# Adopting low-GWP refrigerants in industrial refrigeration, heating and energy solutions

A Johnson Controls White Paper

The power behind **your mission**

# Executive summary

Businesses that are heavy users of refrigeration systems and heat pumps are assessing whether their current choice of refrigerant represents the most sustainable long-term choice.

The European Union (EU) plans to introduce legislation to limit emissions caused by F-gases, which may result in F-gas shortages and price rises in future. Businesses that are considering adopting natural refrigerants to avoid these potential challenges should consider the strengths and weaknesses of both natural and synthetic refrigerants.

In particular, they should carefully assess the Global Warming Potential (GWP) and the health & safety impact of their preferred type of refrigerant, especially in areas like flammability and toxicity.

However, businesses that put the right health & safety systems in place may be able to take the natural refrigerant approach with complete confidence in order to meet their environmental, performance, regulatory and lifecycle cost objectives.

# Introduction

The existential threat of global warming, and growing pressure to run sustainable operations, means businesses look at every opportunity to reduce the production of man-made greenhouse gases (GHGs). This issue can be especially urgent for owners of refrigeration systems and heat pumps in buildings, industrial facilities, utility installations and any equipment that uses refrigerants.

While much of today's discussion tends to revolve around carbon emissions, in the industrial refrigeration, heating and energy sector, the management of refrigerants that have high GWP is an important challenge. Industrial equipment typically has a refrigerant leakage rate of around 1-2% per year.

Yet selecting the right refrigerant requires careful consideration of the pros and cons – a delicate balance between environmental impact, performance, health & safety as well as lifecycle cost. Asset owners also have to consider future restrictions or bans on certain types of refrigerants.

# 1. The regulatory and environmental landscape

While refrigerants have been subject to restrictions since the 1980s, starting with the Montreal Protocol, hydrofluorocarbons (HFCs) or F-gases, are coming under increasing pressure as HFC's are associated with higher CO2 emissions.

On April 5, 2022 the EU made a legislative proposal to update the F-gas Regulation.

The current Regulation, which has applied since January 1, 2015, replaced the original F-gas Regulation adopted in 2006. It strengthened the previous measures and introduced far-reaching changes by:

- Limiting the total amount of the most important F-gases that can be sold in the EU from 2015 onwards and phasing them down in steps to one-fifth of 2014 sales in 2030.
- Banning the use of F-gases in many new types of equipment where less harmful alternatives are widely available.
- Preventing emissions of F-gases from existing equipment by requiring checks, proper servicing and recovery of the gases at the end of the equipment's life.

Under this F-gas Regulation, the EU's F-gas emissions will be cut by two-thirds by 2030 compared to 2014 levels.

### Regulatory alignment

The new legislative proposal is designed to update and align the existing F-gas Regulation with:

- The European Green Deal and the European Climate Law.
- Recent international obligations on HFCs under the Montreal Protocol.
- Progress made and lessons learned.

This package of measures is designed to prevent emissions amounting to 40 MtCO2e (million tonnes of CO2 equivalent) by 2030 and 310 MtCO2e by 2050, on top of the amount the current Regulation would achieve. The proposal would accelerate Europe's HFC phase-down from 2024, with the aim of reducing HFC use by 97.6 percent by 2048, based on 2015 levels. Previous iterations of the regulation had an 80 percent reduction target over the same period.

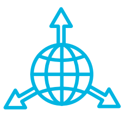
The package will also safeguard Montreal Protocol compliance and help enable better enforcement and monitoring.

### Financial and business impact

Any move to accelerate the phase-down of F-gases will mean steep cuts in the current number of issued quotas and a subsequent rise in F-gas cost. The consequence will be faster phasing down of the production and consumption of HFCs and pressure on availability of such refrigerants.

Owners of systems that depend on cold and/or heat in their process could face the prospect of downtime if there are refrigerant shortages and should therefore plan their switch to sustainable refrigerants.

With decades of experience in refrigeration, Johnson Controls is well placed to work with plant owners to help them manage that transition.



*Selecting the right refrigerant requires careful consideration of the pros and cons – a delicate balance between environmental impact, performance, health & safety as well as lifecycle cost.*

# 2. Refrigerant types: their pros and cons

A refrigerant is a working fluid primarily used in the refrigeration cycle of refrigerators/freezers, air-conditioning, and in heat pumps. In most cases, during the refrigeration cycle, the refrigerant changes from gas to liquid and then back to gas in a cycle transporting energy from cold to hot.

Only a handful of elements in the periodic table have the right properties to use for refrigeration, meaning that all refrigerants are made from combinations of this select group of elements.

Refrigerants are named using an 'R' (as in Refrigerant) followed by a dash and a two to four digit number. Some refrigerants will also have a letter prefix or suffix that further specifies the chemical makeup. Refrigerants are classified into 10 groups called series. For the first four series (000, 100, 200, 300), the synthetic refrigerants are generally a combination of carbon (C), hydrogen (H) and fluorine (F) with some other elements mixed in, e.g. Series 000 are methane-based, Series 100 are ethane-based, etc. For example, R-410A and R-32 are refrigerants commonly used in medium and high temperature refrigeration applications, such as commercial and domestic refrigeration and chillers.

Refrigerants are typically evaluated on their GWP. The GWP scale is standardized to carbon dioxide, where the refrigerant's GWP is the multiple of the heat that would be absorbed by the same mass of carbon dioxide over a period of time. For example, 1 kg of R-134a has the same GWP as 1.434 kg of CO2.

*An overview of the most common refrigerants, highlighting the implications for use and production status*

| | Refrigerant charge | GWP | New Construction | Use | Production |
|---|---|---|---|---|---|
| **Natural** | Ammonia ($NH_3$) | 0 | No Restrictions | No Restrictions | No Limitations |
| | $CO_2$ | 1 | | | |
| | Propane | 3 | | | |
| | Butane | 3 | | | |
| **Synthetic** | HFO R1234ze | 7 | No Restrictions | No Restrictions | No Limitations |
| | R32 | 675 | Until 2021: for cooling systems in retail and hospitality | No Restrictions | Restriction of production the quota system |
| | R134a | 1.434 | | | |
| | R407C | 1.774 | | | |
| | R407F | 1.825 | | | |
| | R410A | 2.088 | | | |
| | R449A | 1.397 | | | |
| | R404A | 3.922 | Until 2019 | As of January 1 2020 the supplement is only allowed with recycled and / or regenerated refrigerant. As of January 2030, it is a refilling completely prohibited | Restriction of production the quota system |
| | R507 | 3.985 | | | |
| | R422D | 2.620 | | | |
| | R22 | 1.810 | Prohibited | Prohibited | Ban |

## Natural and synthetic refrigerants

Broadly, there are two types of refrigerants – natural and synthetic.

### Natural refrigerants

occur in nature's biological and chemical cycles without human intervention, i.e. they are made from molecules containing hydrogen, carbon, nitrogen or oxygen. Ammonia ($NH_3$), carbon dioxide ($CO_2$), hydrocarbons (HC), water ($H_2O$) and air are therefore all classed as natural refrigerants.

### Synthetic refrigerants

are substances that do not occur naturally, but have been created by industrial synthesis processes. In the past, the most common synthetic refrigerants were chlorofluorocarbons (CFCs) but when they were found to be depleting the ozone layer in the late 1980s, there was a worldwide effort to phase them out. This drive to eliminate CFCs resulted in many chemical manufacturers choosing to replace them with two groups of chemicals with a different problem – hydrofluorocarbons (HFCs) and hydrochlorofluorocarbons (HCFCs). These refrigerants break down ozone molecules far less, but are extremely potent greenhouse gases. Their GWP is thousands of times greater than carbon dioxide.

The need for refrigerants with lower GWP has also led to a new class of synthetic refrigerants as an alternative to HFCs. These new hydrofluoro-Olefins (HFOs) are blends of refrigerants with GWPs that are hundreds of times lower than the HFC alternatives. For example, R1234yf can be used as an alternative to R134a (widely used in chillers and refrigeration equipment) and has a GWP that is 335 times lower. Its GWP is only four times higher than $CO_2$.

# 3. Balancing GWP with health & safety

Refrigerants are heavily regulated due to, among other things, their I) toxicity, II) flammability and III) the contribution of HFC refrigerants to climate change. They are categorised into different classes, according to the ASHRAE Standard 34. This assigns numbers and a safety classification based on toxicity and flammability data submitted by the refrigerant's manufacturer.

## I) Toxicity

There are two classes of toxicity: lower toxicity (Class A) and higher toxicity (Class B). Class A refrigerants are those for which toxicity has not been identified at concentrations less than or equal to 400 parts per million (ppm) by volume. Class B refrigerants are refrigerants for which there is evidence of toxicity at concentrations below 400 ppm by volume.

## II) Flammability

For flammability, there are three classes: 1, 2, 3 and one more recently introduced – subclass 2L. Class 1 is for refrigerants that do not propagate a flame when tested as per the standard; class 2 is for refrigerants of lower flammability; and class 3 is for highly flammable refrigerants such as hydrocarbons. The newer subclass 2L is for flammability class 2 refrigerants that burn very slowly.

| | lower toxicity | higher toxicity |
|---|---|---|
| higher flammability | A3 | B3 |
| lower flammability | A2 | B2 |
| | A2L | B2L |
| no flame propagation | A1 | B1 |
| | no identified toxicity at concentrations <400ppm | evidence of toxicity below 400ppm (based on data for TLV-TWA or consistent indices) |

*Refrigerant safety classification from ASHRAE Standard 34*

## III) GWP contribution

The amount of chlorine and fluorine in each refrigerant determines the GWP, toxicity and flammability, wherein the addition of chlorine and fluorine lowers the toxicity and flammability of synthetic refrigerants. However, their downside is their GWP. For example, 1 kg of R-134a has the same GWP as 1.434 kg of $CO_2$. Some also have ozone depletion potential (ODP).

Today, GWP is perhaps the most important driver in whether to choose natural or synthetic refrigerants. Assessing GWP between now and 2050, if synthetic refrigerants and F-gases are removed, global warming could be reduced by 15 percent.

According to the Environmental Investigation Agency (EIA), a non-profit organization that investigates and campaigns against environmental abuse, the combination of CFCs, HFCs and HCFCs have accounted for close to 11 percent of total warming emissions to date.

## III) GWP contribution cont.

The GWP of synthetic refrigerants can be illustrated by a simple example. An old car might leak 1 kg of R-134a refrigerant from its air conditioning system during a recharge. If an average European citizen has an annual carbon footprint of about 8000 kg (Eurostat), this leakage of a refrigerant that has the GWP of 1.434 kg of $CO_2$, represents nearly 20 percent of an individual's annual carbon footprint.

This level of impact on global warming can be avoided through the use of natural refrigerants, but with potential consequences for toxicity when using $NH_3$.

HFOs, meanwhile, exhibit no toxicity but low flame propagation. GWP is also low, although still higher than natural refrigerants. These substances, however, may not be long-term solutions as they break down in the atmosphere, potentially causing pollution of groundwater. Further, because HFOs are made from a blend of refrigerants, their efficiency and performance can be lower compared to pure HC and HFC's.

> *In essence, this would mean that if an asset owner wants to move away from high GWP HFCs, they might have to compromise on flammability or toxicity.*

## EU quota legislation for lower emissions

In order to help tackle global warming, the EU has introduced a regulation aimed at phasing down or eliminating HFCs. This is part of the European 2050 Vision to reduce greenhouse gas emissions by 80-95 per cent compared to 1990 levels. The EU F-Gas regulation, which came into force in January 2015, is intended to phase down HFCs from 2015 to 2030 by means of a quota system and bans on high GWP refrigerants in certain sectors. The quota system limits the supply of HFCs across the EU, based on the total $CO_2$ equivalent that is calculated, i.e. refrigerant charge multiplied by GWP.

In practice, this would meant that if 1 kg of ammonia has a GWP of zero, then there would be no limit on the amount that can be sold or consumed. If the refrigerant is propane, with a GWP of 3, then 3 quotas would have to be used to sell it. Similarly, selling a system containing R-134a would require 1.434 quotas.

The quota system is therefore a commercially functioning system intended to drive down GHG emissions in the EU.

This system is to work alongside the Kigali Amendment to the Montreal Protocol to gradually reduce the consumption and production of HFCs worldwide.

Signed by more than 150 countries in 2016, the Kigali amendment aims to reduce HFC consumption by 80 percent by 2047. If achieved, this could avoid more than 0.4°C of global warming by the end of the century – a sizeable amount in the global effort to reduce the effects of climate change.

*Today,* ***GWP*** *is perhaps the most important driver in whether to choose* ***natural*** *or* ***synthetic refrigerants.***

# 4. Managing refrigerant toxicity and flammability

With this GHG reduction legislation in place, businesses will need to manage their transition from synthetic refrigerants to natural refrigerants such as ammonia, while meeting health & safety requirements that apply to toxicity and flammability.

It should be noted that incidents resulting from ammonia leakage are extremely rare. Some 30-40 per cent of refrigeration equipment in food & beverage in France uses ammonia but there are no reports that these have experienced any leakages. Further, when accidents do occur, they are almost always the result of poor health & safety working practices or insufficient maintenance.

The likes of cold stores, dairies and abattoirs are well-experienced in handling ammonia, and risks posed by any potential leakage to the environment are minimised still further since such facilities are generally located at industrial sites. For heat pump installations in buildings in city centres, any potential leakage could have a greater impact.

The good news is that risks associated with natural and low GWP refrigerants can be effectively mitigated with the correct prevention systems and the right legislation.

Johnson Controls meets the strictest requirements when it comes to safety provisions and construction quality.

## Risk mitigation best practices

When building a new installation, it is very important to provide the correct protection systems – regardless of whether the equipment in question uses natural (potentially toxic, low flammable) or HFO (non-toxic, low-flammable) refrigerant. In fact the machine rooms of each should be identical.

In line with codes and standards, an installation should have its own fire cell. Refrigeration sniffers, or leak detectors, are needed in the water circuits that transfer energy. These are intended to shut down the system itself, as well as ventilation systems in the machine room, to confine leakages.

Once the leakage is confined, technicians wearing health & safety equipment enter the machine room to fix the leakage, start the emergency ventilation system and then slowly release the ammonia into the atmosphere. The leaked ammonia could also be passed through a scrubber system that uses water to capture the ammonia before venting to the atmosphere.

Although ammonia is used in fertilizers and would not be harmful to the environment if released in small doses, water contaminated with ammonia is subject to restrictions and should only be released in accordance with environmental authorities.

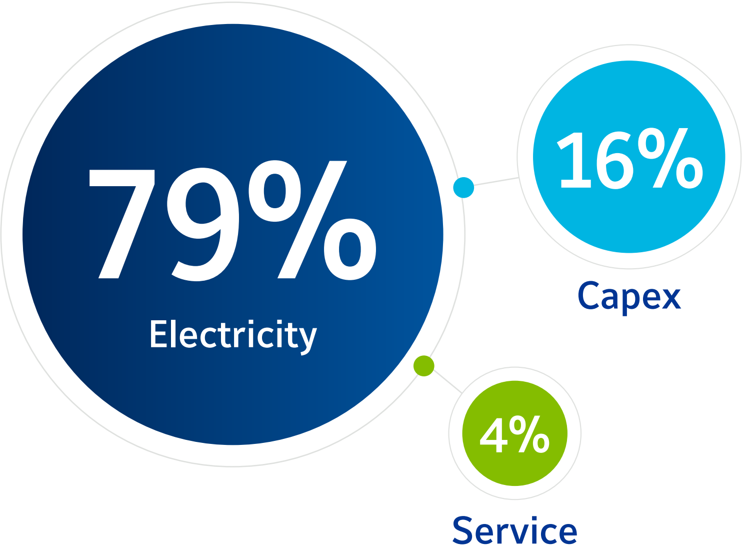
Johnson Controls has offered products and solutions to help safely manage its installed base of ammonia equipment in the food & beverage sector for more than 125 years. Our proven track record demonstrates that ammonia and other natural refrigerants can be handled safely.

*Risks associated with natural and low GWP refrigerants can be effectively mitigated with the correct prevention systems and the right legislation*

## 5. Conclusion and next steps: making the right choice

Ultimately, the choice of refrigerants can be determined by four factors. The first is simply customer preference due to familiarity, followed by GWP and health & safety, with the final determining factor being cost.

Natural refrigerants offer superior energy performance compared to other refrigerants. Even with their higher capital cost, they can still offer a better business case, especially in larger systems with high running hours. When calculating the lifecycle cost of a system, the capital cost is typically just 10 percent, with energy costs by far the biggest element.




*Total cost of ownership, 25yr lifetime for 500kW cold stores*

**Going forward,** choosing the right refrigerant calls for a holistic approach – selecting the best fit in terms of preference, business case, environment and health & safety.

However, with future legislation and global warming, there should be a move to natural and low GWP refrigerants.

Companies like Johnson Controls have the systems and expertise to help eliminate any potential health & safety issues. Our award-winning technologies help businesses with a heavy dependency on refrigeration systems and heat pumps to operate safely, affordably and in compliance with all applicable regulations – and to create a more sustainable future for everyone.

**Let's continue the conversation**

To discuss how Johnson Controls can help you choose the right refrigeration solution for your business, book your expert consultation now.

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