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](http://ozone.unep.org/sites/ozone/files/pdfs/FAQs_Kigali_Amendment.pdf)

Refrigerant Management Requirements

Section 608 of the U.S. Clean Air Act – effective January 1, 2017, the requirements are becoming more stringent. Initially covering only CFCs and HCFCs, the requirements are being extended to include all replacement refrigerants, including HFCs and next-generation HFOs and HFO blends. The more stringent handling requirements that go into effect starting in 2018 enhance the appeal of leak-tight (such as hermetically-sealed) designs.

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

[Documentation of the Final Rules in the Federal Register](https://www.epa.gov/section608/FR-2016-12-01/pdf/2016-25167.pdf)


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 (CO₂), 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 GWP s given their fluorine content. Currently targeted for global phase-down under the Montreal Protocol and by the U.S. EPA for use in certain applications.

HFOs & HFCos – hydrofluoroolefins (e.g. R-1234yf, R-1234ze) and hydrochlorofluoroolefins (e.g. R-1233zd) – next-generation refrigerants that are non-ozone-depleting with ultra-low GWP s and very short atmospheric lives (measured in days vs. years or decades).

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/sec 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 concern 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 at 200 ppm
- Class B refrigerants have an OEL at 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.

To avoid confusion with building code definitions, ASHRAE 34 was updated to reflect the theoretical properties of the refrigerant alone, with all design variables held constant for objective comparison.

Refrigerant Safety Groups

<table>
<thead>
<tr>
<th>Class</th>
<th>Flammability</th>
<th>Toxicity</th>
<th>OEL</th>
<th>Efficiency (COP)</th>
<th>Capacity Change</th>
<th>Atmospheric Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>Class A</td>
<td>Non (1)</td>
<td>Non (1)</td>
<td>50</td>
<td>Higher (B)</td>
<td>~35% gain</td>
<td>1.3 years</td>
</tr>
<tr>
<td>Class B</td>
<td>Non (1)</td>
<td>Non (1)</td>
<td>320</td>
<td>Higher (B)</td>
<td>~5% loss</td>
<td>2 days</td>
</tr>
<tr>
<td>Class C</td>
<td>Non (1)</td>
<td>Non (1)</td>
<td>1000</td>
<td>Lower (A)</td>
<td>~25% loss</td>
<td>9 years</td>
</tr>
<tr>
<td>Category D</td>
<td>Non (1)</td>
<td>Non (1)</td>
<td>1000</td>
<td>Lower (A)</td>
<td>~25% loss</td>
<td>9 years</td>
</tr>
<tr>
<td>BV0.0*</td>
<td>BV1.5</td>
<td>BV3.0</td>
<td>BV3.8</td>
<td>Lower (A)</td>
<td>~25% loss</td>
<td>9 years</td>
</tr>
<tr>
<td>BV3.8</td>
<td>BV1.5</td>
<td>BV1.5</td>
<td>BV1.5</td>
<td>Lower (A)</td>
<td>~25% loss</td>
<td>9 years</td>
</tr>
</tbody>
</table>

1None of the refrigerants shown in the table are considered “toxic” or “highly toxic” as defined by the IFC, UFC or OSHA regulations.

2GWP values reported are per the Fifth Assessment Report (AR5) of the IPCC (Intergovernmental Panel on Climate Change).

Ingersoll Rand (IR) 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).

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).

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

Low Pressure Medium Pressure High Pressure

R-513A R-452R R-454B R-514A R-1233zd R-1234ze R-410A R-134a R-32

Environmental Impact

- Flammability
- Toxicity
- Efficiency (COP)
- Capacity Change
- Atmospheric Life

Additional Information About Select Refrigerants

R-452B, R-454B

Two of the least flammable alternatives for R-410A that, when used as a drop-in, deliver about 50% better efficiency, opportunity for a charge reduction, and minimal 2L flammability.

R-513A

Non-flammable replacement for R-134a, which has no impact on capacity, near-zero ODP 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 replacement for R-123 that offers the highest performance of all next-generation options available today with 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, a fluid that has been safely used for 500,000 chiller years of operation over the past 25 years.

R-1233zd

A single molecule non-flammable replacement for R-123, which offers near-zero ODP and an ultra low GWP of 1. Often referred to as a “ze”, it is classified as an “A1” refrigerant.

Operating Pressure by Refrigerant
This graphic compares the operating pressures of each refrigerant:

- Low Pressure
- Medium Pressure
- High Pressure

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.