HVAC Industry Update

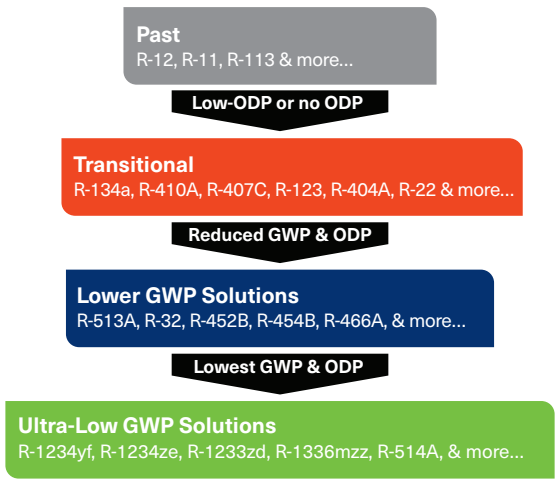
Industry Progress to Transition Away from High HFC Refrigerants

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

R-410A for chillers and other equipment will be replaced with alternatives that have been described as having low flammability characteristics. These new refrigerants have been widely tested and many of the smaller systems have been in use for some time. 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 electrification. Please visit:
https://www.trane.com/commercial/north-america/us/en/decarbonization.html

Refrigerant Regulatory Evolution

The global scrutiny on refrigerants continues as there is continued focus on sustainability, which has resulted in the development of lower global warming potential (GWP), next generation options. This will help to offset increasing global demand for HVAC while continuing to reduce greenhouse gas emissions.



Global HFC Phase-Down Effective January 1, 2019

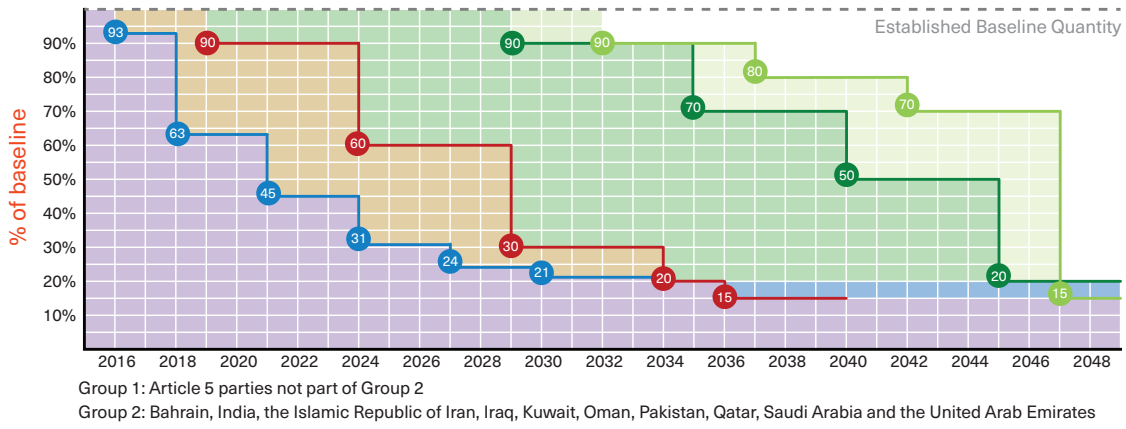
The 2016 Kigali Amendment to the Montreal Protocol phases down the supply of HFCs, as shown for both Non Article 5 (developed) nations and Article 5 (developing) nations. The European Union is shown separately with their earlier and slightly different schedule.

The U.S. American Innovation and Manufacturing (AIM) Act mandates that EPA phase down the supply of HFCs on the same schedule as the Kigali Amendment: 10 percent reduction now and 40 percent reduction compared to the baseline in 2024. The AIM Act also authorizes EPA to require "Technology Transitions" by limiting the global warming potential (GWP) of refrigerants for different types of equipment.

https://www.epa.gov/climate-hfcs-reduction

Global timeline for HFC reduction according to 2016 Kigali agreement to the Montreal Protocol

The redline represents U.S. HFC Production and Consumption reduction timeline.



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

More information available at
https://www.epa.gov/section608/revised-section-608-refrigerant-management-regulations

National and regional regulations restrict the use of high GWP HFCs

Regulatory Timeline

Regulatory timeline for US EPA proposal - United States and Canada

January 1, 2024	January 1, 2025	January 1, 2026
State Regulations: • CA, CO, DE, MA, MD, ME, NJ, NY, RI, VA, VT, WA • Chiller transition to refrigerants <750 GWP	**California:** • Stationary AC <750 GWP • New ice rink chillers <150 GWP **US EPA proposal:** • New ice rink chillers <150 GWP • Chillers and stationary AC transition <700 GWP **Canada** • Chillers <750 GWP	**California:** • VRF GWP <750 **US EPA proposal:** • VRF GWP <700

Codes and Standards Changes

Building codes are being updated by the latest safety standards which incorporate requirements for the safe use of next generation refrigerants. The underlying safety standards are ASHRAE® 15 and CSA/UL 60335-2-40.

ASHRAE® 15-2019 adds new requirements for direct systems using A2L refrigerants. For example, refrigerant detectors should be factory installed at the evaporator coil, quick acting at low level, and increasing airflow to the occupied space with critical components turned off. Also, the A2L refrigerant should be located away from ignition sources.

For indirect systems such as chillers, ASHRAE® 15-2019 adds more new requirements with A2L refrigerants including similar requirements on refrigerant detectors for direct systems, remote safety control sequence, and higher ventilation rate. It is also important to note the multiport refrigerant detector can no longer be used for indirect systems with A2L refrigerants.

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. EPA is expected to incorporate additional requirements for refrigerant management in the AIM Act.

Future Availability

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

Key Terms Defined:

ODP – ozone depletion potential – 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.

GWP – global warming potential – 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. The buildup of GHGs can cause climate change.

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.

HCFCs – hydrochlorofluorocarbons (e.g. R-22, R-123) – also contain chlorine, but contribute less to ozone depletion and climate change due to shorter atmospheric lives. 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 do 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) – blends including an HFO. 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.

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.

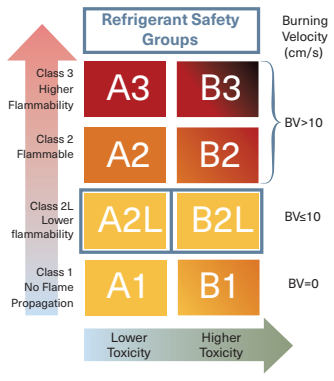
De minimis - lacking significance or importance; too trivial or minor to merit consideration.

Considerations When Selecting Refrigerants

Choose the best refrigerant for each application based on a balance of safety (toxicity, flammability, asphyxiation, and physical hazards), environmental impacts (lowest GHG 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 higher operating pressures.



In 2010, a new flammability category was created within ASHRAE® 34. Subclass 2L captures refrigerants with a Burning Velocity (BV) less than 10 cm/second and a high Minimum Ignition Energy (MIE), indicating higher difficulty to ignite.

2L refrigerants have faced challenges in application due to being governed as Class 2 refrigerants. Codes and standards are now in the process of being updated to include requirements that reflect the less flammable nature of 2L refrigerants compared to Class 2 flammability. ASHRAE® 15 and ASHRAE® 34 were updated to reflect this change in 2019, and UL 60335-2-40 was updated in 2017. These changes have been fully adopted by International Mechanical Code (IMC).

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

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 of refrigerant 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

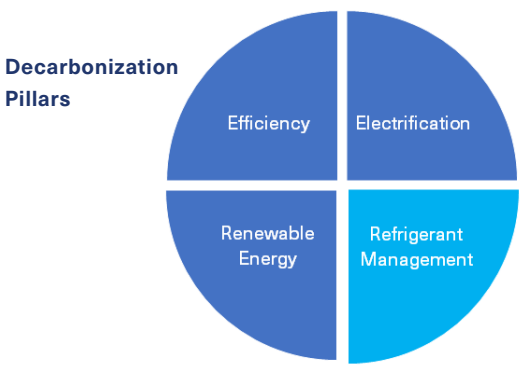
R-514A has an OEL of 320 ppm. This means you should see no negative effect if you are exposed to 320 ppm of R-514A for 8 hours/day, 40 hours/week. For chiller applications, rarely do mechanical rooms see > 2 ppm, and this exposure typically occurs during servicing for very short periods of time.

To avoid confusion with building code definitions, ASHRAE® 34 was updated to indicate toxic, highly toxic or neither as defined in the International Fire Code (IFC), Uniform Fire Code (UFC), and OSHA regulations. None of the refrigerants shown in the table are considered toxic or highly toxic by the IFC, UFC, OSHA, or in 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
- Intelligent Services, which monitor system abnormalities that could result in refrigerant leaks
- 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

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

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

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

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 of 2. While classified a "B1", R-514A has a dramatically improved exposure limit (6X higher) 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 an "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 4-6% 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 "A2L" under ASHRAE® Standard 34. Differences in the European flammability classification have resulted in early adoption in Europe. Most local codes in the United States are expected to allow the use of A2L refrigerants as of January 1, 2024.

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-32, R-452B, R-454B, R-466A:

Leading options to replace R-410A for unitary and residential applications. Each of these solutions offers different trade-offs in GWP, efficiency, and flammability, and are under consideration by the industry as a next generation solution to replace R-410A.

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

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