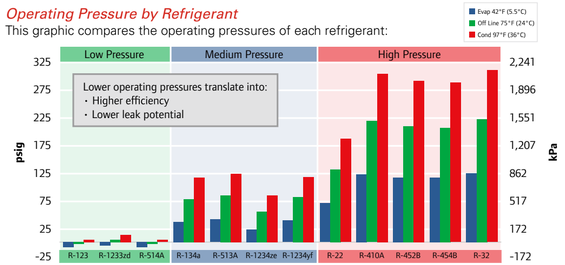
Considerations When Selecting Refrigerants

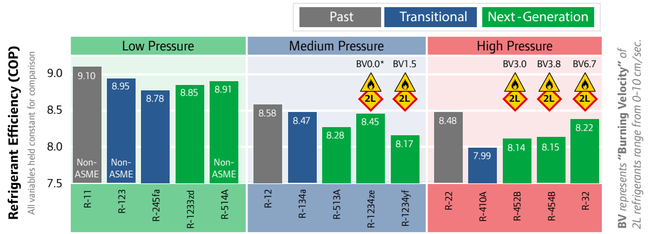
Operating Pressure by Refrigerant

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:



*R-1234ze is not flammable at room temperature, so its BV is zero by definition. It does, however, become flammable at temperatures above 30°C (86°F).

Refrigerant for HVAC

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.

		Low Pressure			Medium Pressure				High Pressure			
		R-123	R-1233zd	R-514A	R-134a	R-513A	R-1234ze[3]	R-1234yf	R-22	R-410A	R-452B	R-32[4]
Flammability	ASHRAE Class BV (cm/s)	Non (1) n/a	Non (1) n/a	Non (1) n/a	Non (1) n/a	Non (1) n/a	Slight (2L) 0.0	Slight (2L) 1.5	Non (1) n/a	Non (1) n/a	Slight (2L) 3.0	Slight (2L) 6.7
Toxicity[1]	ASHRAE Class OEL	Higher (B) 50	Lower (A) 800	Higher (B) 320	Lower (A) 1000	Lower (A) 650	Lower (A) 800	Lower (A) 500	Lower (A) 1000	Lower (A) 1000	Lower (A) 870	Lower (A) 1000
Efficiency (COP)		8.95	8.85	8.91	8.47	8.28	8.45	8.17	8.48	7.99	8.14	8.22
Capacity Change		baseline	~35% gain	~5% loss	baseline	similar	~25% loss	~5% loss	-	baseline	~2% loss	~9% gain
GWP[2]		79	1	2	1300	573	1	1	1760	1924	675	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	5.5 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).
[3]R-1234ze is not flammable at room temperature, so its BV is zero by definition. It does, however, become flammable at temperatures above 30°C (86°F).
[4]R-32 is an existing refrigerant but never used alone in the past due to its flammability.

EcoWise™

The Ingersoll Rand 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.

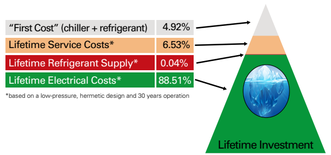
Trane Sintesis™ air-cooled chillers and Series R™ Helical Rotary water-cooled chillers are energy efficient and quiet, and offer customers the choice of operating with a next generation, low GWP refrigerant R-513A that is non-flammable and has a 55 percent lower GWP than the current refrigerant R-134a.

Trane Series E™ CenTraVac is a large-capacity chiller that uses the same low-pressure design on which current CenTraVac chillers were based, and uses a next generation, low GWP refrigerant, R-1233zd(E). It is up to 10 percent more energy efficient than the next available centrifugal chiller available today, and is available in Europe, the Middle East and other 50hz markets including Japan.

Thermo King truck and trailer refrigeration products sold in Europe and global marine refrigeration units are safe, reliable and efficient, and use R-452A refrigerant which has about 50 percent less GWP than current refrigerant R-404A.

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).



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Trane has a policy of continuous product and product data improvement and reserves the right to change design and specifications without notice.

ENV-SLB022-EN June 26, 2017

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Technology and development of refrigerant for HVAC

Trane environmental perspective

Technology and development of refrigerant for HVAC

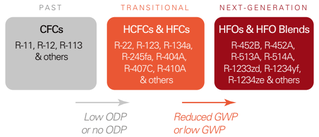
Commercial, residential and industrial buildings are responsible for about half of the world's energy consumption and greenhouse gas (GHG) emissions, with HVAC systems playing a significant role in both of these impacts.

Industry Consensus on HFC Refrigerants

The industry is working through its national associations to engage non-governmental organizations (NGOs) and governments around the world to ensure that the Montreal Protocol is used to transition away from high-GWP refrigerants in a way that is technically feasible and allows for service.

Refrigerant Regulatory Evolution

The global scrutiny on the GWP of all current-generation refrigerants continues to grow, pushing the industry to next-generation options.

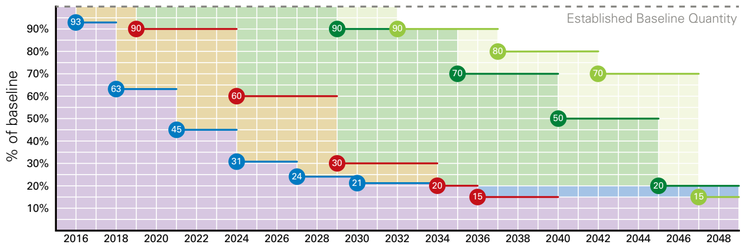


Global HFC Phase-Down Under the Montreal Protocol

A look at the global phase-down schedule established by the Kigali Amendment to the Montreal Protocol.

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/ozone/files/pdfs/FAQs_Kigali_Amendment.pdf*



Group 1: Article 5 parties not part of Group 2, e.g. China, Indonesia, Korea, Malaysia, Philippines, Singapore, Thailand, Vietnam, etc.
Group 2: Bahrain, India, the Islamic Republic of Iran, Iraq, Kuwait, Oman, Pakistan, Qatar, Saudi Arabia and the United Arab Emirates

Country regulations are coming into force around the world that restrict the use of HFCs.

Refrigerant Management Requirements

Australia Green Star (29 – Refrigerant Impact) awards 1 credit point for equipment using refrigerants with GWP ≤ 10.

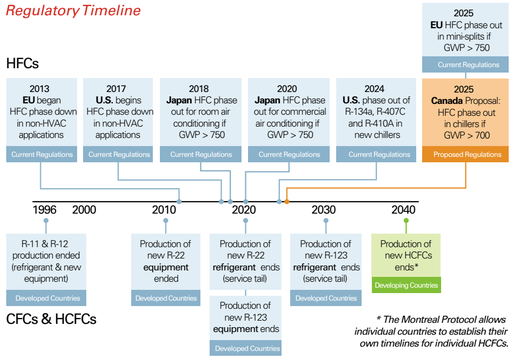
Japan Since April 2015, all equipment using HFC refrigerant must be carried out quarterly inspection and record-keeping of refrigerant management; but HFO refrigerants and CO_2 are excluded.

U.S. LEED (Energy and Atmosphere) awards 1 credit point for equipment using refrigerants with GWP ≤ 50.

Future Availability

Most countries allow for continued use of recycled, recovered and stockpiled supplies of all refrigerants indefinitely, regardless of phase out date.

Regulatory Timeline



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

Documentation of the Final Rules in the U.S. Federal Register

2024 phase-out date for chillers -
https://www.gpo.gov/fdsys/pkg/FR-2016-12-01/pdf/2016-25167.pdf

Updated Refrigerant Management Requirements -
https://www.gpo.gov/fdsys/pkg/FR-2016-11-18/pdf/2016-24215.pdf

Key Terminology:

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 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 ozone-depleting substances (ODS) 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-245fa, R-125, R-32): non-ODS, but they do have high GWPs given their fluorine content. Currently targeted for global phase down under the Montreal Protocol and phase-out by the U.S.A.,Canada, Japan and other countries for use in certain applications.

HFO – olefin based (e.g. R-1234yf, R-1234ze,R-1233zd, R-1336mzz) next-generation refrigerants: non-ODS with ultra-low GWPs and very short atmospheric lives (measured in days vs. years or decades).

HFO blends – blends of an HFC or HCFC with an HFO e.g. R-452B, R-452A, R-513A, R-514A. They feature lower GWPs and, as they receive ASHRAE classification, are approved or listed for use in HVAC&R applications in many countries.

- 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 Amendment was signed on 15 October 2016, extending the scope of the Montreal Protocol to phase down the global production and consumption of HFCs.

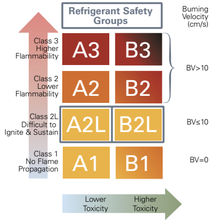
Flammability

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 slightly flammable (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. The OEL for R-514A is 320, 6 times greater than that of R-123. In the event of a leak of R-514A, the blend refrigerant will leak as one chemical, not as individual components.

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 Selecting Refrigerants

R-452B	One of the least flammable alternatives for R-410A that, when used as a drop-in, deliver about 5% better efficiency, opportunity for a charge reduction, and minimal 2L flammability. GWP is significantly lower than R-410A (675 vs. 1924).
R-513A	Non-flammable alternative for R-134a, which has no impact on capacity, non-ODS and 55% lower GWP (573 vs. 1300). While the theoretical efficiency drop is about 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 low pressure alternative for R-123 that offers the highest performance of all next generation options available today with an ultra low GWP of 2 and yet non-ODS.
R-1233zd	A single molecule non-flammable alternative for R-123, which is also non-ODS and has an ultra low GWP of 1. Often referred to as "zd", it is more widely used as a foam blowing agent and a low-pressure refrigerant as well.