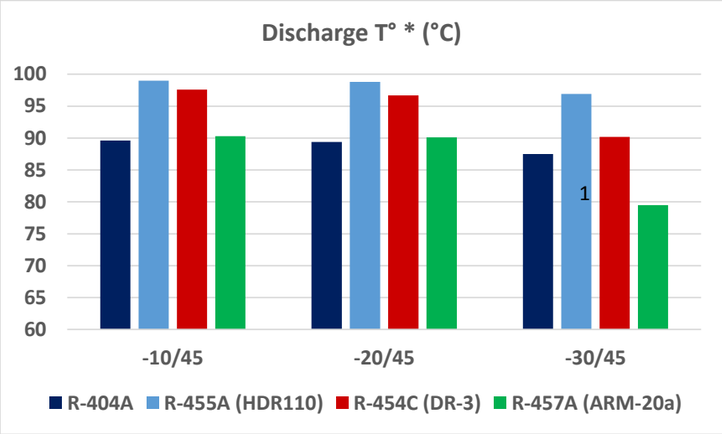
** Includes ice machines connected to a supermarket rack refrigeration system.

*** EPA uses term “retrofit” to indicate the use of a refrigerant in an appliance that was designed for and originally operated using a different refrigerant. Term does not apply to upgrades to existing equipment where the refrigerant is not changed.

Forane® 457A (ARM-20a) — R-404A/R-22 Replacement for HVACR

R-404A Replacement Comparison[1]:

- Efficiency consistently higher
- Similar Discharge Temperature
- Lower Capacity (15–20%)

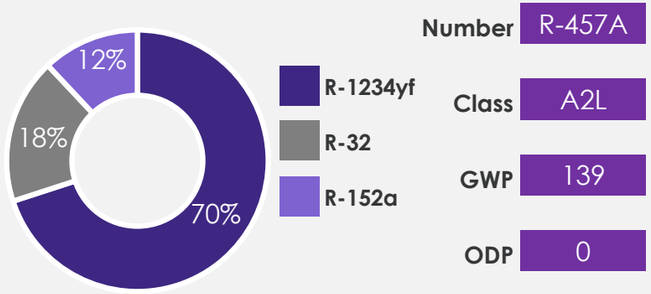


R-22 Replacement Comparison in AC[2]:

- Higher Efficiency Than R-22 in RTU at Standard Conditions and High Ambient

	AHRI Standard Rating Conditions Outdoor: 35.0°C (95°F) Indoor: 26.7°C (80.0°F)	
	COP	Cooling Capacity, $kW_{th.}$
R-22 (Baseline)	3.04	25.27
L-20A (R-444B)	2.94 (-3.3%)	25.46 (+0.7%)
DR-7 (R-454A)	2.86 (-6.2%)	27.15 (+7.4%)
ARM-20a	3.21 (+5.5%)	24.58 (-2.8%)

R-457A SUMMARY



APPLICATIONS

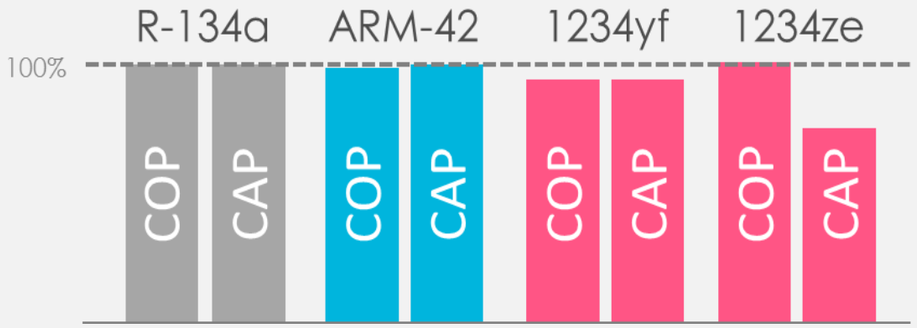
- Stand-alone Refrigeration
- Supermarket Refrigeration
- Packaged, RTU
- Split Systems, Unitary

1. Embraco Slovakia – AHRI – Low GWP AREP – test reports n°49, 50- R-457A results to be reviewed and approved by the AREP Technical Committee
2. Abdelaziz et al. (2016) ORNL/TM-2016/513, Oak Ridge National Laboratory, Oak Ridge, Tenn.

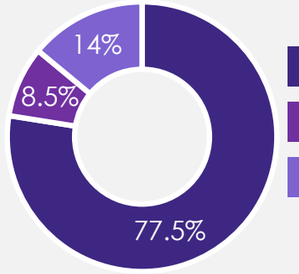
Forane 457A — Universal Replacement for R-404A/R-22 HVACR

Forane® 516A* (ARM-42) — R-134a Replacement

- **Near Drop-in for R-134a Equipment**
  - No or Minimal Design Changes
- **Performance**
  - Efficiency and Capacity Almost Identical to R-134a
- **Very Low GWP (< 150)**
- **Long-term Replacement to R-134a**
- **Near-zero Glide (R-516A Anticipated)**
  - Significantly Less Than R-410A or R-404A



R-516A* SUMMARY



Number	R-516A*
Class	A2L
GWP	131
ODP	0

** Anticipated; submitted to ASHRAE*

APPLICATIONS

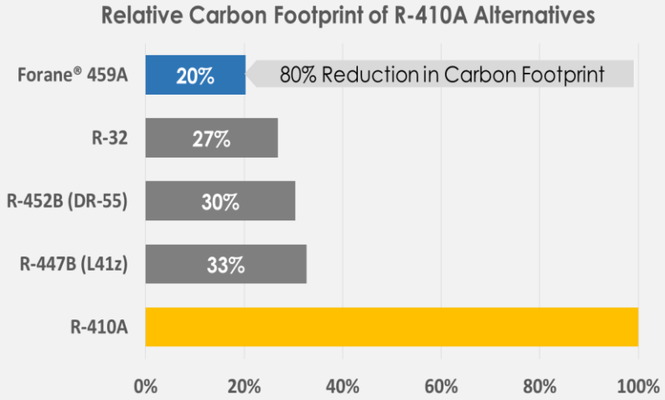
- Medium-temp Refrigeration
- Stand-alone Refrigeration
- Cascade Refrigeration
- Positive Displacement Chillers
- Centrifugal Chillers

**** In ASHRAE public review process***

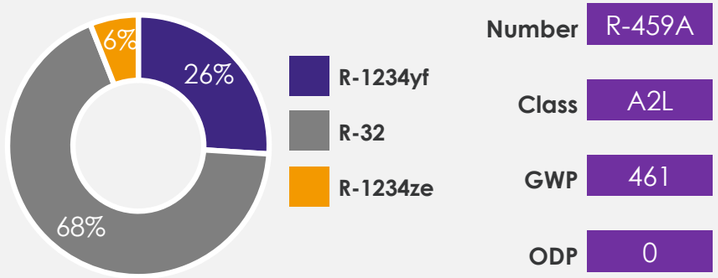
Forane 516A* — Lowest GWP Near-drop in Replacement for R-134a

Forane® 459A (ARM-71) — R-410A Replacement

- **Compatible With R-410A Equipment**
  - Similar Capacity and Efficiency
- **Low Glide (1.5K)**
- **Limited Compressor Discharge Temperature**
- **Demonstrated More Efficient Than 410A[1]**
  - At Standard Conditions and High Ambient
  - Lowest GWP of Alternatives Tested
  - Greatest Reduction in Carbon Footprint



R-459A SUMMARY



APPLICATIONS

- **Split Systems, Unitary AC**
- **Ducted Splits**
- **Packaged, RTU**
- **VRF Systems**
- **Water-cooled Chillers**

1. Abdelaziz et al. (2016) ORNL/TM-2016/513, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Forane 459A — The Lowest GWP R-410A Replacement

Alternative Forane® Refrigerants for HVACR Applications

		MAC	Refrigeration				Air Conditioning and Heat Pumps				Chillers			Energy Recovery	
		MAC	LT Ref	MT Ref	Transport	Stand-alone	Split Systems	VRF	Packaged	Heat Pump	Scroll, Rotary	Screw, Recip	Centrifugal	HTHP	ORC
Alternative	**Baseline**														
R-1234yf A2L, GWP < 1	R-134a														
R-427A A1, GWP = 2024	R-22														
R-407C A1, GWP = 1624	R-22														
R-407A A1, GWP = 1923	404A/22														
R-452C A1, GWP = 2019	R-404A														
R-449B A1, GWP = 1296	404A/22														
ARM-25 A2L, GWP < 150	R-404A														
R-457A A2L, GWP = 139	404A/22														
R-516A A2L, GWP = 131	R-134a														
ARM-20b A2L, GWP ~ 250	R-22														
R-459A A2L, GWP = 461	R-410A														
R-1233zd A1, GWP = 1	R-123														

Primary End-use Applications for Each Refrigerant Identified in Shaded Region

Refrigerant Options: Chemours Perspective

Dr. Charles Allgood
Technology Leader – Refrigerants
Chemours

Alternatives: Chemours Perspective

	*Final Rule: July 20, 2015								*Final Rule: September 26, 2016				
					Stand-Alone								
Phase-out refrigerant	Supermarket (New**)	Supermarket (Retrofit***)	Remote condensing unit (New)	Remote condensing unit (Retrofit***)	MT < 2,200 BTU/hr. and not contain flooded evap. (New)	MT ≥ 2,200 BTU/hr. with or without flooded evap. (New)	LT (New)	LT and MT (Retrofit***)	Refrigerated food processing and dispensing equipment (New)	Cold storage warehouses (New)	Ice machines (New)	Very low-temp refrigeration (New)	Positive displ. chiller (New)
R-404A/507A	Jan. 1, 2017	July 20, 2016	Jan. 1, 2018	July 20, 2016	Jan. 1, 2019	Jan. 1, 2020	Jan. 1, 2020	July 20, 2016	Jan. 1, 2021	Jan. 1, 2023	OK	OK	Jan. 1, 2024
R-410A	OK	-	OK	-	Jan. 1, 2019	Jan. 1, 2020	Jan. 1, 2020	-	Jan. 1, 2021	Jan. 1, 2023	OK	OK	Jan. 1, 2024
R-407A/C/F	OK	OK	OK	OK	Jan. 1, 2019	Jan. 1, 2020	Jan. 1, 2020	OK	Jan. 1, 2021	R-407C/F OK R-407A: Jan. 1, 2023	OK	R-407C only	Jan. 1, 2024 R-407C
HFC-134a	OK	OK	OK	OK	Jan. 1, 2019	Jan. 1, 2020	OK	OK	OK	OK	OK	-	
Likely alternatives													
XP40: R-449A	OK	OK	OK	OK	✓	✓	OK	MT: ✓ LT: OK	OK	OK	OK	OK	✓
XP10: R-513A	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK		OK
XP44: R-452A							✓	✓			✓	✓	
XL10: R-1234yf	✓ - Indirect		✓		✓	✓	✓		✓	✓ - Indirect	OK		✓
XL40: R-454A	✓ - Indirect		✓		✓	✓	✓		✓	✓ - Indirect	OK	✓	✓
XL20: R-454C	✓ - Indirect		✓		✓	✓	✓		✓	✓ - Indirect	OK		✓
XL55: R-452B												✓	✓
XL41: R-454B												✓	✓

OK = SNAP-approved for application
✓ = Areas of possible use in the future

- Abbreviated – For complete listing, see EPA final rules; go to: https://www.gpo.gov/fdsys/pkg/FR-2015-07-20/pdf/2015-17066.pdf https://www.gpo.gov/fdsys/pkg/FR-2016-04-18/pdf/2016-08163.pdf

** Includes ice machines connected to a supermarket rack refrigeration system.

*** EPA uses term “retrofit” to indicate the use of a refrigerant in an appliance that was designed for and originally operated using a different refrigerant. Term does not apply to upgrades to existing equipment where the refrigerant is not changed.

Details on the Chemours Options for “R-22, 404A/507-Like” Equipment

Non-flammable (Class 1)

GWP = 1,282

Opteon™ XP40 (R-449A)

- R-22 and R-404A retrofit and/or new equipment
- Up to 12% energy savings, comparable capacity
- 67% lower GWP vs. R-404A; 27% lower vs. R-22
- Approved by major equipment manufacturers
- Already used in thousands of supermarkets and commercial refrigeration systems worldwide

Mildly Flammable (Class 2L)

GWP = 146

Opteon™ XL20 (R-454C)

- R-22 and R-404A alternative with GWP <150
- Close performance match to R-404A; slightly reduced capacity, comparable efficiency
- 96% lower GWP vs. R-404A; 92% lower vs. R-22
- GWP < 150

Opteon.com

Details on the Chemours Options for “R-134a-Like” Equipment

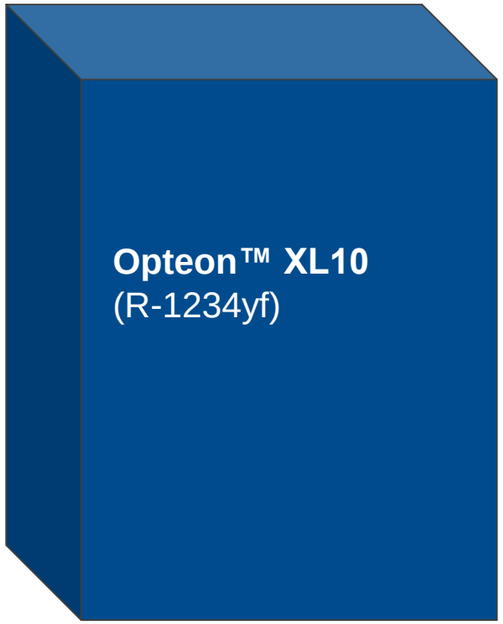
Non-flammable (Class 1)

GWP = 573

Opteon™ XP10 (R-513A)

- Near drop-in replacement for R-134a
- Azeotrope (no temperature glide)
- 56% lower GWP vs. R-134a
- Specified by major equipment manufacturers for use in chillers and refrigeration applications

Mildly Flammable (Class 2L)



GWP < 1

Opteon™ XL10 (R-1234yf)

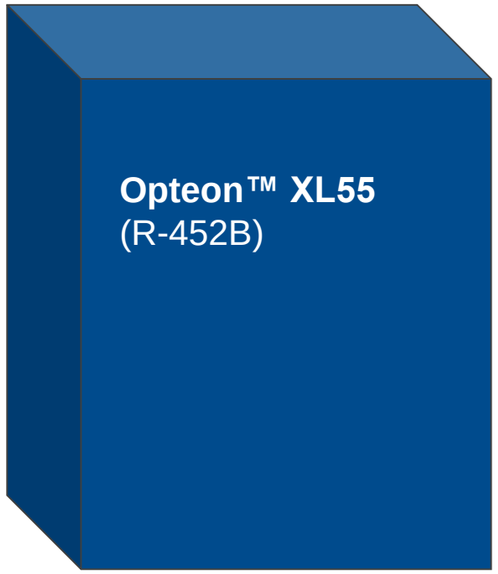
- Replacement for R-134a
- Close performance match (capacity and efficiency) to R-134a
- >99% lower GWP vs. R-134a
- Globally adopted by automotive OEMs to replace R-134a
- Single component, no temperature glide

Opteon.com

Details on the Chemours Options for “R-410A-Like” Equipment

Non-flammable (Class 1)

Mildly Flammable (Class 2L)



GWP = 676

GWP = 466

Opteon™ XL55 (R-452B)

- Compatible R-410A replacement
- Up to 5% energy improvement vs. R-410A
- Excellent performance in normal, high ambient conditions
- 65% lower GWP vs. R-410A
- Lowest flammability and reduced compressor discharge temperature vs. other R-410A replacements

Opteon™ XL41 (R-454B)

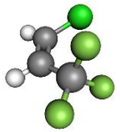
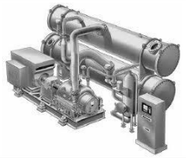
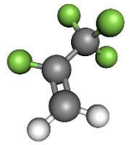
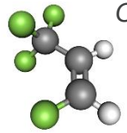
- Lowest GWP replacement for R-410A
- Improved capacity and efficiency vs. R-410A
- Excellent performance in normal, high ambient conditions
- 76% lower GWP vs. R-410A

Opteon.com

Refrigerant Options: Honeywell Perspective

Dr. Gustavo Pottker
Refrigerants Technology Lead
Honeywell International

What Are the Options Available to Us?

Current Product	*Solstice® N Series* Non-flammable (A1)	*Solstice® L Series* Mildly Flammable (A2L)
R-123 GWP = 79	**Solstice® zd** (R-1233zd) GWP = 1  *Centrifugal chillers* 	
R-134a GWP = 1,300	**N-13** (R-450A) GWP = 547 **R-515A** GWP = 403 *MT refrigeration MP chillers* 	**Solstice® yf** (R-1234yf) GWP<1  **Solstice® ze** (R-1234ze) GWP<1  *Chillers* 
R-22 GWP = 1,760	**N-20** GWP = 903 *Commercial refrigeration* 	**L-20** (R-444B) GWP=295 *Stationary AC* 
R-404A GWP = 3,943	**N-40** (R-448A) GWP = 1,273 *Commercial refrigeration* 	**L-40X** (R-455A) GWP=146 *Self-contained refrigeration* 
R-410A GWP = 1,924		**L-41z** (R-447B) GWP=714 *Stationary AC* 

Note: All GWP values from the IPCC, "AR5"

Solstice HFO Blends for Low-, Medium- and High-pressure Applications

Alternatives — Honeywell Perspective

	Final Rule: July 20, 2015								Proposed Rule: April 18, 2016^				
Phase-out refrigerant	Super-market (New**)	Super-market (Retrofit***)	Remote condensing unit (New)	Remote condensing unit (Retrofit***)	Stand-Alone				Refrigerated food processing and dispensing equipment (New)	Cold storage warehouses (New)	Ice machines (New)	Very low-temp refrigeration (New)	Positive displ. chiller (New)
					MT < 2,200 BTU/hr. and not contain flooded evap. (New)	MT ≥ 2,200 BTU/hr. with or without flooded evap. (New)	LT (New)	LT and MT (Retrofit***)					
R-404A/507A	01/ 2017	July 20, 2016	01/ 2018	July 20, 2016	01/ 2019	01/ 2020	01/ 2020	July 20, 2016	^Jan. 1, 2021	^Jan. 1, 2023	OK	OK	
R-410A	OK	-	OK	-	01/ 2019	01/ 2020	01/ 2020	-	^Jan. 1, 2021	^Jan. 1, 2023	OK	OK	
R-407A/C/F	OK	OK	OK	OK	01/ 2019	01/ 2020	01/ 2020	OK	^Jan. 1, 2021	R-407C/F OK R-407A: ^Jan. 1, 2023	OK	R-407C only	
HFC-134a	OK	OK	OK	OK	01/ 2019	01/ 2020	OK	OK	OK	OK	OK	-	
Likely alternatives													
R-450A	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	-	OK
R-448A	OK	OK	OK	OK	Appr. Pending	Appr. Pending	OK	OK	OK	Appr. Pending	OK	-	-
R-455A	-	-	-	-	SNAP in Prep.	SNAP in Prep	SNAP in Prep	-	-	-	-	-	-
R-515A	Future Alternative	-	Future Alternative	-	Future Alternative	Future Alternative	Future Alternative	-	Future Alternative	Future Alternative	Future Alternative	-	-
R-1234yf	-	-	-	-	Appr. Pending	Appr. Pending	Appr. Pending	-	-	-	Future Alternative	-	-
R-1234ze(E)	-	-	-	-	Future Alternative	Future Alternative	Future Alternative	-	-	-	Future Alternative	-	OK
R-1233zd(E)	-	-	-	-	-	-	-	-	-	-	-	-	Future Alternative
R-447B/ R-452B	-	-	-	-	-	-	-	-	-	-	-	-	Future Alternative .

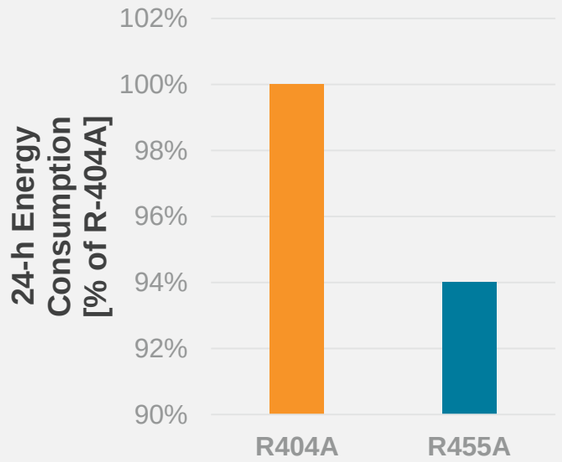
- Abbreviated – For complete listing, see EPA final rules; go to: https://www.gpo.gov/fdsys/pkg/FR-2015-07-20/pdf/2015-17066.pdf https://www.gpo.gov/fdsys/pkg/FR-2016-04-18/pdf/2016-08163.pdf

** Includes ice machines connected to a supermarket rack refrigeration system.

*** EPA uses term “retrofit” to indicate the use of a refrigerant in an appliance that was designed for and originally operated using a different refrigerant. Term does not apply to upgrades to existing equipment where the refrigerant is not changed.

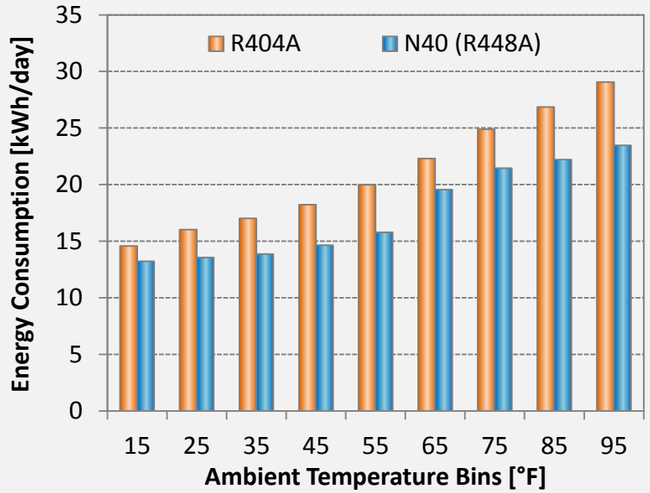
Refrigeration Applications

Solstice® L40X
R-455A



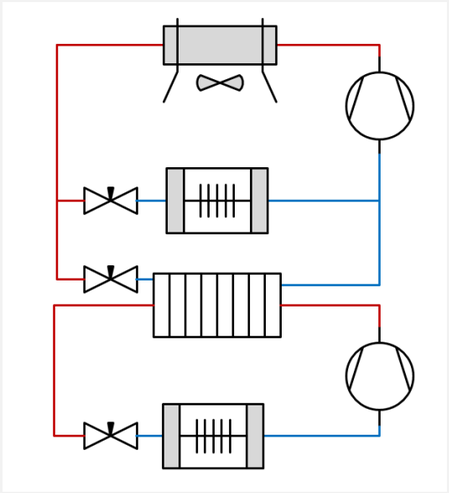
- GWP<150
- Mildly flammable (A2L)
- Match in capacity vs. R-404A
- Superior efficiency
- Self-contained systems
- Commercially available

Solstice® N40
R-448A



- 68% lower GWP than R-404A
- Non-flammable (A1)
- Match in capacity
- 5–10% improved efficiency
- 2,000 systems at end of 2016

Solstice® 515A



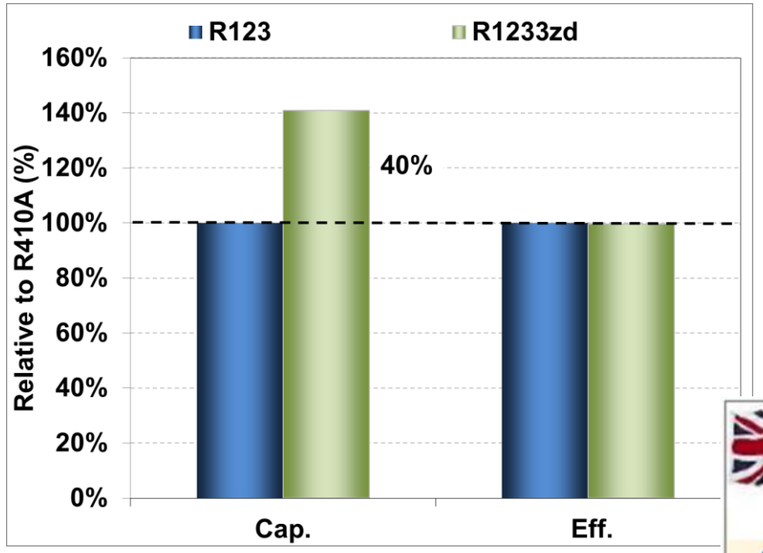
- Lowest GWP of non-flammable R-134a replacement options
- Flooded chiller applications
- MT commercial refrigeration and cascade systems

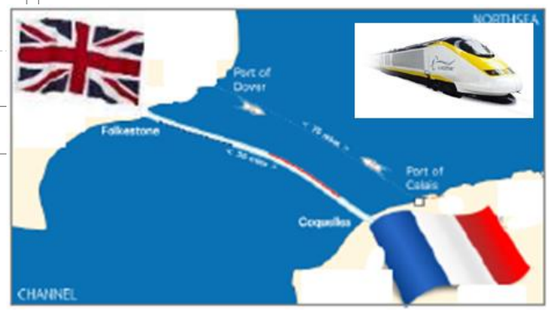
Solstice HFO Blends Confirmed Superior Performance in Many Applications

Chillers: R-123 and R-134a Replacements

R-1233zd Low-Pressure Chillers

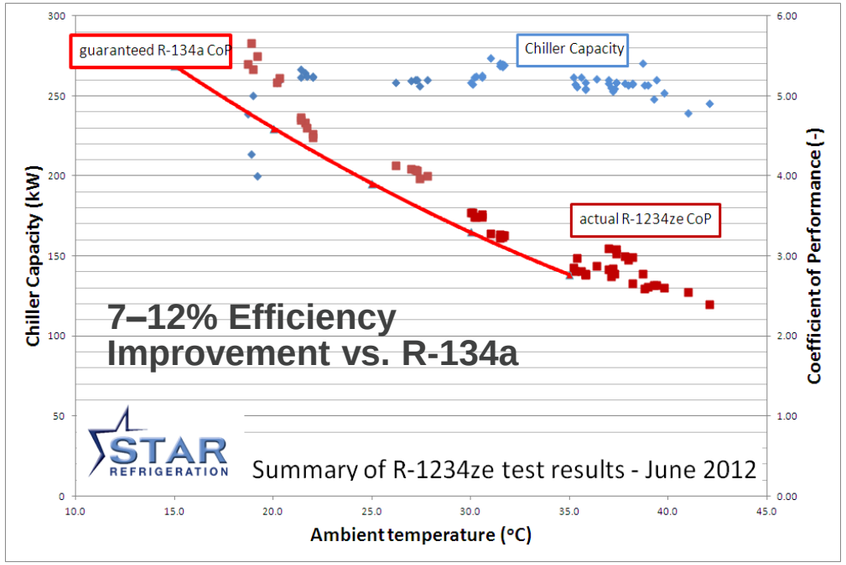
- Similar efficiency to R-123, with 40% higher capacity
- Successful use for the EU Channel Project
  - 40% higher efficiency than the existing R-22 system (savings of 200 k€/year)
  - Long-term solution with GWP = 1





Medium-Pressure Chillers

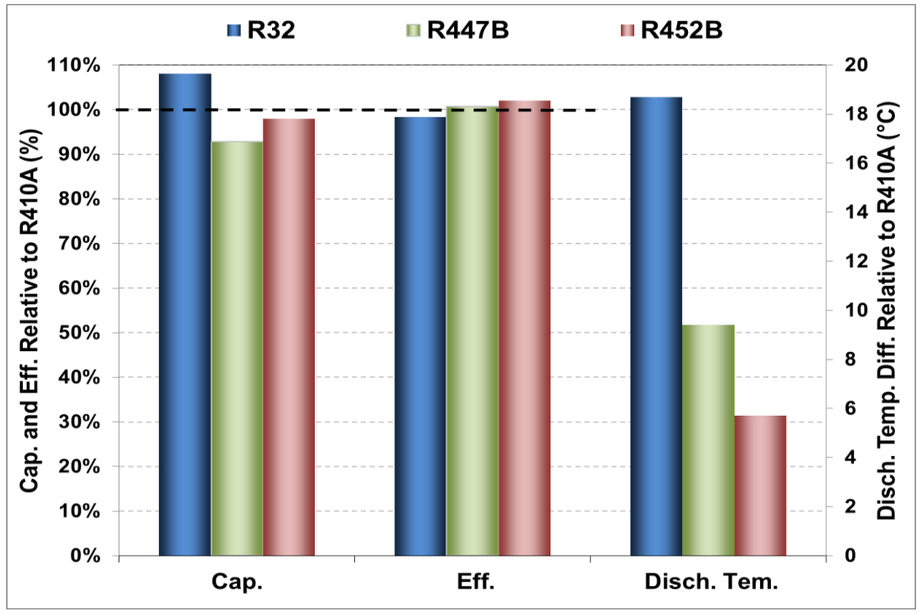
- Solstice® ze (R-1234ze) provides significant efficiency improvement vs. R-134a
- R-515A is non-flammable R-134a replacement with performance similar to R-1234ze
  - Can be used while the safety standards and building codes are being modified for flammables
  - Systems designed for R-515A can be used with R-1234ze (due to similar thermal properties)



R-410A Replacements — DX Systems

R-447B and R-452B — DX Chillers

- R-452B closely matches performance of R-410A
- R-447B has slightly lower capacity with similar efficiency
- Discharge temps are very close to R-410A (significant advantage in high ambient)
- The inclusion of 2L refrigerants in the building codes could enable use of these refrigerants in indirect systems



R-447B and R-452B — Commercial AC

- Both R-447B and R-452B have reduced flammability
- Low likelihood of getting an ignition event
  - Narrow difference between LFL and UFL
  - Hard to ignite due to high MIE
- Low BV reduces severity of any event

Flammability Characteristics				
Refrig.	LFL	UFL	Burning Velocity	MIE (23 °C, Dry)
R-32	14.5%	31%	6.7 cm/s	15 to 100 mj
R-447B	12.1%	20.9%	2.9 cm/s*	288 to 299 mj
R-452B	11.9%	—	3.5 cm/s**	—

**R-447B properties measured at Honeywell*
***R-452B properties extracted from ASHRAE submission*

- Existing and upcoming standards should be considered to address the mild flammability in direct systems

Thank You!

Questions?

DISCLAIMER
Although all statements and information contained herein are believed to be accurate and reliable, they are presented without guarantee or warranty of any kind, expressed or implied. Information provided herein does not relieve the user from the responsibility of carrying out its own tests and experiments, and the user assumes all risks and liability for use of the information and results obtained. Statements or suggestions concerning the use of materials and processes are made without representation or warranty that any such use is free of patent infringement and are not recommendations to infringe on any patents. The user should not assume that all toxicity data and safety measures are indicated herein or that other measures may not be required.