VERTIV WHITE PAPER

Evolving Refrigerant Regulations and Applications in Data Center Environments

Looking into the changing regulatory landscape
and a technical overview of the low GWP refrigerants

Table of Contents

Executive Summary

Around the world, regulators are mandating a transition from high global warming potential (GWP) refrigerants to those with low GWP values, generally defined as less than 750. Changing refrigerants will help data centers meet regulatory mandates, improve progress toward corporate sustainability goals, and reduce climate change impacts. However, this is a significant change management challenge.

Far from a rip-and-replace operation, deploying new refrigerants requires carefully studying relevant regulations, use cases, data center systems, and refrigerant options. Adding to the complexity is the fact that regulatory requirements and timeframes vary – and many are still being updated.

The white paper is designed to support teams, including data center operators, facilities managers, and their mechanical and cooling consultants, as they navigate the transition to low GWP refrigerants. These individuals can use the information in this paper to understand compliance obligations and consider which refrigerants meet their regulatory, performance, safety, and other requirements.

White Paper Overview

This white paper:

- Provides a historical analysis of regulations governing refrigerants to date.
- Discusses low GWP refrigerant impacts and phaseout timelines.
- Introduces low GWP refrigerants; provides their compounds; and elaborates on their properties, including flammability, toxicity, and high-pressure risks.
- Serves as a run-through of the low GWP transition roadmap for companies and data centers. Vertiv will subsequently produce thought leadership articles on the transition to low GWP refrigerants, providing deeper dives into key topics covered in this paper.

A History of Refrigerants and Regulations

Refrigerants' Environmental Impacts

The concept of refrigeration using ice has been around for centuries but took a giant leap forward with the development of mechanical refrigeration in the early 1900s.[1] Using mechanical refrigeration equipment enabled operators to cool buildings, people, products, and equipment predictably, transforming industry operations and community life. When enterprises began operating data centers, refrigerant based cooling technology was introduced to reliably protect IT and networking equipment. The ability to consistently cool IT infrastructure increased device lifespan and gave rise to the modern data driven business that we know today.

However, commercial refrigerants were negatively impacting the environment. In 1974, a landmark paper was published[2] that set off a global discussion about the atmospheric impact of chlorofluoromethanes, ultimately leading to the 1987 Montreal Protocol, a global agreement to protect the stratospheric ozone layer by phasing out production and consumption of ozone-depleting substances.[3]

In 1990 and 1992, the **Intergovernmental Panel on Climate Change** published its seminal report, discussing global warming trends and evaluating the impact of commercial refrigerants on the environment.

The report recommended that industry organizations find alternatives to chlorofluorocarbons CFCs beyond the hydrochlorofluorocarbons (HCFCs) and hydrofluorocarbons (HFCs) being considered. This report lead to the development of the Kigali Amendment, which calls for a worldwide phased reduction in HFC consumption and production.[4] CFCs, HCFCs, and HFCs are fluorinated greenhouse gases (F-gases), human-made compounds with a warming impact a thousand times higher than carbon dioxide (CO2). These gases are used for refrigeration, heat pumps, insulation, fire protection, and power lines, among other common and industrial uses.[5]

The report also introduced the concept of global warming potential (GWP), which measures the potential warming impact on the earth's surface and troposphere created by gas emissions compared to carbon dioxide (CO_2), typically over a 100-year timeframe.[6] This report and subsequent updates have assigned GWP values to common refrigerants. For example, R-410A has a GWP value of 2,088, meaning that it has a 2,088 times greater impact on global warming than carbon dioxide, which has a GWP value of one over 100 years.

The European F-gas regulation was among those that set targets for developing refrigerants with GWP values of 750 or less.[7] The U.S. Environmental Protection Agency (EPA) has mandated a maximum GWP of 700 for data center cooling equipment. As a result, data center cooling equipment manufacturers will need to find alternatives to meet regulatory mandates.

How Global Protocols Shaped International Action on Refrigerants

In parallel with research, international agreements established targets and timeframes for phasing out environmentally harmful refrigerants. These treaties include:

- The Montreal Protocol of 1987 is a multilateral environmental agreement regulating the production and consumption of ozone-depleting substances. As a result of this agreement, which came into force in 1989, industry organizations began adopting HFCs to replace CFCs in HVAC and other industries.
- The Kyoto Protocol 1997, which came into force in 2005, committed industrialized countries and economies via binding agreements to reduce greenhouse gas emissions per individual targets. On average, these targets sought 5% emission reductions from 2008 to 2012 compared to 1990 levels.[8] This protocol created international pressure to reduce the use of low GWP HFC refrigerants.
- With the Montreal Amendment of 2017, developed nation signatories agreed to phase out HCFCs by 2020, while developing nations committed to do so by 2030.[9]
- Finally, the Kigali Amendment 2016 added HFCs to the list of globally controlled substances. Signatory nations agreed to reduce their use by 80-85% by 2047, with developed countries beginning reductions first.[10]

The Montreal and Kigali Amendments modified and updated the Montreal Protocol, while the Kyoto Protocol was a stand-alone agreement. In conjunction with new scientific insights, these protocols and regional regulations have driven refrigerants' evolution, resulting in lower GWP values.

Regulations Governing High GWP Refrigerant Phasedown and Low GWP Adoption

Regional, country, and state government regulators have passed legislation to meet or exceed protocol agreements. These regulations include:

- The European Union's F-gas Regulation, first adopted in 2006, was updated to F-gas Regulation 573/2024 in March 2024, building upon the previous regulation's success in reducing emissions. It can be downloaded here.

  It aims to prevent F-gas emissions by implementing requirements for documentation, labeling, checks, servicing, and monitoring. One of its key aspects is the reduction of (HFCs) on the market through a quota system. This system mandates a significant reduction in the amounts of HFCs that importers and producers can place on the EU market. Starting in 2025, companies will be granted production rights equivalent to 60% of their average annual production from 2011 to 2013. This rate will decrease over time, with companies being granted only 15% of their original production rights by 2036. The ultimate goal is to phase out HFCs in the EU by 2050.

  Furthermore, the updated regulation prohibits the use of HFCs with high Global Warming Potential (GWP) for most refrigerant applications. For example:

  - AC packaged units up to 50 kW must use refrigerants with a GWP lower than 150 starting from 1st January 2027.
  - Liquid Chillers larger than 12 kW must use refrigerants with a GWP lower than 750 starting from 1st January 2027.
  - AC split units larger than 12 kW must use refrigerants with a GWP lower than 750 starting from 1st January 2029.

  The impacts of Regulation (EU) 2024/573 will be reviewed by the European Commission by 1st January 2030.

- The American Innovation and Manufacturing (AIM) Act authorizes the U.S. EPA to phase down the production and consumption of critical HFCs, manage these HFCs and substitutes, and facilitate the transition to next-generation technologies by imposing sector-based restrictions.[11] The act provides a multi-year phasedown schedule, reducing HFC production and consumption by 10% in 2023, 30% in 2024, and another 30% by 2029.[12]

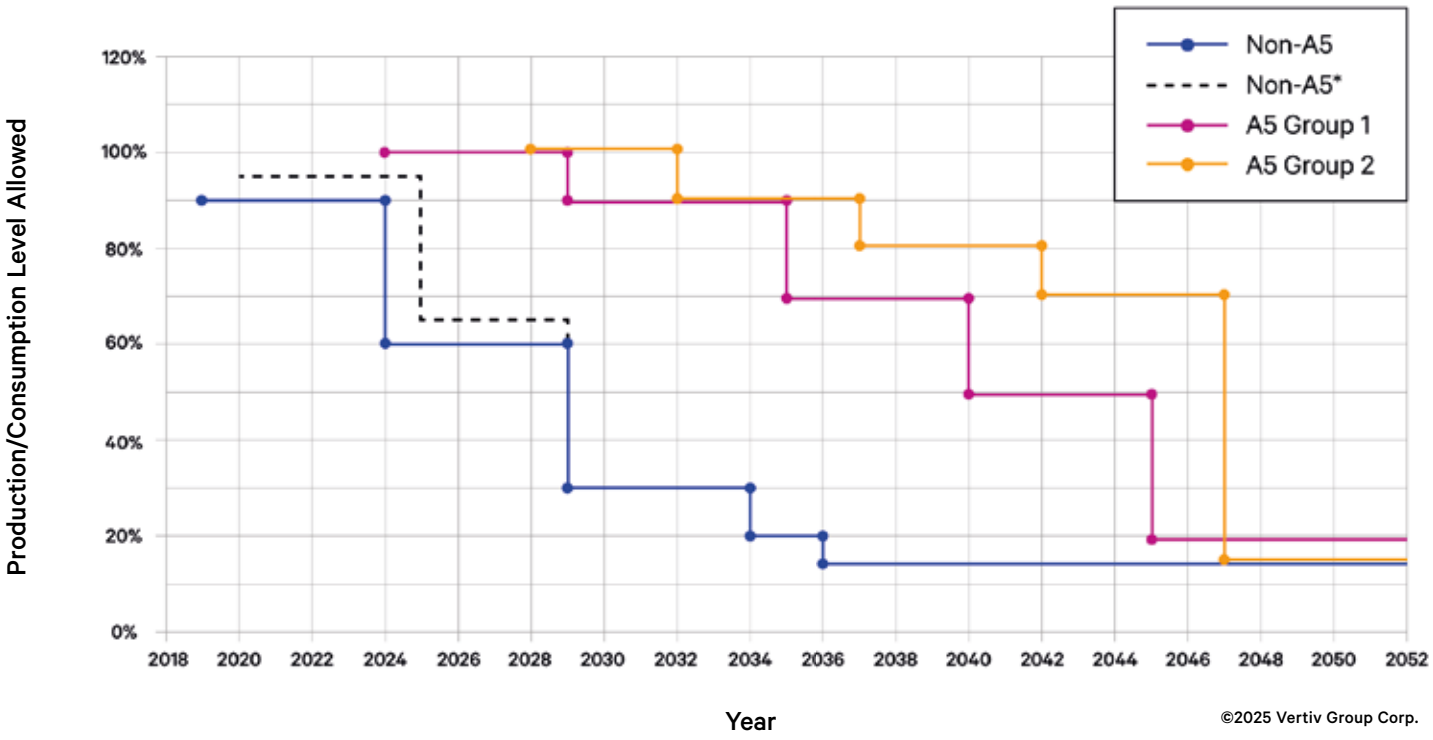
  Notably, the act includes timelines and guides wherein the EPA will regulate HFC management by providing calendar-year allowances for refrigerant manufacturers and encouraging HVAC equipment manufacturers and users to reduce production and consumption. While comfort-cooling equipment must comply with the Act by January 1, 2025, data center cooling equipment was given a special exception to meet later dates, given the complexity of implementing new refrigerants and processes.

  The EPA's final rule states that by January 1, 2027, all newly installed data center cooling equipment classified as self-contained refrigeration, air conditioning, heat pump products or split systems must use refrigerants with a 700 GWP limit. Factory-charged equipment with higher GWP refrigerants can be sold until December 31, 2026, and installed by end-users until December 31, 2029; whereas newly installed split systems must be field-charged by December 31, 2026.

- In Japan, the Law Concerning the Recovery and Destruction of Fluorocarbons, passed in 2001, requires the recovery of used CFCs, HCFCs, and HFC refrigerants during maintenance and disposal. Updated in 2015 as the **Act on Rational Use and Proper Management of Fluorocarbons,** the law requires organizations using fluorocarbons to create plans in line with national targets to decrease their usage and use designated product manufacturers that offer low GWP or medium GWP (up to 1,500) for critical use cases.[13]
- China ratified the Kigali Amendment in 2021 and froze production on five widely used HFCs as of January 1, 2022. Under the agreement's provisions, China will freeze all HFC production by 2024 and phasedown production to 20% of current capacity by 2045. However, the country has yet to identify a monitoring mechanism to enforce compliance.[14]

Below is a table outlining the general phasedown timeline for HFCs based on the agreements in the Montreal Protocol:

HFCs (Annex F) Consumption/Production Reduction Schedule



Non-A5 Baseline = Average HFC for 2011-2013 + 15% of HCFC baseline.

Non-A5* Baseline = Average HFC for 2011-2013 + 25% of HCFC baseline.

A5 - Group 1 Baseline = Average HFC for 2020-2022 + 65% of HCFC baseline.

A5 - Group 2 Baseline = Average HFC for 2024-2026 + 65% of HCFC baseline.

The phasedown timeline in the EU is more complicated in order to comply with the new F-gas Regulations. Below is a chart outlining this schedule:

The New F-gas Regulation (EU) 2024/573

Annex IV, Bans Impacting Vertiv Applications

		PFAS Constraints Not Active						Earliest PFAS Ban Possibly Active						
	Product Class Affected	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**	**2033**	**2034**	**2035**
AC Split	AC Split < 3kg charge	Fluorinated refrigerants allowed		1st January 2025 GWP < 750										
AC Split	AC Aircooled Splits < 12kW	Fluorinated refrigerants allowed						1st January 2029 GWP < 150 (*)						1.1.2035 Naturals (*)
AC Split	AC Split > 12kW	Fluorinated refrigerants allowed						1st Jan 2029 GWP < 750 (*)				1st Jan 2033 GWP < 150 (*)		
AC Package	AC Self-contained Units < 12 kW	Fluorinated refrigerants allowed				1st January 2027 GWP < 150 (**)					1st January 2032 Naturals (**)			
AC Package	AC Packaged Units > 12 kW, < 50 kW	Fluorinated refrigerants allowed				1st January 2027 GWP < 150 (**)								
AC Package	AC Packaged Units > 50 kW	Fluorinated refrigerants allowed						1st January 2030 GWP < 150 (**)						
Chiller	Liquid Chillers > 12 kW	Fluorinated refrigerants allowed				1st January 2027 GWP < 750 (*)								
Liquid Cooling	Refrigeration eqpmt not self-contained, except chillers	HFC GWP <2500		1st January 2025 GWP < 2500				1st January 2030 GWP < 150 (*)						
Liquid Cooling	Refrigeration eqpmt self-contained, except chillers	Fluorinated refrigerants allowed		1st January 2025 GWP < 150 (*)										

By 2030, a full review of the subsequent bans is expected.

(*) Except if required to meet safety requirements at the site of operation.
(**) Except if required to meet safety requirements. If safety requirements at the site of operation would not allow using fluorinated greenhouse gases with GWP of less than 150, the GWP limit is 750.

Refrigerant Classification and Acceptable Limits

There are multiple ways to evaluate and classify refrigerants, including toxicity, operational pressures, flammability risks, and chemical compounds. The American Society of Heating, Refrigeration, and Air-Conditioning Engineers (ASHRAE) has developed and published their standardized tests for refrigerant toxicity and flammability classification as part of ANSI/ASHRAE Standard 34-2022, Designation and Safety Classification of Refrigerants.

- **Determining toxicity levels:** Class A refrigerants have lower toxicity, while Class B refrigerants have higher toxicity. For example, Class A refrigerants, such as carbon dioxide which has a GWP value of 1, aren't currently practical for data center applications – but could be in the future. B-class refrigerants, such as ammonia and sulfur dioxide, are not used for data center applications, because of their higher toxicity.
- **Evaluating flammability risks:** According to ASHRAE, three classifications and a subclass denote flammability:
  - Class 1 includes refrigerants that don't propagate a flame when tested against the standard.
  - Class 2 includes refrigerants with low flammability risks.
  - Class 3 includes highly flammable refrigerants such as hydrocarbons.[15]
  - Class 2L, a new subclass, signifies mild flammability.

While the concerns about toxicity and why the risks of flammability are implausible are discussed in depth in the next paper in this series, "The Business Challenges and Benefits of Moving to Low GWP Refrigerants," we emphasize that data centers' approaches to managing various refrigerants will be different. Moreover, the management and use of these new low GWP refrigerants include redundant safety measures and devices according to the safety classifications of the refrigerants, and local building codes and safety standards. Data centers will likely use A1 or A2L refrigerants for their respective facilities in the future.

The chart below shows standard classifications of refrigerants as well as their flammability risks at different temperatures and pressures.

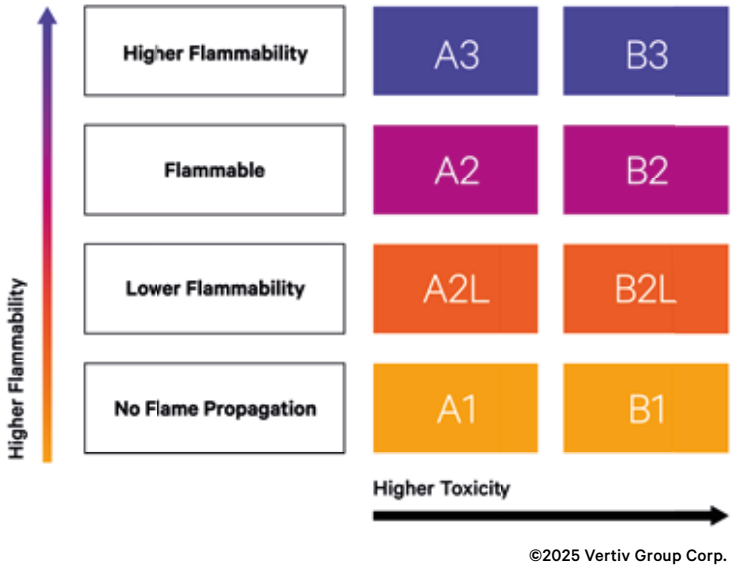


Figure 1. *Classifications of refrigerants based on flammability, temperatures, and pressure.* [16]

- **Understanding chemical compounds:** Refrigerants are composed of a wide array of chemical compounds, including:
  - **Chlorofluorocarbons (CFCs):** Legal sales of these refrigerants were phased out worldwide by 2010 due to chlorine's negative impact on the ozone layer.[17]
  - **Hydrocarbons (HCs):** Most HC refrigerants have low toxicity, good thermodynamic properties, and low GWP values. However, they are highly flammable and are not well suited for data centers and their respective applications.
  - **Hydrochlorofluorocarbons (HCFCs):** They are being phased out due to their high GWP values and environmental impact. Developed nations phased them out in 2020, and developing nations will follow suit by 2030.[18]
  - **Hydrochlorofluoro–olefins (HCFOs):** Identified as non-flammable and having low toxicity, HCFOs also have low GWP values.
  - **Hydrofluorocarbons (HFCs):** They have low toxicity and mild flammability, but many have high GWP values. Those HFCs with high GWP values are being phased out globally via different regulations. In the US, the phaseout will take place between 2025 and 2036.[19] In Europe, the phaseout began in 2019 and will be completed by 2030.[20]
  - **Hydrofluoro-olefins (HFOs):** These chemical compounds have low toxicity and GWP values but are mildly flammable.

Refrigerants	Chemical compound	Classification	GWP value*
R410A	HFC Blend	A1	2088
R407C	HFC Blend	A1	1774
R134a	HFC	A1	1430
R32	HFC	A2L	675
R513A	HFC/HFO Blend	A1	631
R454B	HFC/HFO Blend	A2L	466
R471A	HFC/HFO Blend	A1	145
R515A	HFC/HFO Blend	B1	7
R1234ze	HFO	A2L	7
R1234yf	HFO	A2L	4
R290	HC	A3	4
R744 (Carbon Dioxide)	Natural Refrigerant	A1	1

**GWP Values based on AR4 by IPCC*

Table 1. *Overview of commonly used refrigerants, including their respective chemical compounds, classifications, and GWP values.*

The Current Refrigerant Landscape

The chart below depicts how refrigerants used today compare regarding GWP values, operating density, and flammability risks. What's clear, at a first glance, is that there is no "one-size-fits-all" low-GWP refrigerant to replace their high-GWP counterparts. There are multiple choices for different applications: heat pumps, commercial refrigeration, automotive, comfort cooling and heating, and, of course, IT cooling.

- Currently available fluids have different GWP values and are subject to the regulations and restrictions we've outlined, globally and regionally.
- They cover a large range of operating densities, which is impacting the size of not only the cooling device but of the refrigerant piping as well.
- According to the specific chemical properties, some refrigerants are positioned above the "flammability line" under specific conditions (e.g. the concentration of gas in the ambient environment, the amount of energy required to ignite the refrigerant, flame propagation velocity, etc.). As mentioned previously, there are changes in local building codes and safety standards to minimize this risk for A2L refrigerants when followed properly.

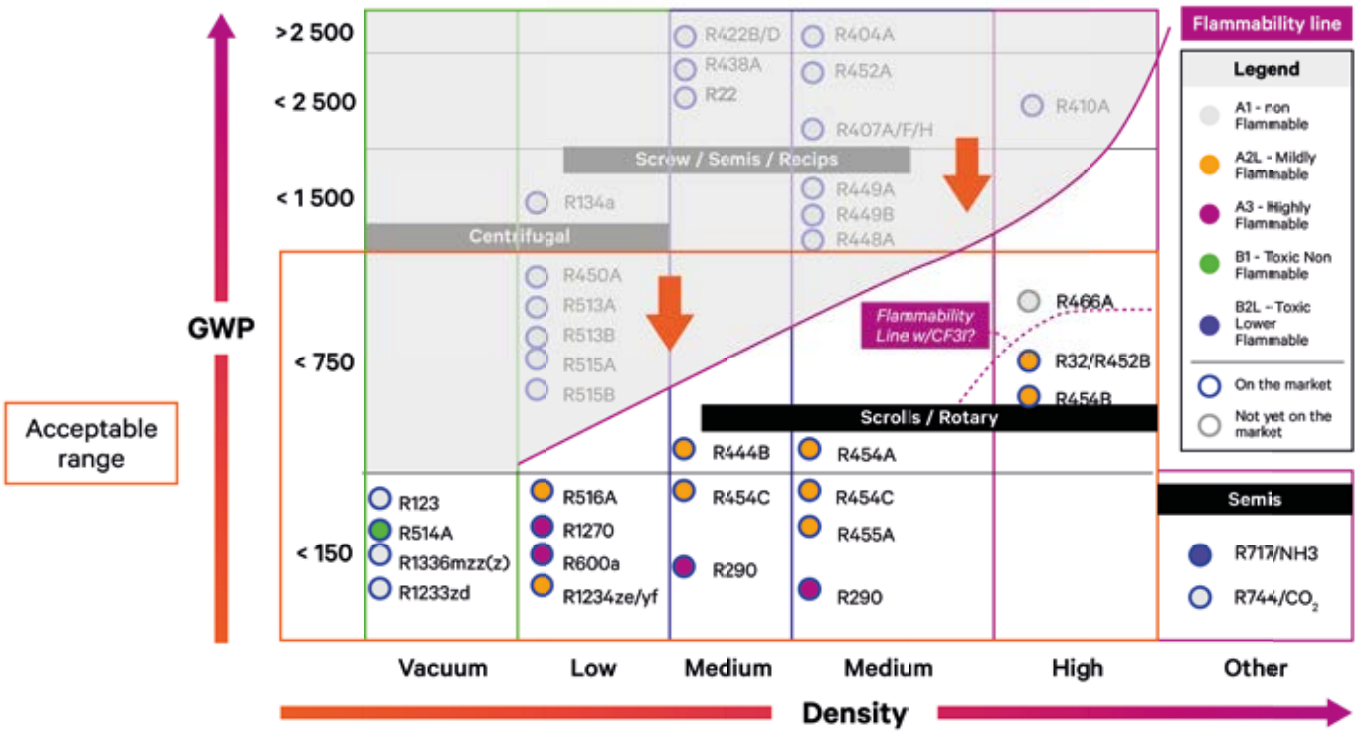


Figure 2. *Refrigerants currently in use around the world. Source: Danfoss.*[21]

What is clear is that data center operators and companies will need to contend with various low GWP refrigerant regulations depending on the region in which they operate. The compounds allowed by US and EU regulators for use in data centers are different in each region because the upcoming regulations are based on the systems and high GWP refrigerants historically used. To better appreciate these differences, the standards need to be viewed from multiple perspectives:

1. From the outset, the acceptable refrigerants must be below a specific GWP value, as shown by the different international protocols and agreements listed previously.
2. From a technical point of view, the new low GWP refrigerants that are selected should be similar or close to the density of the compounds currently in use.
3. From a procurement standpoint, the new refrigerants allowed in each region are also dependent on the more widely available components (such as compressors), varied and distributed according to residential and commercial use.
4. From a regulatory standpoint, local codes and standards (e.g., buildings, flammability limits, and safety standards, among others) would also have to be considered and followed for proper compliance.

Vertiv strives to provide our customers with the best refrigerant choice in terms of GWP value while balancing cost effectiveness, energy efficiency and safety. In a global scenario that sees large regulatory differences among regions, A2L refrigerants (R454B primarily) are widely accepted in North America to leverage high densities while the European Union markets are going for A1 refrigerants (R513A primarily) for IT cooling devices.

The regulations governing GWP values and refrigerant usage are dynamic, changing on a regional basis over time. Additionally, local laws and prescriptions treat flammable refrigerants in a variety of ways, requiring specific safety measures to be followed. As an example, in the United States, there are specific regulations for IT equipment facilities with no major concerns about mildly flammable (A2L) refrigerants. Meanwhile, in the European Union, the F-gas regulations that are in place are written such that they exclude the use of most A2L refrigerants, making those compounds more difficult to be widely adopted in that region.

There is also a circulating belief that operators should avoid specific refrigerants in data centers due to the potential increase in capital expenditure for installing safety devices such as leak detectors and mechanical ventilation. However, Vertiv and its partners remain active in research for new technologies and developing new products that meet safety standards and local regulations as they evolve over time and in different regions. Following professional guidelines and working with various industries worldwide, a growing set of solutions addressing companies' and data centers' needs for compliance has been continuously developing to accommodate the use of different compounds.

Get Ready for a New Era of Cooling

Data center operators and consultants are navigating a complex regulatory landscape where the only constant is change. Refrigerant manufacturers will constantly innovate products over the next few decades to reduce GWP values while providing equivalent or improved performance.

As operators evaluate refrigerants, they are balancing a wide array of considerations to ensure their selections are safe, sustainable, and efficient. They can turn to Vertiv for guidance on relevant regulations, help selecting the suitable refrigerants for their use cases, and systems optimized for new low GWP refrigerants.

References

[1] Bernard Nagengast with help from Barry Donaldson, Gerald Groff, Dr.-Ing. Wolf Eberhard Kraus, and the International Institute of Refrigeration and ASHRAE staff, "Air Conditioning and Refrigeration Timeline," ASHRAE, undated, https://www.ashrae.org/about/mission-and-vision/ashrae-industry-history/air-conditioning-and-refrigeration-timeline

[2] Mario J. Molina and F. S. Rowland, "Stratospheric sink for chlorofluoromethanes: chlorine atom-catalysed destruction of ozone," scientific paper, Nature, June 28, 1974, https://www.nature.com/articles/249810a0

[3] "The Montreal Protocol on Substances that Deplete the Ozone Layer," article, undated, U.S. Department of State, https://www.state.gov/key-topics-office-of-environmental-quality-and-transboundary-issues/the-montreal-protocol-on-substances-that-deplete-the-ozone-layer/ and "No. 26369: MULTILATERAL Montreal Protocol on Substances that Deplete the Ozone Layer (with annex). Concluded at Montreal on 16 September 1987," United Nations Treaty Collection, https://treaties.un.org/doc/publication/unts/volume%201522/volume-1522-i-26369-english.pdf

[4] "2.f amendment to the Montreal Protocol on Substances that Deplete the Ozone Layer," Kigali, October 15, 2016, United Nations Treaty Collection, https://treaties.un.org/Pages/ViewDetails.aspx?src=IND&mtdsg_no=XXVII-2-f&chapter=27&clang=_en

[5] "About F-gases," webpage, undated, under "EU Action," European Commission, https://climate.ec.europa.eu/eu-action/fluorinated-greenhouse-gases/about-f-gases_en

[6] Climate Change: The IPCC 1990 and 1992 Assessments, two reports, pages 28, 56, and 57, Intergovernmental Panel on Climate Change, https://www.ipcc.ch/site/assets/uploads/2018/05/ipcc_90_92_assessments_far_full_report.pdf

[7] The European F-Gas regulation, which has been updated several times, has provided progressively restrictive GWP values for f-gases (HFCs) sold in the European Union. The regulation initially targeted the GWP value of 750 but has increased restrictions for some use cases, mandating the use of f-gases with values of 150 or less. See "EU Releases Proposed F-Gas Regulation, Opening Doors for Hydrocarbons," article, Hydrocarbons21, April 14, 2022, https://hydrocarbons21.com/eu-releases-proposed-f-gas-regulation-opening-doors-for-hydrocarbons

[8] "What is the Kyoto Protocol?," webpage, Climate Change, undated, United Nations, https://unfccc.int/kyoto_protocol#

[9] "About Montreal Protocol," fact sheet, undated, UNEP, https://www.unep.org/ozonaction/who-we-are/about-montreal-protocol

[10] "About Montreal Protocol," ibid.

[11] "Background on HFCs and the AIM Act," fact sheet, US Environmental Protection Agency (EPA), last updated November 22, 2023, https://www.epa.gov/climate-hfcs-reduction/background-hfcs-and-aim-act

[12] "Final Rule - Phasedown of Hydrofluorocarbons: Restrictions on the Use of Certain Hydrofluorocarbons under Subsection (i) of the American Innovation and Manufacturing Act of 2020," fact sheet, US EPA, https://www.epa.gov/system/files/documents/2023-10/technology-transitions-final-rule-fact-sheet-2023.pdf

[13] "Act on Rational Use and Proper Management of Fluorocarbons Packaged Air Conditioner Refrigeration and Cold Storage Showcase Commercial Refrigerator-Freezer Transport Refrigeration," online fact sheet, Ministry of the Environment, Government of Japan, March 2016, https://www.env.go.jp/content/900451359.pdf

[14] Phil McKenna, "China Moves to Freeze Production of Climate Super-Pollutants but Lacks a System to Monitor Emissions," article, Inside Climate News, January 21, 2022, https://insideclimatenews.org/news/21012022/china-super-pollutant-emissions

[15] "Update on New Refrigerants Designations and Safety Classifications," fact sheet, ASHRAE, November 2022, https://www.ashrae.org/file%20library/technical%20resources/bookstore/factsheet_ashrae_english_november2022.pdf

[16] Inspired by "Update on New Refrigerants," et al, ASHRAE, page 2, ibid.

[17] Madeleine Cuff, "Ozone-destroying CFC chemicals are on the rise again despite ban," article, New Scientist, April 3, 2023, https://www.newscientist.com/article/2367525-ozone-destroying-cfc-chemicals-are-on-the-rise-again-despite-ban/

[18] "About Montreal Protocol," ibid.

[19] "Frequent Questions on the Phasedown of Hydrofluorocarbons," webpage, US EPA, last updated December 23, 2023, https://www.epa.gov/climate-hfcs-reduction/frequent-questions-phasedown-hydrofluorocarbons#

[20] "Hydroflourcarbon phasedown in Europe," webpage, November 8, 2023, European Environment Agency, https://www.eea.europa.eu/en/analysis/indicators/hydrofluorocarbon-phase-down-in-europe#

[21] Refrigerant options now and in the future, white paper, Danfoss, page 13, updated December 2023, https://assets.danfoss.com/documents/latest/357917/AD224586434178en-001201.pdf

Vertiv.com | **Vertiv Headquarters,** 505 N Cleveland Ave, Westerville, OH 43082, USA

SL-71228 (01/25)