HVAC Industry Update

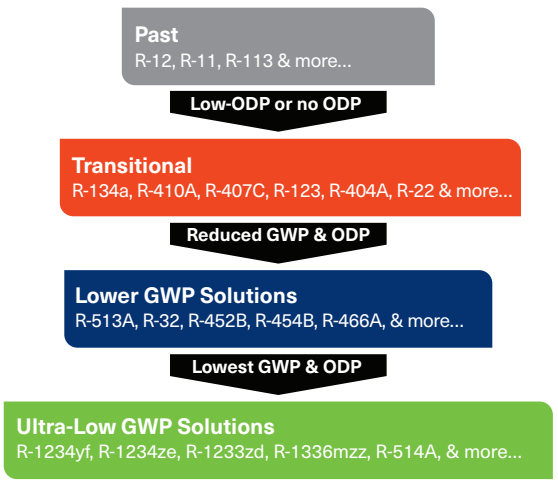
Industry Progress to Transition Away from High HFC Refrigerants

The industry is working diligently to update safety standards and building codes, globally as new products are commercialized to quickly enable next generation, lower GWP refrigerants.

While many nonflammable chiller solutions have been deployed, the traditional R-410A equipment is moving to flammable refrigerants. 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 the GWP of all current generation refrigerants continues to increase, pushing the industry to next-generation options, including the introduction of new transitional refrigerants to help offset the increasing global demand for HVAC with the requirements to reduce greenhouse gas emissions.



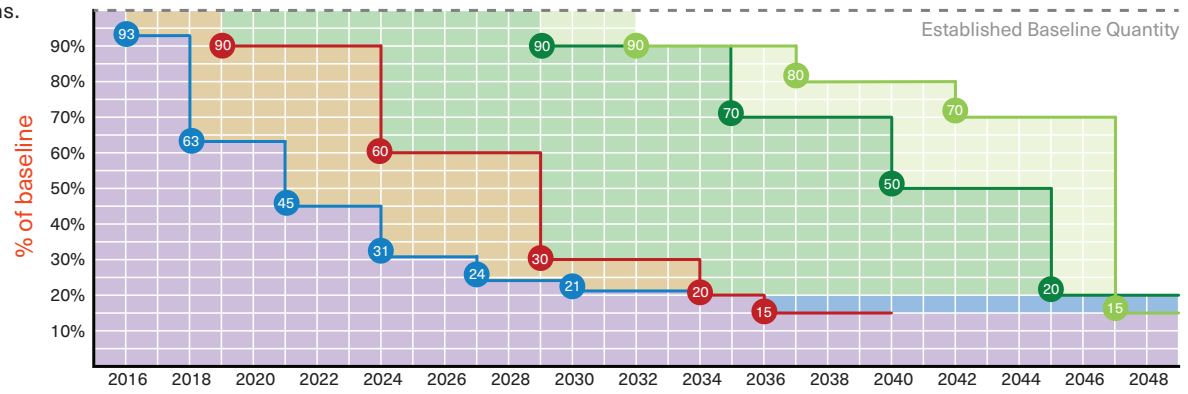
Global HFC Phase-Down Effective January 1, 2019

A look at the global phase-down schedule established in 2016 by the Kigali Amendment to the Montreal Protocol is shown for both Non Article 5 Nations (developed) and Article 5 Nations (developing). Europe is shown separately as they are leading the global phase-down with actions already taken under the Kyoto Protocol. The U.S. American Innovation and Manufacturing (AIM) Act established the HFC phase-down in the U.S. in line with the schedule of Kigali Amendment. The U.S. EPA set HFC allocations representing a 10 percent GWP reduction for 2022 and 2023 and is working on a 40 percent reduction rule for 2024.

More information available at:
http://ozone.unep.org/sites/default/files/FAQs_Kigali_Amendment.pdf

*The AIM Act is a bipartisan bill enacted December 17, 2020. It directs the EPA to address the environmental impact of hydrofluorocarbons (HFCs) by phasing down production and consumption, maximizing reclamation and minimizing releases from equipment, and facilitating the transition to next-generation technologies through sector-based restrictions.

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

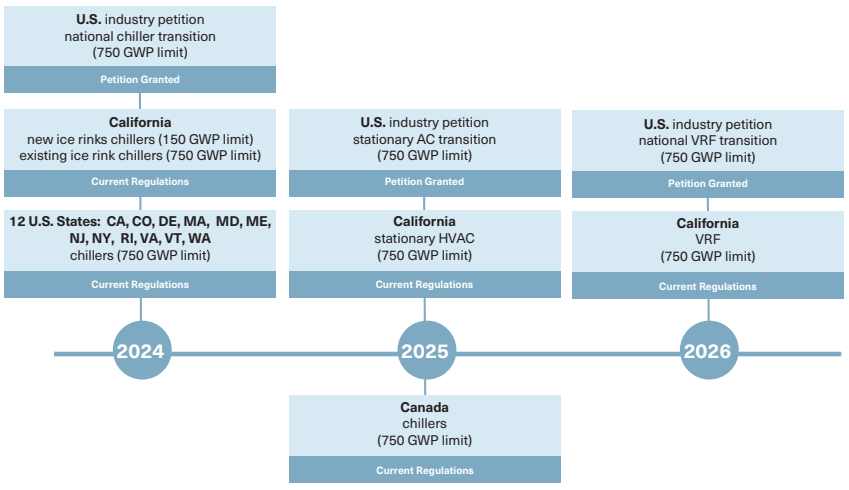


Group 1: Article 5 parties not part of Group 2
Group 2: Bahrain, India, the Islamic Republic of Iran, Iraq, Kuwait, Oman, Pakistan, Qatar, Saudi Arabia and the United Arab Emirates

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



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.

Codes and Standards Changes

Building codes and safety standards are being updated to incorporate next generation refrigerants. The underlying safety standards are ASHRAE® 15 and CSA/UL 60335-2-40. The model mechanical codes (International Mechanical Code and the Uniform Mechanical Code) incorporate these standards. Chillers using A2L refrigerants were enabled in the 2018 model codes, and the direct systems (unitary, VRF, and residential) are being enabled in the 2024 model codes.

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 away from the 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. The U.S. EPA revised its refrigerant management rule in 2016 to add HFCs, increase leak detection, repair and record keeping requirements. The rule was partially rolled back in 2020 following litigation, but the EPA is expected to restore the provisions based on a recent petition from states and cities.

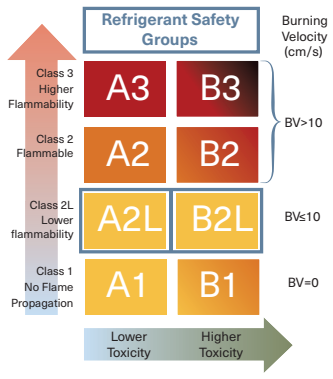
TRANE TECHNOLOGIES

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 more reasonable 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 making their way into UMC and IMC code over subsequent years, with full adoption still pending for certain equipment.

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 or OSHA, or in the NFPA 1 (National Fire Protection Association) Fire Code.

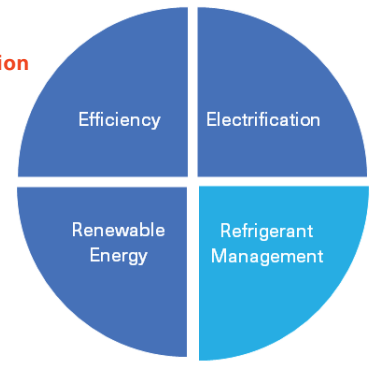
Refrigerant Management Matters to Your Building

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

Decarbonization Pillars



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).

R514A:

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.

R1233zd(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)	R-717 Ammonia
Flammability	ASHRAE® Class	1	1	1	2L	2L	2L
Toxicity[1]	ASHRAE® Class	Lower (A)	Lower (A)	Lower (A)	Lower (A)	Lower (A)	Higher (B)
	OEL	1000	650	810	500	800	25
Efficiency (COP)		8.47	8.27	8.32	8.17	8.45	8.77
Capacity Change		baseline	similar	~25% loss	~5% loss	~25% loss	~70% gain
GWP[2]		1430	630	298	6	4	0
Atmospheric Life		13.4 years	5.9 years	3.1 years	11 days	18 days	<1 day

R513A:

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

R1234ze(E):

Single molecule replacement for R-134a, which offers zero ODP and an ultra-low GWP of 1. It is classified as "A2L" under ASHRAE® Standard 34. Differences in European flammability classification have resulted in some early adoption in Europe, but use in the U.S. has been hindered by the A2L flammability classification.

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

HIGH PRESSURE

		R-410A	R-454B	R-32	R-290 Propane	R-744 CO_2
Flammability	ASHRAE® Class	1	2L	2L	3	1
Toxicity[1]	ASHRAE® Class	Lower (A)	Lower (A)	Lower (A)	Lower (A)	Lower (A)
	OEL	1000	850	1000	1000	5000
Efficiency (COP)		7.99	8.16	8.22	8.34	4.41
Capacity Change		baseline	~3% loss	~8% gain	~40% loss	~330% gain
GWP[2]		2088	467	675	3	1
Atmospheric Life		17 years	3.6 years	5.2 years	13 days	20-200 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 tradeoffs 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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