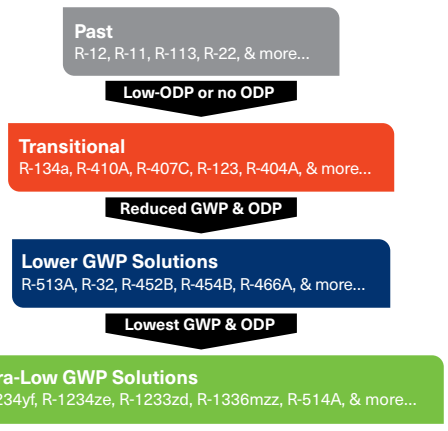
HVAC Industry Update

Industry Consensus on HFC Refrigerants

The industry continues to work through global and national associations to engage with non-governmental organizations (NGOs) and governments to ensure that the Kigali Amendment to the Montreal Protocol is used to transition away from high-GWP refrigerants in a way that is technically feasible, safe, and allows for servicing of existing equipment to ensure a useful life from equipment investments.

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.



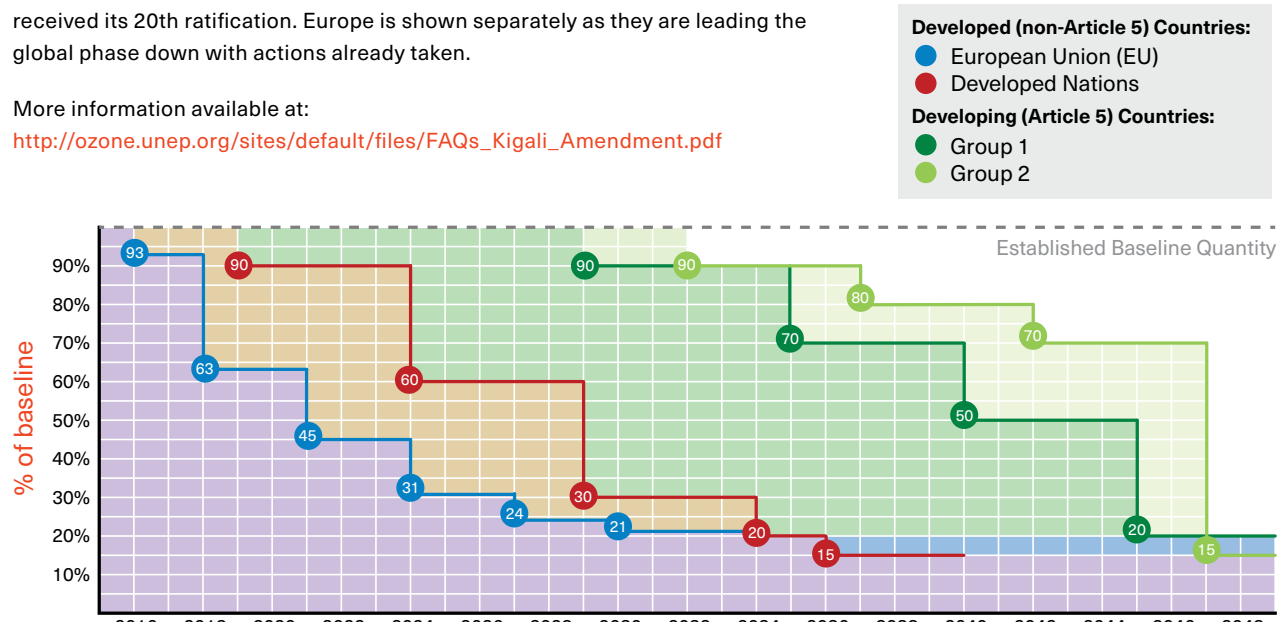
Next-Generation Refrigerants – November 2019

Commercial, residential and industrial buildings are responsible for about half of the world's energy consumption and greenhouse gas (GHG) emissions, with HVAC systems playing a significant role in both of these impacts.

Global HFC Phase-Down Effective January 1, 2019

A look at the global phase-down schedule established by the Kigali Amendment to the Montreal Protocol, which became official on November 17, 2017 when it received its 20th ratification. Europe is shown separately as they are leading the global phase down with actions already taken.

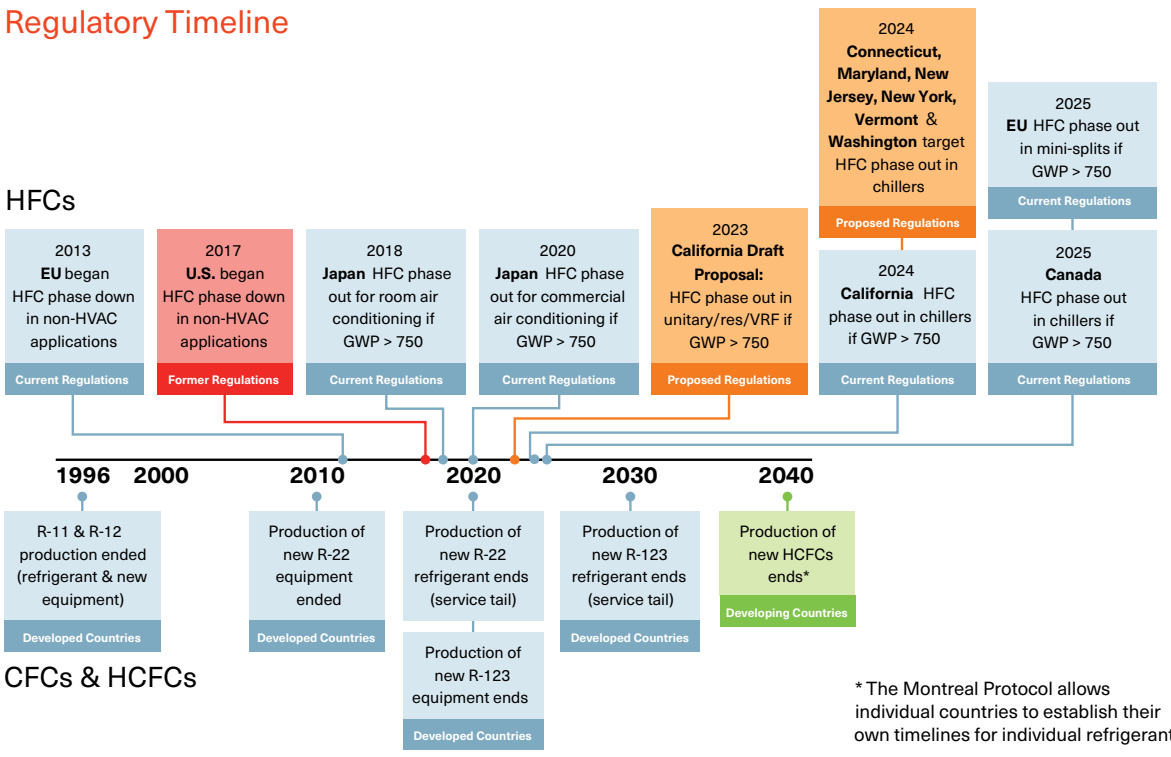
More information available at:
http://ozone.unep.org/sites/default/files/FAQs_Kigali_Amendment.pdf



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

National and regional regulations are coming into force around the world that will restrict the use of HFCs.

Regulatory Timeline



* The Montreal Protocol allows individual countries to establish their own timelines for individual refrigerants.

Refrigerant Management Requirements

Emerging regulations present new challenges for servicing companies and owners of HVAC equipment. Future refrigerant management requirements are not clear, but environmental responsibility dictates close monitoring and tracking of all refrigerants with the expectation of minimizing leakage.

Section 608 of the U.S. Clean Air Act continues to evolve, becoming increasingly more stringent. The EPA is busy trying to adapt to the latest court opinion about how to regulate HFCs, but the industry is pushing for certainty and individual states are poised to take action.

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

Future Availability

The U.S. EPA allows for continued use of recycled, recovered and stockpiled supplies of all refrigerants indefinitely, regardless of phase out 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) and hydrochlorofluoro-olefins (e.g. R-1233zd) – 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-452B, R-454B, R-466A, R-513A, R-514A) – 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.

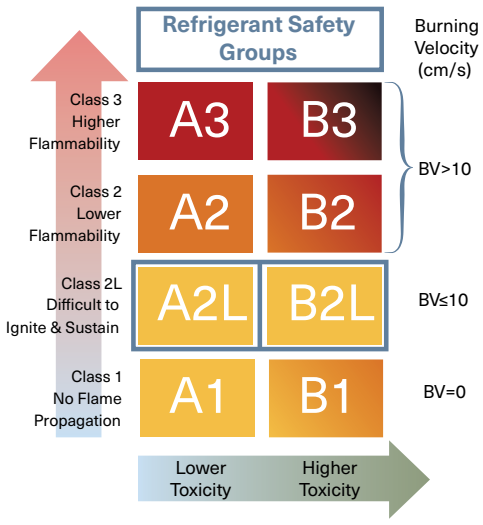
Considerations When Selecting Refrigerants

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), i.e. difficult to ignite and sustain a flame.

The industry continues to debate the application of 2L refrigerants. Specifically, ASHRAE 15 and UL 60335-2-40 need to be updated to include more reasonable requirements that reflect the less flammable nature of 2L refrigerants compared to Class 2 flammability on which current standards are based.



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 operational 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-123 has an OEL of 50 ppm. This means you should see no negative effect if you are exposed to 50 ppm of R-123 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.

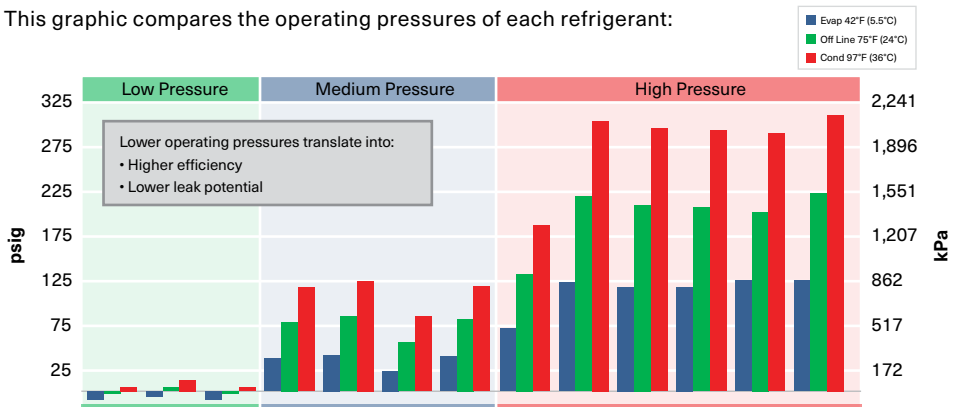
To avoid confusion with building code definitions, ASHRAE 34 was updated to indicate toxic, highly toxic or neither as defined in the International Fire Code (IFC), Uniform Fire Code (UFC) and OSHA regulations. None of the refrigerants shown in the table are considered toxic or highly toxic by the IFC, UFC or OSHA, or in the NFPA 1 (National Fire Protection Association) Fire Code.

Additional Information About Select Refrigerants

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.
R-513A	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.
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	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.
R-1234ze	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. It is considered non-flammable for handling, manufacturing and design by European pressure equipment directive (PED), resulting in some early use in Europe, but U.S. standards all consider it flammable.

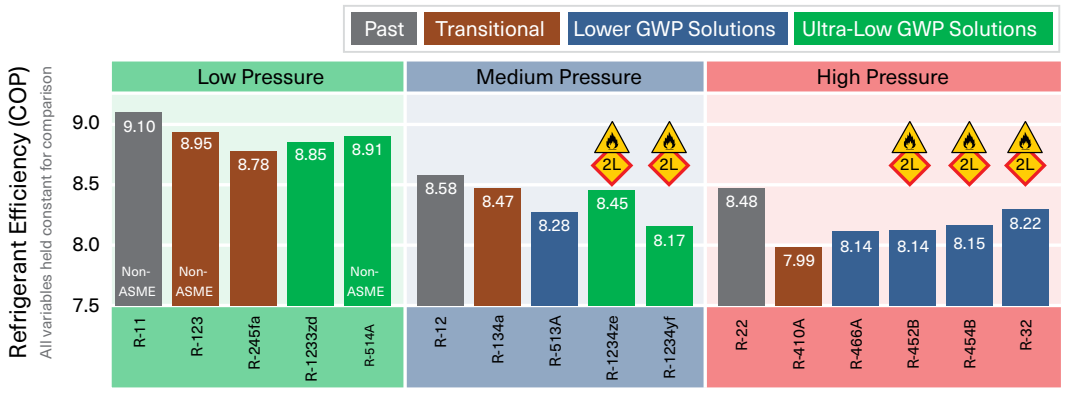
Operating Pressure by Refrigerant

This graphic compares the operating pressures of each refrigerant:



Environmental Impact by Refrigerant

Below are the theoretical efficiencies of common refrigerants, with all variables held constant for comparison:



Refrigerant Choices

This table compares various properties of both current and next-generation refrigerants. The efficiencies and capacity changes shown are based on the theoretical properties of the refrigerant alone, with all design variables held constant for objective comparison.

Past | Transitional | Lower GWP Solution | Ultra-Low GWP Solution

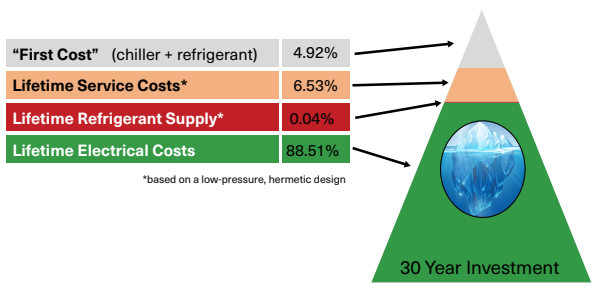
		Low Pressure			Medium Pressure				High Pressure					
		R-123	R-1233zd	R-514A	R-134a	R-513A	R-1234ze	R-1234yf	R-22	R-410A	R-466A	R-452B	R-454B	R-32
Flammability	ASHRAE Class	1	1	1	1	1	2L	2L	1	1	1	2L	2L	2L
Toxicity[1]	ASHRAE Class	Higher (B)	Lower (A)	Higher (B)	Lower (A)	Lower (A)	Lower (A)	Lower (A)	Lower (A)	Lower (A)	Lower (A)	Lower (A)	Lower (A)	Lower (A)
	OEL	50	800	320	1000	650	800	500	1000	1000	860	870	850	1000
Efficiency (COP)		8.95	8.85	8.91	8.47	8.28	8.45	8.17	8.48	7.99	8.14	8.14	8.15	8.22
Capacity Change		baseline	~35% gain	~5% loss	baseline	similar	~25% loss	~5% loss		baseline	~1% loss	~2% loss	~3% loss	~9% gain
GWP[2]		79	1	2	1300	573	1	1	1760	1924	703	675	466	677
Atmospheric Life		1.3 years	26 days	22 days	13.4 years	5.9 years	16 days	11 days	11.9 years	17 years	5.6 years	5.5 years	3.6 years	5.2 years

[1]None of the refrigerants shown in the table are considered "toxic" or "highly toxic" as defined by the IFC, UFC, NFPA 1 or OSHA regulations.
[2]GWP values reported are per the Fifth Assessment Report (AR5) of the IPCC (Intergovernmental Panel on Climate Change).

How Do You Protect Your Investment?

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).

The Trane Technologies EcoWise™ portfolio of products designed to lower environmental impact with next-generation, low-GWP refrigerants and higher efficiency operation is part of our climate commitment to increase energy efficiency and reduce the GHG emissions related to our operations and products.



EcoWise™

TRANE TECHNOLOGIES

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