HVAC Industry Refrigerant Update

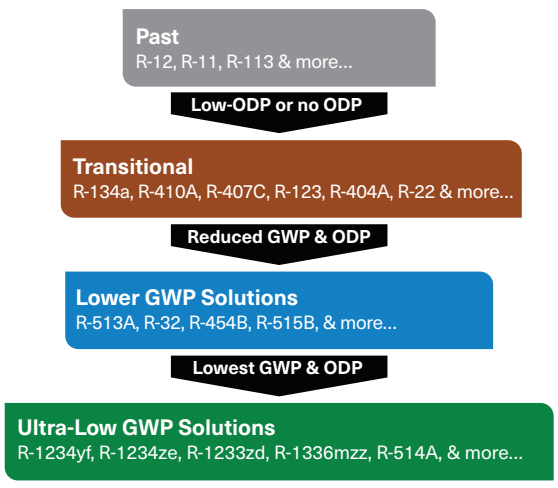
Transition Away from High-GWP HFC Refrigerants

The global scrutiny on refrigerants continues with a greater focus on sustainability, which has resulted in the development of lower global warming potential (GWP) refrigerants. This will help offset increasing global demand for HVAC while continuing to reduce greenhouse gas emissions.

As an example, R-410A will be replaced with alternatives that reduce GWP by over 65 percent, but have been described as having "lower flammability" characteristics. These new refrigerants have been widely tested and many smaller systems have used them for some time.

And as governments focus on building decarbonization to achieve commitments under the Paris Agreement, the incorporation of highly-efficient, lower-GWP electric heating equipment is a high priority, so innovation in this space is significant. Trane is taking industry leadership in low GWP decarbonization: https://www.trane.com/commercial/north-america/us/en/decarbonization.html

Globally, the HVAC industry is working diligently to incorporate updated safety standards into building codes as new products are commercialized to enable these next generation, lower-GWP refrigerants.

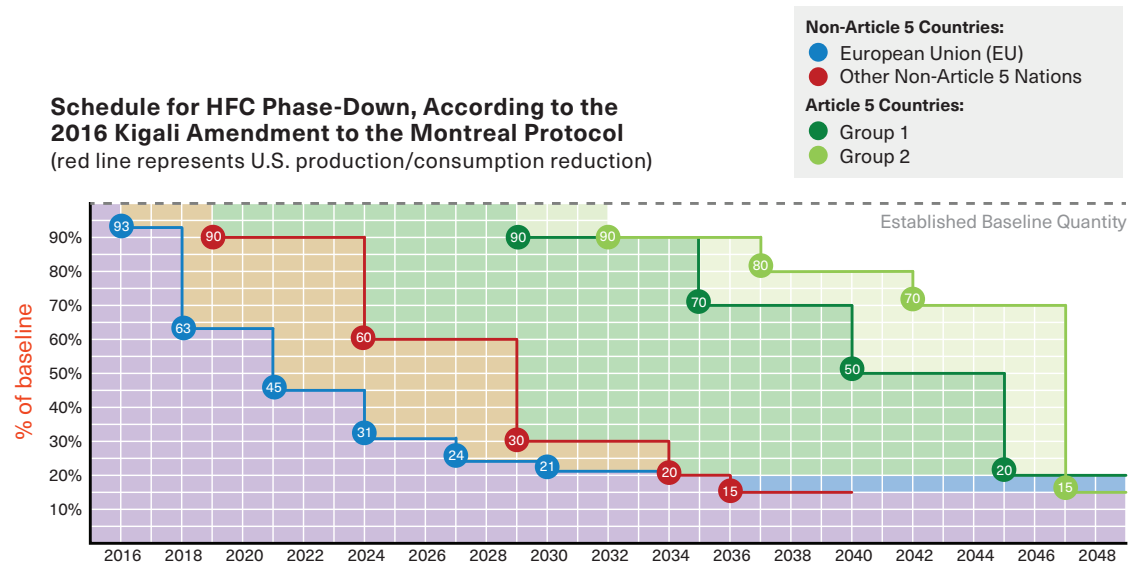


Global HFC Phase-Down

The 2016 Kigali Amendment to the Montreal Protocol phases down the supply of HFC refrigerants, as shown below for both Non-Article 5 (developed) and Article 5 (developing) countries. The European Union is shown separately with their earlier, and slightly different, schedule.

In the U.S., the American Innovation and Manufacturing (AIM) Act mandates that the Environmental Protection Agency (EPA) phase down the supply of HFCs on the same schedule as the Kigali Amendment: 40 percent reduction by 2024, compared to the baseline. The AIM Act authorizes EPA to require "Technology Transitions" by limiting the GWP of refrigerants used in various types of equipment. https://www.epa.gov/climate-hfcs-reduction

Schedule for HFC Phase-Down, According to the 2016 Kigali Amendment to the Montreal Protocol
(red line represents U.S. production/consumption reduction)



Group 1: Article 5 parties not part of Group 2
Group 2: Bahrain, India, the Islamic Republic of Iran, Iraq, Kuwait, Oman, Pakistan, Qatar, Saudi Arabia and the United Arab Emirates

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

National and regional regulations restrict the use of high-GWP HFC refrigerants

Regulatory Timeline

Summary for the United States and Canada

January 1, 2024	January 1, 2025	January 1, 2026
CA*, CO, DE, MA*, MD, ME, NJ, NY, RI, VA, VT, WA: • Chillers < 750 GWP * Permits required to install systems with refrigerant > 750 GWP manufactured prior to January 1, 2024	**U.S. EPA*:** • Chillers and stationary AC < 700 GWP • New ice rink chillers < 700 GWP **California:** • Stationary AC < 750 GWP • New ice rink chillers < 150 GWP **Canada:** • Chillers < 750 GWP *EPA allowing additional time for installation	**U.S. EPA*:** • VRF < 700 GWP **California:** • VRF < 750 GWP *EPA considering additional time for installation

https://www.epa.gov/climate-hfcs-reduction/regulatory-actions-technology-transitions

Building Code and Standard Changes

Building codes are being updated to the latest safety standards, which include requirements for the safe use of these next generation refrigerants. These underlying safety standards are ASHRAE® Standard 15 and UL 60335-2-40/CSA C22.2 No. 60335-2-40.

Safety requirements for Class 2L (lower flammability) refrigerants were first added to ASHRAE® 15 in its 2019 published version. For "high-probability" systems, these requirements underwent major revisions for the 2022 version, in an attempt to better harmonize with the requirements in the UL/CSA product safety standard. Some common examples of "high-probability" systems include direct-expansion (DX) split systems, packaged DX rooftop units, self-contained DX units, water-source heat pumps, variable refrigerant flow (VRF) systems, and PTACs.

For "low-probability" systems, such as a water chiller located either in a machinery room or outdoors, these requirements are largely unchanged between the 2019 and 2022 versions of ASHRAE® 15.

Refrigerant Management Requirements

Section 608 of the U.S. Clean Air Act defines proper management of refrigerants used in HVAC equipment, including maximum limits for fugitive emissions and proper handling requirements during service and repair of the equipment. It continues to evolve, generally with increasing stringency. The U.S. EPA is expected to incorporate additional requirements for refrigerant management in the AIM Act.

TRANE TECHNOLOGIES

Future Availability

The U.S. EPA allows for continued use of recycled, recovered, and stockpiled supplies of all refrigerants indefinitely, regardless of the phase-down date.

Key Terms Defined:

CFCs – chlorofluorocarbons (e.g. R-11, R-12) – Phased out by the Montreal Protocol in 1996 because of their very high ODPs. Significant impact on both ozone depletion and global warming due to the chlorine and fluorine atoms and very long atmospheric lives.

GWP – global warming potential – The degree to which a greenhouse gas (GHG) traps heat in the atmosphere; all measurements relative to a similar mass of carbon dioxide (CO_2), which is indexed at 1.0.

HCFCs – hydrochlorofluorocarbons (e.g. R-22, R-123) – Still contain chlorine, but contribute less to ozone depletion and global warming due to a shorter atmospheric life. Still in use globally, but have phase-out dates scheduled under the Montreal Protocol.

HFCs – hydrofluorocarbons (e.g. R-134a, R-404A, R-407C, R-410A) – Do not contain chlorine, but they have high GWPs given their fluorine content. Now being phased down globally under the Kigali Amendment to the Montreal Protocol.

HFOs & HCFOs – hydrofluoro-olefins (e.g. R-1234yf, R-1234ze(E)) and hydrochlorofluoro-olefins (e.g. R-1233zd(E)) – Next-generation refrigerants that are non-ozone-depleting with ultra-low GWPs and very short atmospheric lives (measured in days vs. years or decades).

HFO blends (e.g. R-454B, R-513A, R-514A, R-515B) – They feature lower GWPs and, as they receive ASHRAE® classification and SNAP approval, are becoming available for use in specific applications.

- **Zeotropes** (400 series blends) – Have components that boil and condense at different temperatures (i.e. have some degree of temperature glide). Lower glide is typically preferred for HVAC applications.
- **Azeotropes** (500 series blends) – Behave like a single-component refrigerant during phase change, with virtually no temperature glide.

Montreal Protocol – International treaty signed in 1987, originally designed to protect the ozone layer by phasing out the production and consumption of ozone depleting substances. The **Kigali Agreement** was officially ratified in 2017 as an amendment to the Montreal Protocol, and phases down the global production and consumption of HFCs beginning January 1, 2019. Individual countries must ratify the amendment for it to apply domestically.

ODP – ozone depletion potential – The degree to which a substance can degrade the ozone layer; all measurements relative to a similar mass of CFC-11, which is indexed at 1.0.

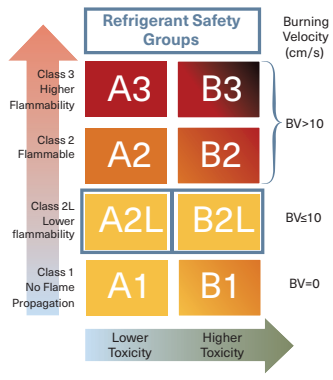
SNAP – The Significant New Alternatives Policy of the U.S. Environmental Protection Agency (EPA) evaluates refrigerants and classifies them as acceptable or unacceptable replacements based on their overall risk to human health and the environment.

Considerations When Selecting Refrigerants

Manufacturers choose the best refrigerant for each application based on a balance of safety (toxicity and flammability), environmental impacts (lowest greenhouse gas emissions) and total cost of ownership (energy efficiency of the entire system).

Flammability

With the transition to lower-GWP refrigerant options, flammability has emerged as a new variable for consideration, especially in equipment with higher operating pressures.



In 2010, a new flammability classification was created in ASHRAE® Standard 34. Class 2L includes refrigerants that have a Burning Velocity (BV) ≤ 10 cm/second and a high Minimum Ignition Energy (MIE), indicating they are more difficult to ignite.

Class 2L refrigerants have faced challenges in application due to being governed the same as Class 2 refrigerants. Codes and standards are in the process of being updated to include requirements that reflect the less flammable nature of Class 2L refrigerants compared to Class 2. ASHRAE® 15 was first updated to address this new class in its 2019 version, and UL 60335-2-40 was first updated in 2017. These updated standards have since been adopted into the International Mechanical Code (IMC).

Trane® is committed to offering non-flammable solutions whenever possible, and the lowest possible flammability class when slightly-flammable solutions are required to meet the low GWP threshold.

Toxicity

This is, perhaps, one of the most misunderstood properties of refrigerants. Specifically, it is important to distinguish between toxicity and safety; they are not the same. Because refrigerants displace oxygen, the greatest safety risk associated with all refrigerants is exposure leading to asphyxiation. Occupants are significantly less likely to be exposed to unsafe levels of low-pressure refrigerants because, in the event of a leak, air would leak into the machine rather than being expelled into the space.

ASHRAE® 34 classifies a refrigerant's toxicity based on its Occupational Exposure Limit (OEL). OEL refers to the time-weighted average concentration to which "nearly all workers can be repeatedly exposed without adverse effect" over the course of "a normal eight-hour workday and a 40-hour workweek":

- Class A refrigerants have an OEL ≥ 400 ppm
- Class B refrigerants have an OEL < 400 ppm

For example, R-514A has an OEL of 320 ppm. This means you should see no adverse effect if exposed to 320 ppm of R-514A for 8 hours/day and 40 hours/week. For chiller applications, machinery rooms rarely see > 2 ppm, and this exposure typically occurs during servicing for very short periods of time.

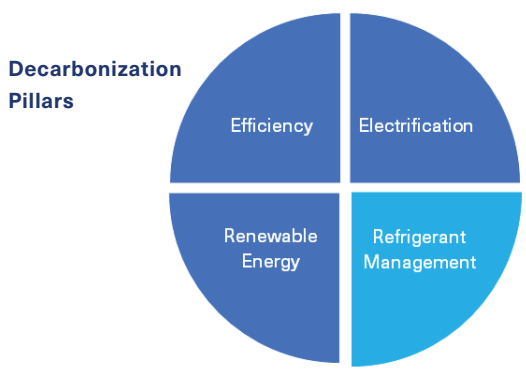
To avoid confusion with building code definitions, the tables in ASHRAE® 34 also indicate if a refrigerant is considered "toxic," "highly toxic," or "neither" as defined in the International Fire Code (IFC), Uniform Fire Code (UFC), and OSHA regulations. Only a few refrigerants listed in ASHRAE® 34 are considered "toxic" or "highly toxic" by the IFC, UFC, OSHA, or the NFPA 1 (National Fire Protection Association) Fire Code.

Refrigerant Management Matters to Your Building

Decarbonization Plan

Trane® is committed to reducing the potential environmental impacts associated with refrigerants used in our products. We do this through:

- The EcoWise® portfolio of products with low-GWP refrigerants
- Trane® Intelligent Services, which monitor system abnormalities that could result in refrigerant leaks
- Trane® Mechanical Services, which include tracking refrigerant replacement and completing the proper documentation for annual emissions reporting



Refrigerant Choices

Transitional | Lower GWP Solution | Ultra-Low GWP Solution

[1] None of the refrigerants shown in these tables are considered "toxic" or "highly toxic" as defined by the IFC, UFC, NFPA 1, or OSHA regulations.

[2] GWP values per the Fourth Assessment Report (AR4) of the IPCC (Intergovernmental Panel on Climate Change).

LOW PRESSURE		R-123	R-514A	R-1233zd(E)
Flammability	ASHRAE® Class	1	1	1
Toxicity[1]	ASHRAE® Class	Higher (B)	Higher (B)	Lower (A)
	OEL	50	320	800
Efficiency (COP)		8.95	8.91	8.87
Capacity Change		baseline	~5% loss	~35% gain
GWP[2]		77	1.7	1
Atmospheric Life		1.3 years	22 days	26 days

R-514A:

Non-flammable replacement for R-123 that offers the highest performance of all next-generation options available today with near-zero ODP and a GWP < 2. While classified as a Group B1 refrigerant, R-514A has a dramatically improved exposure limit (6 times higher OEL) compared to R-123, which has been safely used for ≥ 500,000 chiller years of operation for more than 25 years.

R-1233zd(E):

Single-molecule. non-flammable replacement for R-123, which offers near-zero ODP and an ultra-low GWP of 1. Often referred to as "zd," it is classified as a Group A1 refrigerant.

Equipment that uses ***low****-pressure refrigerants: larger centrifugal compressors*

MEDIUM PRESSURE		R-134a	R-513A	R-515B	R-1234yf	R-1234ze(E)
Flammability	ASHRAE® Class	1	1	1	2L	2L
Toxicity[1]	ASHRAE® Class	Lower (A)	Lower (A)	Lower (A)	Lower (A)	Lower (A)
	OEL	1000	650	810	500	800
Efficiency (COP)		8.47	8.27	8.32	8.17	8.45
Capacity Change		baseline	similar	~25% loss	~5% loss	~25% loss
GWP[2]		1430	630	298	6	4
Atmospheric Life		13.4 years	5.9 years	3.1 years	11 days	18 days

R-513A:

Non-flammable replacement for R-134a, with no capacity impact, zero ODP, and 55% lower GWP. While the theoretical efficiency drop is ~2%, when used as a supplement, the actual impact on chiller efficiency has been approximately 4% to 6% depending on the application.

R-1234ze(E):

Single-molecule replacement for R-134a, offering zero ODP and an ultra-low GWP of 4. It is classified as a Group A2L by ASHRAE® Standard 34. Differences in the European flammability classification have resulted in early adoption there. Most local codes in the United States are being updated to allow for the use of A2L refrigerants.

Equipment that uses ***medium****-pressure refrigerants: screw compressors and smaller centrifugal compressors*

HIGH PRESSURE		R-410A	R-454B	R-32
Flammability	ASHRAE® Class	1	2L	2L
Toxicity[1]	ASHRAE® Class	Lower (A)	Lower (A)	Lower (A)
	OEL	1000	850	1000
Efficiency (COP)		7.99	8.16	8.22
Capacity Change		baseline	~3% loss	~8% gain
GWP[2]		2088	467	675
Atmospheric Life		17 years	3.6 years	5.2 years

R-454B and R-32:

Leading options to replace R-410A in unitary and residential applications. Each of these solutions offers different trade-offs in terms of GWP, efficiency, and flammability. Both are classified as a Group A2L by ASHRAE® Standard 34.

Equipment that uses ***high****-pressure refrigerants: scroll compressors, unitary and packaged equipment*

Trane – by Trane Technologies (NYSE: TT), a global climate innovator – creates comfortable, energy efficient indoor environments through a broad portfolio of heating, ventilating and air conditioning systems and controls, services, parts and supply. For more information, please visit *trane.com or tranetechnologies.com.*

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